Ph. D. Dissertation in Engineering

Research on the Diversity of R&D Alliance Portfolios:

Determinants and Effects on Innovation Performance

R&D 제휴 포트폴리오의 다양성에 관한 연구:

기업의 혁신 성과에 미치는 영향을 중심으로

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Abstract

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Strategic alliances are a valuable tool for firms to exchange technologies or jointly perform R&D and to spread the risks and costs of the innovation process. In many high-tech industries, firms form alliances at an increasing rate. As often a single partner cannot provide all the required inputs, firms pursue more than one alliance at the same time, giving rise to the concept of alliance portfolios. The increased importance of alliance portfolios resulted in research focusing on issues such as interactions between the individual alliances and the management of the portfolio. Within the alliance portfolio focused research, in recent years the concept of alliance portfolio diversity has been given increasing attention and some studies have begun to investigate how diverse alliance portfolios affect the performance of firms. Previous literature, however, has left gaps in the understanding of

alliance portfolio diversity. While most literature has focused on effects of alliance portfolio diversity, most research treats the diversity of alliance portfolios as a given fact and did not investigate possible determinants. Only recently, a number of studies have begun to identify the determinants of alliance portfolio diversity using limited definitions and contexts and none so far have investigated them in the context of technological alliance portfolio diversity, an important factor in R&D focused alliance portfolios. This dissertation aims at increasing the understanding of alliance portfolio diversity by investigating three key questions: "What are some of the determinants of alliance portfolio diversity?", "How do different dimensions of alliance portfolio diversity affect innovation performance?", and "Which factors moderate the relationship between alliance portfolio diversity and innovation performance?".

Previous literature on alliance portfolio diversity has mostly considered the diversity as an exogenous factor and has only recently acknowledged that it is not a fixed firm characteristic, but rather the reflection of a firm's strategy to actively influence and deal with its business environment. Chapter 3 examines the determinants of technological alliance portfolio diversity. Following the understanding that the evolution of alliance networks is shaped by both endogenous and exogenous forces, both internal and external factors are investigated. For the internal factor, this dissertation focuses on internal technological diversity, i.e., the diversity of the knowledge and technology held by the firm. Previous literature has also linked alliance portfolio diversity and the uncertainty of the external environment of the firms, leading this dissertation to focus on the uncertainty of

the environment, measured as the yearly degree of technological change in the industry, as the external determinant. This allows to complement previous research which had tested uncertainty only in the context of larger, industry-reshaping events on alliance portfolios. The hypotheses are tested on a sample of R&D alliances of US-listed semiconductor firms. The findings of this chapter reveal that internal technological diversity negatively affects technological alliance portfolio diversity. These result falls in line with a stream of research advocating for organizational ambidexterity. Technological alliance portfolio diversity, however, seems unaffected by year-to-year changes in the technological environment of the firm.

Alliance portfolio diversity can be categorized in different ways, focusing on either dimensions based on partner characteristics or dimensions based on alliance characteristics. Chapter 4 focuses on these different dimensions of alliance portfolio diversity and their effect on innovation performance. This dissertation defines alliance portfolio diversity using both partner characteristics (partner industrial background) and alliance characteristics (alliance objective). Unlike previous studies which compare the effects of different dimensions of alliance portfolio diversity on innovation performance, this research additionally investigates the interaction of the diversity of alliance partners and the diversity of the alliance objectives. The hypotheses are tested on a dataset of R&D alliances in the US biopharmaceutical industry from 1998-2002. The findings of Chapter 4 imply that firms with diverse alliance partners in particular need to be careful not to focus on too many objectives at the same time.

Firms always strive to increase their innovation performance and gain the most benefit from alliances with diverse partner firms. Chapter 5 focuses on factors that can moderate the relationship between alliance portfolio diversity and firms' innovation performance. Firms have to support their external knowledge acquisition using their internal R&D capabilities. In this context, the firm's existing knowledge base, R&D focus as well as the possibility to increase R&D spending as a result of available organizational slack can be expected to influence the extent to which a firm can turn the diverse technological resources available within its alliance portfolio into innovative output. The hypotheses of this chapter are tested on a dataset of high-tech firms identified in the Forbes 500 list of companies. Various analysis of the data shows that the interaction of internal technological diversity and alliance portfolio diversity of the focal firm increases the innovation performance. Further tests have been conducted on the influence of organizational slack, however, no statistically significant effect could be found.

Overall, this dissertation increases the understanding of the diversity of R&D alliance portfolios by following a comprehensive view. The individual chapters focus on the determinants of this diversity as well as the effects of the alliance portfolio diversity on innovation performance. The hypotheses are tested on three different datasets containing information on the R&D alliances of firms in various high-tech industries including semiconductor and bio-pharmaceutical industries. It is shown that internal technological diversity of the firm reduces the diversity of its alliance portfolio but supports the firm in turning the alliance partners' resources into innovative output. Alliance portfolio diversity

itself has been defined using different approaches focusing on the characteristics of the partner firms or the alliances. This dissertation shows that these different dimensions of diversity should not be viewed separately as their interaction has a strong effect on the innovation performance of the firm.

Keywords: strategic alliance, alliance portfolio, alliance portfolio diversity, innovation performance, external knowledge acquisition

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Chapter 1. Introduction

1.1. Backgrounds

In many different industries, firms feel an increasing pressure to innovate due to increasingly rapid technological progress which leads to uncertain business environments. At the same time, many industries are becoming more knowledge-intensive and without sufficient knowledge, firms cannot produce a level of innovative output that it sufficient to sustain competitive advantages or even to survive. Consequently, as Figure 1-1 shows, firms enter R&D partnerships to access the knowledge and resources of other firms at an increasing rate.

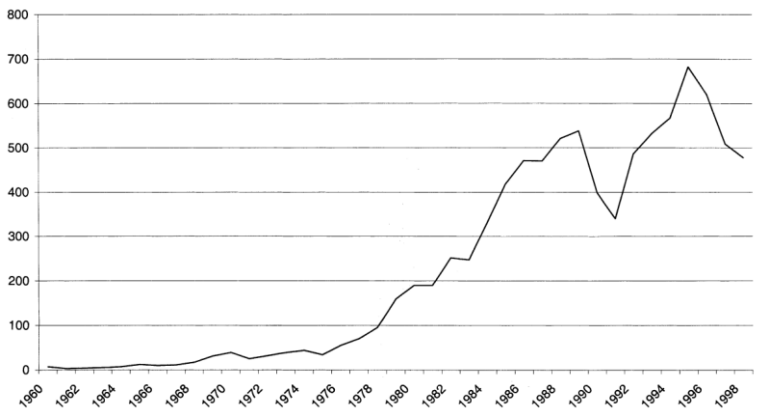

Figure 1-1. Growth of R&D partnerships (1960-1998).
Source: Hagedoorn (2002)

Strategic alliances are widely recognized as an important form of R&D partnership to access external sources of knowledge (Mowery, Oxley, & Silverman, 1996) and overcome the limitations of producing innovation from internal R&D (Hagedoorn & Schakenraad, 1994). Firms in many high-tech industries are entering alliances with other firms on a regular basis, which often leads to them conducting more than one alliance at the same time, giving rise to what literature refers to as the "alliance portfolio". In the context of this dissertation, the alliance portfolio is comprised of all the currently active alliances with other firms. As an example of the alliance portfolio of a high-tech firm, Figure 1-2 shows the 2006 alliance portfolio of Qualcomm Inc., a US semiconductor firm well-known for its wireless telecommunication products which are found in many smartphones.

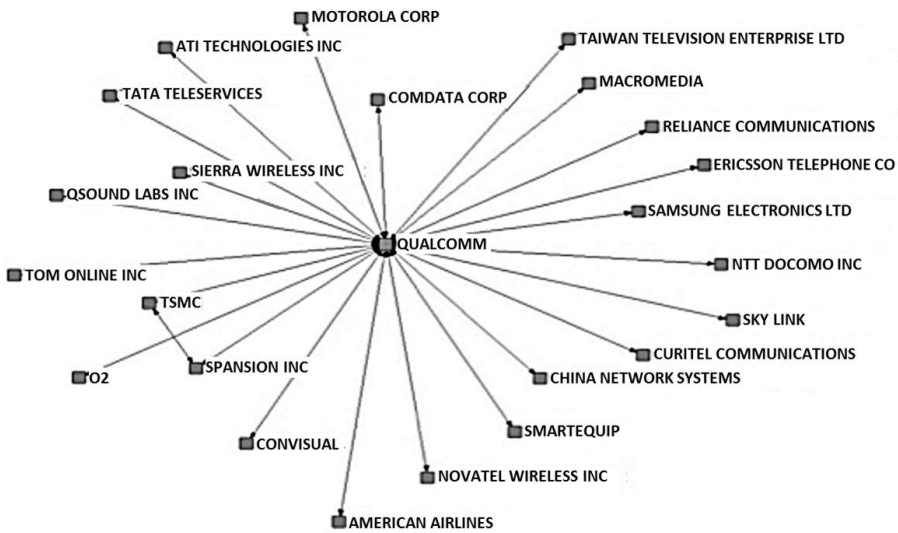

Figure 1-2. Alliance Portfolio of Qualcomm Inc. in 2007.
Source: Adapted from S.-Y. Kim (2014)

The figure, which is typical for the alliance portfolio of a technology-intensive firm, shows that the firm has created a portfolio containing 23 different alliances with diverse partners. Some alliances are formed with firms who use Qualcomm's products in devices sold to end-users such as Samsung Electronics Ltd. or Motorola Corp. Other alliances are formed with firms who have the same industrial background (semiconductor) such as TSMC and Spansion Inc. and a number of further alliances were formed with firms from diverse fields such as mobile telecommunications network operator (NTT DOCOMO Inc.), air transportation (American Airlines) and computer software (Macromedia).

Understanding that the ultimate goal for a firm is not the alliance deal or the alliance portfolio itself, but rather to use the possibilities provided by the alliances, such as access to the resources of the alliance partner, to create innovation, previous literature has investigated how the alliance portfolio contributes to the performance of the firm. While literature on alliance portfolios first focused on the size of the portfolio, i.e., how many alliances the firm is taking part in, it has recognized that the size by itself is not a good predictor for firm performance (Wassmer, 2010). Consequently, literature has investigated other portfolio characteristics (e.g., J. A. Baum, Calabrese, & Silverman, 2000; Gulati, 1999; Stuart, 2000), with recent literature being especially interested various measures related to the diversity of the alliance portfolio (e.g., Duysters, Heimeriks, Lokshin, Meijer, & Sabidussi, 2012; Oerlemans, Knoben, & Pretorius, 2013; Van de Vrande, 2013). Literature on alliance portfolio diversity in general is concerned with three key areas: the determinants of alliance portfolio diversity, the effects of alliance portfolio diversity on

firm performance, and how to improve the performance of diversified alliance portfolios. The interest in alliance portfolio diversity has increased in recent years and various studies have further increased our understanding of diverse alliance portfolios. Major contributions of recent literature include providing various definitions of alliance portfolio diversity (Jiang, Tao, & Santoro, 2010), beginning to investigate determinants of alliance portfolio diversity (Golonka, 2015; Tao, Jiang, & Santoro, 2015) or empirically testing the relationship between alliance portfolio diversity and firm performance in a variety of settings. However, the research on alliance portfolio diversity is still in its early stages, but it has paved the way for further contributions in this field.

1.2. Research purpose

Firms actively managing their technology and innovative activities have long recognized the value of strategic alliances, especially R&D alliances, in providing access to valuable resources that are located outside the boundary of the firm (Dyer & Singh, 1998; Lavie, 2006). The importance of R&D alliances is expected to further grow with a more wide-spread adoption of the open innovation paradigm (Gassmann, Enkel, & Chesbrough, 2010). The increasing use of alliances has led to researchers focus on firms that pursue more than one alliance at a time, and what effect the firm's alliance portfolio has on its performance. In recent years, research has increasingly focused on the diversity of the alliance portfolio as a key characteristic which influences innovation and financial performance. However,

as the research on the diversity of alliance portfolios is relatively sparse, compared to the research on strategic alliances in general, many questions on the concept of diversity itself as well as on its effects remain unanswered.

The aim of this dissertation is to close some of the gaps in the current knowledge about alliance portfolio diversity. Adopting a technological perspective, i.e., focusing in R&D alliances in technology-intensive industries, this dissertation investigates a number of diversity-related effects: First, it aims at increasing the understanding of the determinants of alliance portfolio diversity by investigating how both internal and external factors shape the alliance portfolio of the firm. Second, it aims at investigating the effects of different dimensions of alliance portfolio diversity and their interaction on the innovation performance of firms. Last, it aims to demonstrate which R&D-related characteristics of the firm enable it to profit better from diverse alliance portfolios. Altogether, this dissertation increases both the academic understanding of alliance portfolio diversity as well as provides recommendations for firms to improve the benefits obtained from diverse portfolios.

1.3. Research outline

This dissertation consists of three key parts: the literature review, three different empirical studies on the determinants of alliance portfolio diversity, its dimensions and effects on the firm's innovation performance, and the moderating factors of this relationship, as well as

final chapter providing the conclusions of this research as well as limitations and some directions for future research.

Chapter 2 provides a literature review. Specifically, this chapter presents the extant literature on alliances, alliance portfolios and alliance portfolio diversity. It highlights the importance of strategic alliances as a tool for external knowledge acquisition, how the research focus has shifted from single alliances to a portfolio view, and how research has begun to investigate the characteristics of alliance portfolios, especially those related to the diversity.

The three empirical studies are form the basis for Chapters 3, 4, and 5. Figure 1-3 provides an overview of the three key questions answered by these chapters and how they help to provide a comprehensive view of the origins and effects of alliance portfolio diversity.

Chapter 3 investigates the determinants of alliance portfolio diversity. Previous research on alliance portfolio diversity has primarily focused on investigating and explaining the effects of diverse alliance portfolios on the innovation and financial performance of firms. Treating the diversity of the alliance portfolio as an exogenous variable, only recently has research begun to investigate possible determinants for alliance portfolio diversity. It has, however, to this date not investigated the determinants of technological alliance portfolio diversity, i.e., the diversity of technological resources held by the alliance partners. Following a technological perspective, Chapter 3 investigates the effects of the firm's internal technological diversity and external technological uncertainty

on the technological diversity of its alliance portfolio and tests the hypotheses on a sample of R&D alliances conducted by US-listed semiconductor firms. Chapter 3 empirically verifies that internally diverse firms have less diverse alliance portfolios but fails to find evidence of the diversity being influenced by year-to-year changes in the technological environment of the firm.

Chapter 4 discusses and investigates the effects of alliance portfolio diversity on the innovation performance of the firm. Previous literature has defined alliance portfolio diversity using a variety of definitions, which generally fall into two broad categories: definitions based on the characteristics of the alliance partners, and definitions based on the characteristics of the alliance deals. Chapter 4 follows this distinction and hypothesizes the effects of both partner-background-based alliance portfolio diversity and alliance objective characteristic-based diversity. In general literature has established an inverted U-shaped relationship between the diversity of an alliance portfolio and the focal firm's innovation performance. Chapter 4 also argues for such a relationship based on the fact that more diverse portfolios contribute more to the recombinative, innovation-creating activities of the firm while at the same time more diverse portfolios inflict higher management costs on the firm and can hinder knowledge due to attention-based problems. Chapter 4 finds empirical evidence for an inverted U-shaped relationship between partner-based alliance portfolio diversity and innovation performance in a sample of US biopharmaceutical companies. It also tests and confirms a negative moderating effect of both kinds of diversity and consequently cautions firm to pursuit diverse alliance objectives with diverse partners,

as this has a significant negative effect on the innovation performance.

Focusing on answering the question "How can firms influence the relationship between alliance portfolio diversity and innovation performance?", Chapter 5 investigates moderating factors related to the firm's R&D activities and possibilities, as the firm's internal R&D has been shown by previous research to have an influence on its external knowledge acquisition activities and capabilities. Starting from a base-hypothesis on the inverted U-shaped relationship between alliance portfolio diversity and innovation performance, the chapter investigates the moderating effects of the firm's internal resource diversity, its absorptive capacity, and its level of organizational slack. The hypotheses are tested on a multi-industry sample of US high-tech firms. The chapter finds that the diversity of the firm's internal technological resources has a positive moderating effect due to increased absorptive capacity and the higher potential for recombining internal and external diverse knowledge to create impactful innovation. In a similar fashion, also relative absorptive capacity is found to have a positive affect which shows that firms can better benefit from diverse portfolios if the background of the firm and the portfolio is similar.

Concluding this dissertation, Chapter 6 provides a summary of the results and their implications. This chapter also provides a discussion of the limitations of this research and gives an outlook for future research.

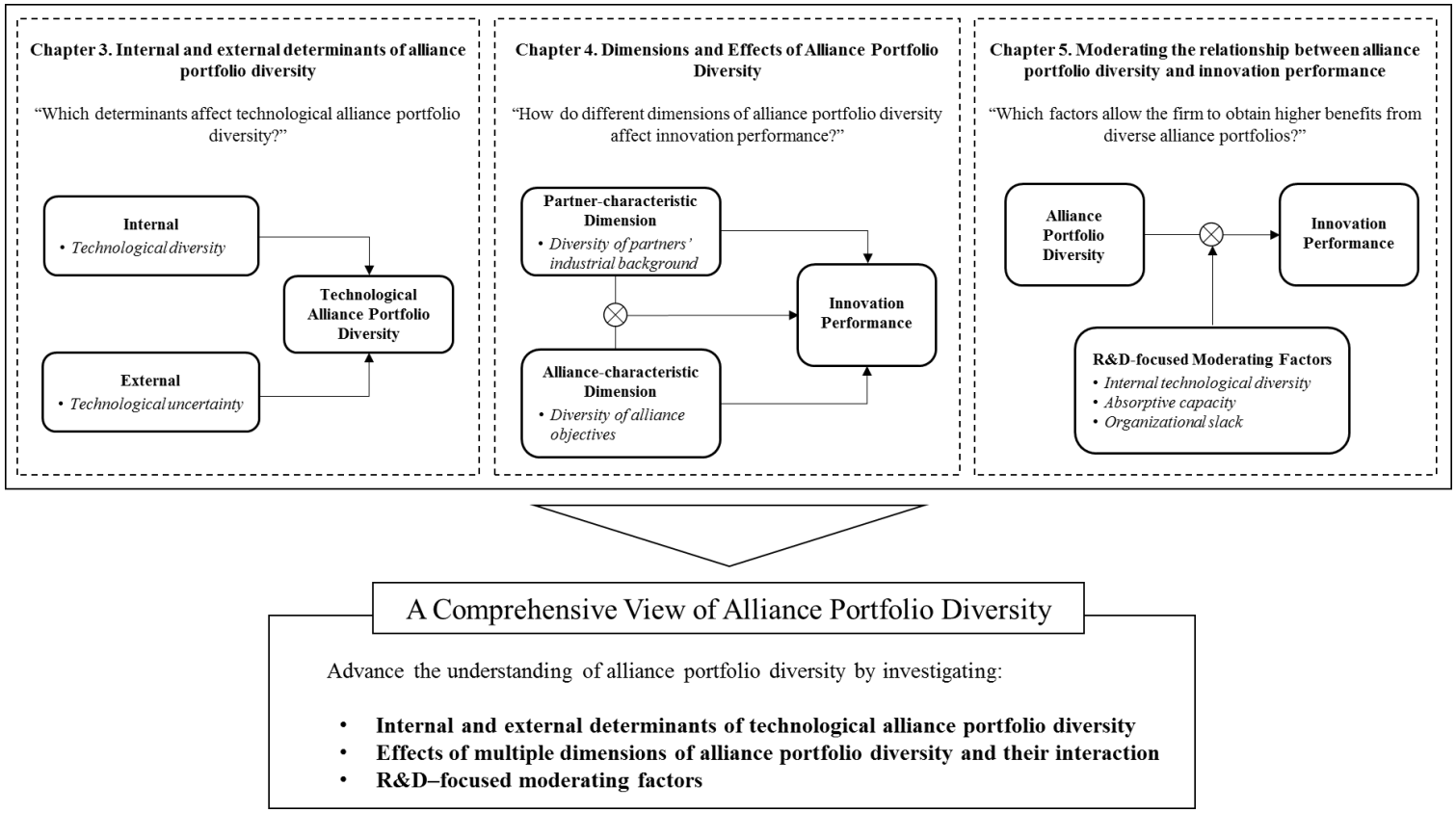

Figure 1-3. Overview of the Dissertation

Chapter 2. Literature review

2.1. Alliance portfolios

2.1.1. Strategic alliances

Parkhe (1991, p. 581) provides a definition of global strategic alliances, which, removing the global aspect, is a useful description on what constitutes a strategic alliance: "the relatively enduring inter-firm cooperative arrangements, involving … linkages that utilize resources and/or governance structures from autonomous organizations …, for the joint accomplishment of individual goals linked to the corporate mission of each sponsoring firm.". Gulati (1998, p. 293) provides a similar definition when he describes alliances as "voluntary arrangements between firms involving exchange, sharing, or co-development of products, technologies, or services. They can occur as a result of a wide range of motives and goals, take a variety of forms, and occur across vertical and horizontal boundaries."

Alliances can be classified depending on the planned activity: Many alliances are geared towards performing R&D-related activities. Such alliances are the focus of this dissertation. However, there are other kinds of alliances focusing on licensing, manufacturing or the provision of certain services, which often are provide complimentary functions to R&D alliances. Firms are known to form strategic alliances for a number of motives: Alliances

provide access to the resources of the partner firms, which can be used to complement existing resources or allow the focal firm to enter new technological areas and markets. Performing joint R&D-projects helps firm to share the costs and risks of developing new technologies. Global alliances help the firm to enter foreign markets. Table 2-1 provides a summary of firms' motives for entering strategic alliances.

Table 2-1. Motives for strategic alliances for technology cooperation

R&D and general technological development	Monitoring of technologies, access to scientific or complimentary knowledge, dealing with the increased complexity and intersectoral nature of new technologies, reduce the uncertainty of R&D, reduce and share the costs of R&D
Concrete innovation processes	Capture partners' tacit knowledge of technology, knowledge transfer, reduce time between innovation and market entry
Market access and search for opportunities	Internationalization, entry into foreign markets, expansion of product range, monitoring of environmental changes

Source: Hagedoorn (1993), Mowery et al. (1996), Spekman, Forbes, Isabella, and Macavoy (1998)

2.1.2. **From alliances to alliance portfolios**

For a long time, research on alliances has placed its focus on the single alliance (Wassmer, 2010) and has investigated why and how firms enter into an alliance, the contractual characteristics of the alliance, their evolution over time, and the performance of the alliance (Gulati, 1998). However, research such as Khanna (1998) has argued that the simple dyadic view is not sufficient to investigate a range of phenomena and that the focus should be placed on networks (Gulati, Nohria, & Zaheer, 2000) and portfolios of alliances. Consequently, literature has begun to increasingly focus on alliance portfolios (Duysters, De Man, & Wildeman, 1999; Faems, Van Looy, & Debackere, 2005; Wassmer, 2010). Previous literature on alliance portfolios has used different definitions, which are summarized in Table 2-2. These definitions differ depending on the focus of the research. Research on alliance networks has found more network-centric definitions for the alliance portfolio such as the firm's egocentric alliance network, while research that is focusing on a certain alliance characteristic might only include partnerships that fit that characteristics such as definitions of alliance portfolios including only joint ventures or portfolios defined as only the international alliances of a firm. Literature that focuses on learning often includes also the firm's past alliances. The definition that is commonly used in research on alliance portfolio diversity, and is also adopted by this dissertation, is the one by Bae and Gargiulo (2004), who focus on the set of alliances in which the firm is involved.

Table 2-2. Definitions of Alliance Portfolios

Definition	Literature
The set of alliances in which a firm is involved	Bae and Gargiulo (2004)
The set of bilateral alliances maintained by a focal firm	Doz and Hamel (1998)
All alliances of a focal firm	Hoffmann (2005, 2007)
A firm's portfolio of strategic agreements or relationships	George, Zahra, Wheatley, and Khan (2001)
A firm's network of business-partner relationships	Parise and Casher (2003)
A firm's accumulated international joint venture experience	Reuer, Park, and Zollo (2002)
All international joint ventures of a focal firm	Reuer and Ragozzino (2006)

Source: (Wassmer, 2010)

Wassmer (2010) has classified the research on alliance portfolios into three categories: the emergence of alliance portfolios, the configuration of alliance portfolios, and the management of alliance portfolios. Research on the emergence of alliance portfolios has investigated the rationale behind forming multiple alliances and found that firms use them to spread risks and obtain greater benefits (e.g., George et al., 2001; Hoffmann, 2007). This stream of literature has also linked the emergence of alliance portfolios to the external environment of the firm (e.g., Dittrich, Duysters, & de Man, 2007; Gimeno, 2004; Lorenzoni & Lipparini, 1999). Research on the management of alliance portfolios focuses on the firms' ability and capability to manage alliances and alliance portfolios (Anand & Khanna, 2000; Draulans & Volberda, 2003; Heimeriks & Duysters, 2007; Kale, Dyer, & Singh, 2002), the development of tools and indicators for alliance portfolio management, and strategies to manage alliance portfolios (Hoffmann, 2005, 2007). The research on the configuration of alliance portfolios focuses on the content and structure of the alliance

portfolio and has researched the size of the portfolio, the diversity of the firms and alliances in the portfolio, structural and relational characteristics and interdependencies. The configuration of the alliance portfolio is of great importance as, according to Hoffmann (2007, p. 834), it determines "the quality, quantity, and diversity of information and resources to which the focal firm has access". As the access to these information and resources are a key motivation to enter into strategic alliance, and are necessary for a firm's innovation output which affects its ability to compete and survive, size and diversity of the alliance portfolio have been recognized as important characteristics of alliance portfolios, with recent literature and this dissertation, placing a focus on aspects related to the diversity.

2.2. Alliance portfolio diversity

2.2.1. Definitions of Alliance Portfolio Diversity

Previous studies have defined alliance portfolio diversity in a variety of ways, which fall into two broad categories: those based on the characteristics of the alliance partners, and those based on the characteristics of the alliance deal itself (Wassmer, 2010). Considering that access to resources held by the alliance partners is common reason to enter into alliances, a logical choice of measure for the diversity of partners' characteristics is the diversity of the partners' resources, knowledge or capabilities. Measuring the knowledge held by a partner can be difficult due to the fact that knowledge exists in codified and tacit

forms (Ancori, Bureth, & Cohendet, 2000). Previous research on innovation has identified several ways to measure technological capabilities (Coombs & Bierly, 2006) or resources (Azzone, Bertelè, & Rangone, 1995). On the level of alliance portfolios, literature has settled on the use of patent-based indicators to define the diversity of firms' resources. Srivastava and Gnyawali (2011) as well as Vasudeva and Anand (2011) defined alliance portfolio diversity using a Herfindahl-based measure on the distribution of the partner firms' patents in distinct technological categories based on patent classes. While the above mentioned research tried to directly measure the technological resources of the alliance partners, other research has focused on the industrial background of the firms in the alliance portfolio. This background can be seen as a proxy for the capabilities and resources of the partner firms, as firms from the same industrial background tend to possess similar resources (L. Wang & Zajac, 2007). Collins (2013) defined alliance portfolio diversity based on the diversity of the 4-digit Standard Industrial Classification (SIC) codes. While also basing the diversity measure on the SIC code, Jiang et al. (2010) used a more complex definition, taking into account the number of shared digits of the focal firm's and partner firms' SIC codes, where a higher overlap shows a greater relatedness between the focal firm and the alliance partner.

Firms do not only differ by the resources they provide or their industrial background, but also by their type. A number of previous studies has focused on the diversity of the types of partners in the alliance portfolio. De Leeuw, Lokshin, and Duysters (2014), Faems, De Visser, Andries, and Van Looy (2010), and Oerlemans et al. (2013) employed a measure

based on the diversity of the type of alliance partners. Common partner types found in these studies are suppliers, competitors, universities and research institutes. Bruyaka and Durand (2012) defined the diversity of the alliance portfolio in terms of partners' position along the value chain. The research considers three distinct relationships: upstream, downstream and horizontal.

The alliance literature's interest in international alliances (e.g., Colombo, Grilli, Murtinu, Piscitello, & Piva, 2009; Li & Zhong, 2003; Narula, 2003; Narula & Duysters, 2004) has led to research also defining alliance portfolio diversity based on the alliance partners' national origin. Duysters and Lokshin (2011) based diversity on the sum of all partnership types while only considering international partnerships. Jiang et al. (2010) used a simple continuous variable indicating the number of countries present in the alliance portfolio.

On the other hand, diversity measures based on alliance characteristics include the diversity of the mode of governance and the functional diversity of the alliance portfolio. Jiang et al. (2010) defined the mode of governance using six categories ranging from non-equity to dominant equity share. To calculate the functional diversity, they considered four different types of alliances: marketing, manufacturing, R&D and other. Van de Vrande (2013) defined the diversity of technology sourcing portfolios by defining five categories of sourcing partnerships including CVC, alliances and joint ventures. The definitions of alliance portfolio diversity found in previous literature are summarized in Table 2-3.

Table 2-3. Definitions of Alliance Portfolio Diversity

Definition	Literature
Definitions based on partner characteristics	
Alliance partners' national origin	Duysters and Lokshin (2011), Jiang et al. (2010)
Alliance partners' industrial background	Jiang et al. (2010), Collins (2013)
Alliance partner type (e.g.,firm, university)	Duysters and Lokshin (2011)
Technology held by Alliance partners	Vasudeva and Anand (2011), Srivastava and Gnyawali (2011), Wuyts and Dutta (2014)
Alliance partners' position along the value chain	Bruyaka and Durand (2012)
Definitions based on alliance characteristics	
Mode of governance	Jiang et al. (2010)
Alliance function (e.g.,R&D, manufacturing)	Jiang et al. (2010)
Partnership type (e.g.,CVC, alliance)	Van de Vrande (2013)

2.2.2. Determinants of alliance portfolio diversity

Despite the growing research interest in strategic alliances and alliance portfolios, only a very limited number of empirical studies has focused on what affects the diversity of a firm's alliance portfolio. Duysters and Lokshin (2011) were some of the first researchers to focus on the determinants of alliance portfolio diversity. They investigated the alliance portfolio diversity, different types of alliance partners, once in general and once only considering international alliances, of firms that are either classified as innovators, imitators or non-innovators. The study employed data from two consecutive Community Innovation Surveys (CIS) performed in the Netherlands. The results find that innovators

have more diverse alliance portfolios than those of imitators, who in turn have more diverse alliance portfolios than non-innovating firms.

Collins (2013) investigated the influence of social capital held by the top management team (TMT) and by the firm itself on the industrial diversity of the alliance portfolios of 300 randomly selected firms from the Standard Poor's 500 list. He defined the TMT's social capital in terms of both social capital connections and social capital strength. The number of social capital connections was defined as the sum of the firm's TMT executives' membership in the board of directors of other firms. The strength is the composite count of the years of membership in other firms' boards. In a similar fashion, the firm's social capital connections are the number direct linkages with joint venture partners as well as the indirect linkages, i.e., their direct linkages. The study uses a weighted count, placing a higher importance on direct connections. The corresponding social capital strength is the time length of all the firm's direct and indirect external connections. The study finds empirical evidence for all the proposed hypotheses, i.e., both social capital connections and social capital strength of the firm's top managers and the firm itself result in a more diverse alliance portfolio in terms of partners' industrial background.

Tao et al. (2015) have linked alliance portfolio diversity and the external environment of the firm. Specifically, they investigated how environmental jolts in the telecom industry lead to firms changing the diversity of their alliance portfolios. In their research, environmental jolts refer to large disruptions to the firm's environment. In the last 20 years, the telecommunications industry has experienced two such disruptions: the 1996

US Telecommunications Act and the 2000 dot.com crisis. The empirical results show that the size of the alliance portfolio size as well the alliance portfolio diversity in terms of functional and governance diversity was affected by these external events. However, the study was not able to find evidence for the environmental jolts leading to the firms in the industry adjusting the diversity of the partner firms in their alliance portfolios.

Most recently, Golonka (2015) used survey data on 146 firms to investigate how ICT firms' cooperation strategy, their proactiveness in forming cooperation and trust in the partners affect the diversity of their alliance portfolios in terms of geographic diversity, governance diversity and partner type diversity. The results confirm that an active cooperation strategy increases the diversity of the alliance portfolio. Also managers' proactiveness in searching and engaging partners has a positive effect. However, the study failed to find statistical evidence for the relationship between the firm's trust in its partners and the diversity of its alliance portfolio.

2.2.3. Effects of alliance portfolio diversity

Previous research has empirically tested the effects of alliance portfolio diversity on various dimensions of firm performance. Owing to the focus on high-tech industries and R&D-driven alliances, most studies have focused on the innovation performance of the firm. Faems et al. (2010), De Leeuw et al. (2014), and Oerlemans et al. (2013), whose studies were based on Community Innovation Survey data, focused on product innovation

performance, defined as the percentage of turnover generated by new or technologically improved products. Sampson (2007), Van de Vrande (2013), and Vasudeva and Anand (2011) focused on the patenting performance of the firm. All three studies employed measures that simultaneously capture the number as well as the impact of the patents. Also focusing on patenting performance, Srivastava and Gnyawali (2011), based their innovation performance measure on the firms' rate of breakthrough innovation, i.e., the number of highly cited or impactful patents. Other than innovation performance, studies have also investigated the effects of alliance portfolio diversity on general alliance success, financial performance or firm exit: Duysters et al. (2012) employed a survey-based indicator on subjective alliance success; Jiang et al. (2010) focused on the three year average of the firms' net profit margin, and Bruyaka and Durand (2012)'s dependent variable is based on firm exit, i.e., whether a firm sells off or shuts down.

Most recent research on the relationship between alliance portfolio diversity and various dimensions of firm performance argues for an inverted U-shape relationship (e.g., De Leeuw et al., 2014; Duysters et al., 2012; Oerlemans et al., 2013). To explain this relationship, previous research has relied on the resource-based view, transaction cost economics and the attention-based view. Low levels of portfolio diversity lead to an increased likelihood of the overlap of ideas and knowledge which limits the advantage firms can draw from their alliance portfolios (Vasudeva & Anand, 2011). Increasing diversity provides access to more diverse resources that the firm can use to generate innovation an increase its performance (Van de Vrande, 2013). However, increasing

diversity increases the likelihood for negative effects such as opportunistic behavior of alliance partners (Combs & Ketchen, 1999), leakage and knowledge spillovers (Jiang et al., 2010) and inefficient resource allocation (De Leeuw et al., 2014). High levels of diversity also lead to difficulties in learning (Vasudeva & Anand, 2011). Together these effects lead to the aforementioned inverted U-shaped relationship.

The relationship between various definitions of alliance portfolio diversity and the performance of the firm has been investigated using datasets from a diverse range of knowledge-intensive industries including semiconductors (Srivastava & Gnyawali, 2011), fuel cell technology (Vasudeva & Anand, 2011) telecommunication equipment (Sampson, 2007), pharmaceuticals (Van de Vrande, 2013), biotechnology (Bruyaka & Durand, 2012), and automobile (Jiang et al., 2010). A number of studies has tested their hypotheses on multi-industry datasets (e.g., Duysters et al., 2012; Faems et al., 2010).

2.2.4. Moderating the effect of alliance portfolio diversity

As described in Section 2.2.3 (Effects of alliance portfolio diversity), most previous literature has hypothesized and empirically verified a positive or inverted U-shape relationship between alliance portfolio diversity and firm performance. The implication of the inverted U-shape relationship is that there exists an optimal alliance portfolio diversity, which allows the firm to gain the maximum benefits from its alliance partners. This opens up the question on how the relationship between alliance portfolio diversity and firm

performance can be influenced to improve the firm's performance.

While technically not a research on alliance portfolios due to focusing on dyad-level diversity, Sampson (2007)'s work paved the way for similar work and thus is included in this literature review. It starts from the well-accepted inverted U-shape relationship between alliance partner's diversity and innovation performance and hypothesizes that at high levels of diversity, alliances in the form of equity joint ventures contribute more to firm innovation than alliances based on bilateral contracts. The argument behind this hypothesis, which was supported by the empirical analysis of firms in the telecommunications equipment industry, is that in bilateral contract alliances the decision making is done on the level of the alliance partners, while in equity joint ventures a joint management enhances monitoring and control of the alliance activities. This is especially beneficial in the case of highly diverse technologies which are harder to transfer. Srivastava and Gnyawali (2011)'s research on US-listed semiconductor firms does not make any direct prediction about the relationship between the technological alliance portfolio diversity and the firm's performance in breakthrough innovation, but empirically finds a positive relationship. The focus of their research is on the moderating effect of internal technological diversity, i.e., the diversity of the firm's internal knowledge base. They argue that increased internal technological diversity diminishes the benefits of diversity in the firm's alliance portfolio due to a number of reasons: the increased complexity of pursuing diversity both within the firm and in its external arrangements, a mismatch of search routines which are more focused on search within the firm, and a general decreased

willingness of internally diverse firms to look for resources in their alliance portfolio. Their empirical analysis confirms the negative moderating effect of internal technological diversity on the relationship between alliance portfolio diversity in terms of partner's technology and breakthrough innovation. Also the work of Vasudeva and Anand (2011) focus on technological alliance portfolio diversity. In their study, which uses a dataset of firms in the fuel cell industry, they find an inverted U-shape relationship between alliance portfolio diversity and innovation performance. They also test the moderating effects of absorptive capacity which they construct using a patent-based measure of technological distance between the focal firm and the alliance portfolio. The results indicate that a reduced technological distance has a positive moderating effect which results in the point of maximum innovation performance shifting towards higher levels of diversity.

Duysters et al. (2012) investigate the moderating effects of alliance experience and alliance capabilities. The study defines performance using a subjective measure based on a survey and defines its alliance experience and alliance capability variables as dummy variables: coded 1 for experience or capabilities that are larger than the mean of the sample and 0 otherwise. Alliance capabilities were constructed using a multi-dimensional approach and included information on dedicated alliance functions, the use of tools such as best practices, and information on the firms' alliance control and management processes. While no statistically significant moderation effect of alliance capability could be found, the research finds a moderating role of alliance experience. Firms with alliance experience can reach their maximum innovation performance at a higher level of alliance portfolio diversity

which shows that firms can learn to manage diverse alliance portfolios.

While Duysters et al. (2012) included a number of management tools in their 34 item list of learning mechanisms that constitute a firm's alliance capability, the study of Oerlemans et al. (2013) focuses on the moderating effect of the use of technology management (TM) tools. The corresponding variable is the number of TM tools used by a firm out of a list of ten identified tools. These include internal tools such as technological audits of the firm or firm competence assessments, external tools such as competitor analysis and technology-monitoring tools such as technology forecasting. Their empirical analysis reveals a strong, positive moderating effect of the use of TM tools. However, they caution managers to consider their alliance portfolio diversity before implementing TM tools. At lower levels of diversity the tools do not contribute much to the performance of the firm, and investments into TM tools might not make economic sense. However, at higher levels of alliance portfolio diversity firms who extensively use such tools, i.e., map their internally available knowledge, perform scans of the external environment and make technological forecasts, are able to turn the negative effects of high levels of diversity into positive effects.

Van de Vrande (2013) finds an inverted U-shape relationship between the variance in relative technological proximity between the firm and its alliance partners and innovation performance. Her study further argues that in portfolios with more diverse technological proximities between firm and alliance partners, a higher diversity of the sourcing modes will lead to better results. Different sourcing modes offer different benefits to the firm, for

example, alliances offer a high flexibility whereas more integrated modes are better suited to transfer distant knowledge. The empirical results on a sample of firms from the pharmaceutical industry confirm the positive moderating effect of sourcing mode diversity.

Chapter 3. Internal and external determinants of alliance portfolio diversity

3.1. Introduction

Strategic alliances are a valuable tool for firms to exchange technologies or jointly perform R&D with their partners and to spread the risks and costs of the innovation process (Hagedoorn, 1993; Mowery et al., 1996). Following the focus on portfolios of alliances (Wassmer, 2010), research has investigated various characteristics of alliance portfolios. In recent years, a stream of literature has focused on alliance portfolio diversity and its influence on the performance of firms (e.g., De Leeuw et al., 2014; Faems et al., 2010; Van de Vrande, 2013), but paid little attention to the factors that influence alliance diversity itself. Alliance portfolio diversity, however, is not a fixed firm characteristic, but rather the reflection of a firm's strategy to actively influence and deal with its business environment (Golonka, 2015). Investigating the determinants of alliance portfolio diversity allows to extend the existing models linking alliance portfolio diversity and firm performance and to increase the understanding of which factors influence performance, a key factor for firms pursuing strategic alliances.

While previous studies have investigated the linkage between alliance portfolio diversity and innovation performance (e.g., De Leeuw et al., 2014; Faems et al., 2010;

Sampson, 2007) or financial performance (e.g., Jiang et al., 2010), only a limited number of empirical studies has focused on what affects the diversity of a firm's alliance portfolio: Duysters and Lokshin (2011) have investigated the alliance portfolio diversity, defined as geographical diversity as well as different types of alliance partners, of firms that are either classified as innovators, imitators or non-innovators. Collins (2013) investigated the influence of social capital held by the top management team and by the firm itself on the industrial diversity of the alliance portfolio. Golonka (2015) used survey data to investigate how various factors influence the diversity of ICT firms' alliance portfolios in terms of geographic diversity, governance diversity and partner type diversity. While the studies on the determinants of alliance portfolio diversity have used a number of different approaches to define alliance portfolio diversity, to my knowledge, no study has yet investigated the determinants of technological alliance portfolio diversity. Technological alliance portfolio diversity is a diversity measure directly based on the technological resources possessed by the partner firms in the alliance portfolio and has been shown to affect firms' innovation performance (Srivastava & Gnyawali, 2011; Vasudeva & Anand, 2011). Consequently, a better understanding of the factors affecting this diversity, as attempted by this study, will have not just academic but also practical implications.

Contributing to a, so far, little studied field within the literature on alliance portfolios (Golonka, 2015), the objective of this study is to investigate internal and external determinants of alliance portfolio diversity. Focusing on technological aspects of the firm, I examine the effects of a firm's internal technological diversity as well as of the

technological uncertainty on the diversity of its alliance portfolio. The results of the empirical study, which uses a dataset of R&D alliances conducted by US-listed semiconductor companies, confirm that increasing internal technological diversity of a firm reduces the diversity of it alliance portfolio but fail to find empirical evidence for the link between external technological uncertainty and alliance portfolio diversity.

This study contributes to strategic alliance literature, which so far has analyzed the determinants of alliance portfolio diversity using limited definitions and empirical settings, by investigating internal and external factors that affect the diversity of a firm's alliance portfolio defined in terms of technological diversity. Unlike previous literature which has mostly relied on surveys, the hypotheses of this study are tested using patent data over a longer time period. The selection of the determinants also allows this study to complement prior research on the linkage between alliance portfolio diversity, internal technological diversity and innovation as well as on the linkage between environmental changes and alliance portfolio diversity.

The remainder of this chapter is organized as follows: First, I develop hypotheses which link internal technological diversity and external technological uncertainty with alliance portfolio diversity. Second, the hypotheses are tested using a dataset of US listed firms in the semiconductor industry. Finally, the chapter present its empirical results and concludes with a discussion of their implications and their linkage to existing research on the topic.

3.2. Research hypotheses

3.2.1. The selection of determinants

Zaheer, Gulati, and Nohria (2000) have argued that the evolution of alliance networks is shaped by both endogenous and exogenous forces. Following this thought, this paper hypothesizes the effect of both endogenous and exogenous factors on the diversity of firms' alliance portfolios.

Previous literature has stressed the importance of the firm's resources (Peteraf, 1993; Wernerfelt, 1984), which often determine the opportunities available to the firm (Penrose, 1959). While the focus was originally placed on resources that are internal to the firm, later work has acknowledged that key resources can span firm boundaries and firms also access and employ the resources of their alliance partners (Dyer & Singh, 1998; Lavie, 2006). In other words, firms access and use internal knowledge, which it created through its own R&D activities as well as the externally sourced knowledge of its partners. While previous literature has not come to an agreement on whether the relationship between internal R&D and external knowledge sourcing is substitutive (Kang, Jo, & Kang, 2015; Laursen & Salter, 2006) or complementary (Cassiman & Veugelers, 2006; Grimpe & Kaiser, 2010), the relationship between the internal knowledge base and external knowledge has been previously investigated in the context of alliances. Among the previous studies that have investigated characteristics of the firm's internal knowledge base and alliance portfolios, a

number of studies have focused on the breadth and diversity aspects (e.g., Srivastava & Gnyawali, 2011; Wuyts & Dutta, 2014; Zhang, Baden-Fuller, & Mangematin, 2007). This paper adopts the internal technological diversity of the firm an important characteristic of the internal knowledge base and investigates how it effects the diversity of the knowledge provided in the firm's alliance portfolio. Selecting the internal technological diversity as the representative endogenous factor has also the added benefit of complementing the work of Srivastava and Gnyawali (2011), who investigated the effect of this diversity on the relationship between alliance portfolio diversity and innovation performance.

In terms of exogenous factors, previous literature has linked alliance portfolio diversity and the uncertainty of the external environment of the firms. Ozcan and Eisenhardt (2009) showed how diversified alliance portfolios help firms to better handle environmental uncertainty. Similarly, Hoffmann (2007) argued that diverse alliance portfolios allow firms to better deal with high levels of uncertainty by increasing their strategic flexibility. While one stream of literature has investigated the positive impact of alliance portfolio diversity in dealing with the environment, another stream of previous research (e.g., Castro, Casanueva, & Galán, 2014; Lavie & Singh, 2012) has argued that firms and their alliance portfolios co-evolve in response to changes of the technological environment. More specifically, Koka, Madhavan, and Prescott (2006) hypothesized that an increasing uncertainty will lead to an increase in the range of partners in the portfolio and Tao et al. (2015) have investigated the effects of environmental jolts on several dimensions of alliance portfolio diversity.

3.2.2. **Internal Technological Diversity**

The resources available to a firm play a critical role in the innovation process as innovation is generally understood to be created by recombining existing resources (Ahuja & Lampert, 2001; Fleming, 2001; Kogut & Zander, 1992). In today's high-tech industries, firms can no longer simply rely on a single product or technology to indefinitely sustain a competitive advantage. Constant innovation is the key for firms to stay ahead of their competition and survive. For successful innovation, not just the amount of resources held by a firm, but also their diversity is important. Due to limits of creating new ideas from a limited and constant set of knowledge, the existence of a more diverse range of resources allows a firm to increase the possibility of developing useful combinations (Katila & Ahuja, 2002). Consequently, more diverse internal resources improve the firm's ability to innovate through resource recombination (Carnabuci & Operti, 2013). A firm which does not possess diverse internal resources can follow two strategies to obtain them: either develop them through internal R&D or use external sourcing modes. Creating new knowledge internally is a difficult process that requires time and the investment of the limited resources of the firm and firms are often limited in their ability to internally produce diverse technologies (Hagedoorn & Schakenraad, 1994). Internal R&D is also inflexible, increases the path-dependency of the firm, and makes it more difficult to move towards radically new or different technologies (Narula, 2001). To overcome these limitations, firms take advantage of external sources of knowledge and access them through various strategies

such as strategic alliances, mergers and acquisitions, joint ventures or venture capital investments (Kang & Kang, 2009; Lee & Kang, 2015; Reus, 2012; H. A. Schildt, Maula, & Keil, 2005; Wubben, Batterink, Kolympiris, Kemp, & Omta, 2015).

To gain access to the diverse knowledge and technological resources needed for recombination, firms with a low internal technological diversity will try to form relationships granting them access to the diverse knowledge and technologies of other firms, for example, by assembling a diverse alliance portfolio. With increasing internal technical diversity of a firm, the need to obtain diverse resources through external acquisition methods becomes less urgent. As they can already use their diverse internal resources to create innovation through the recombination of knowledge, firms see less value in the pursuit of access to external diverse resources due to two important factors: increased costs and changes in the perception of knowledge from outside the firm.

Increasing diversity, both internally and externally, leads to increasing costs. Technology diversification within the firm increased R&D costs (Granstrand, 1998), resulting in less of the firm's limited resources being available to pursue other knowledge acquisition strategies. At the same time, increasing the diversity of an alliance portfolio increases complexity, resulting in higher managerial and coordination costs (Bruyaka & Durand, 2012; Jiang et al., 2010). This makes it difficult for firms to both internally and externally pursue high levels of technological diversity.

Additionally, relying on its diverse internal experiences and knowledge, firms may fall into a competency trap (Levitt & March, 1988) which results in the firm becoming

increasingly unwilling to pursue other options. Possessing already a diversified portfolio of technologies and knowledge, a firm might suffer from the “not-invented-here syndrome” (Hussinger & Wastyn, 2015 (forthcoming); Katz & Allen, 1982). According to Lichtenthaler and Ernst (2006), it affects the preference for outside knowledge and can lead firms to wrongly evaluate and neglect external technology. The reduced willingness of firms possessing a diversified base of technical resources to acquire external resources has also been demonstrated by Srivastava and Gnyawali (2011).

Another possible explanation is that as a firm diversifies its technological portfolio, it gains knowledge and expertise in a wider range of fields. This knowledge allows the firm to better identify technologies and knowledge that can supplement and complement its internal resources. Consequently, such a more experienced firm would pursue a strategy of a more focused external technology acquisition by selecting only the most promising alliance partners (Rothaermel & Hill, 2005). However, one could make the counter-argument that such increased knowledge as the result of a more diverse internal knowledge base raises the firm's absorptive capacity, i.e., its capacity to recognize the usefulness of externally acquired knowledge, to assimilate it and to apply it towards the firm’s business (Cohen & Levinthal, 1990). In other words, the firm would be better equipped to handle and profit from diverse alliance portfolios and would be more likely to pursue a strategy of diversifying its portfolio of alliances. The knowledge of various technological fields is, however, just one of possible sources of absorptive capacity. Previous literature has used factors such as R&D intensity (Cohen & Levinthal, 1990) and the relative relationship

between the firm and its knowledge source (Lane & Lubatkin, 1998) as indicators of firm's absorptive capacity and the empirical section of this study controls for these effects. All of the above lead to the following hypothesis:

Hypothesis 3-1: The level of a firm's internal technological diversity is negatively related with the diversity of its alliance portfolio

3.2.3. External Uncertainty

High-tech industries are often turbulent and characterized by a high level of uncertainty. Previous literature has investigated a range of exogenous and endogenous uncertainties (Folta, 1998). For firms in high-tech industries, uncertainties related to changes in the key technologies of the industry, i.e., technical uncertainty (Gilsing, Vanhaverbeke, & Pieters, 2014; Goerzen, 2007; Van de Vrande, Vanhaverbeke, & Duysters, 2009) are of great concern as firms' existing knowledge and technologies might become obsolete due to technology shifts (Koka & Prescott, 2008). The technological uncertainty has two effects on firms: First, it increases the pressure to innovate, and second, it requires firm to identify technological options to be prepared for when the current capabilities and technologies are no longer sufficient to successfully compete in the industry.

In unstable environments, firms are found to be more likely to exhibit strategic reorientation (Lant, Milliken, & Batra, 1992) and the uncertainty of the environment raises

the necessity for firms to innovate at an increasing rate in order to survive (Rowley, Behrens, & Krackhardt, 2000). Robertson and Gatignon (1998) demonstrated that to cope with the pressure to innovate under the condition of high technological uncertainty, firms are more likely to employ technological alliances rather than just rely on internal R&D.

Being open to external sources of technology allows firms to increase the number of technological opportunities (Laursen & Salter, 2006). When the uncertainty is high, firms find it difficult to predict which technologies will allow it to sustain or gain a competitive advantage in the future. Such effects can be mitigated by the use of real options (McGrath, 1997; Tao et al., 2015). Real options are investments in non-financial assets that provide the firm opportunities to respond to future events (Reuer & Tong, 2005). A small investment into the real option is done immediately, however, the choice to continue with a larger investment or not take up the option is taken at a later point. At this point in time, the firm might possess more information to make the final decision (Bowman & Hurry, 1993). An example of real options would be to conduct pilot tests or exploratory R&D on a small scale, before committing large amounts of the firm's resources into manufacturing facilities or commercialization (Ziedonis, 2007). In terms of innovation and environmental uncertainty, firms will create real options to be able, depending on the direction the industry is taking, to choose between different technologies. Kogut (1991) has investigated firms' use of joint ventures to create real options, which they can later take up or defer. Alliances are another external knowledge acquisition mode which allows firms to learn about opportunities from their partners (Vassolo, Anand, & Folta, 2004). With increasing

uncertainty, firms will try to create a larger number of options to react to the changing trends of technology, which will be reflected in an increasing diversity of its alliance portfolio. The increasing pressure to innovate in an uncertain environment and the firm's use of alliances to create real options lead to the following hypothesis:

Hypothesis 3-2: The level of external uncertainty is positively related with the diversity of a firm's alliance portfolio

The complete conceptual model containing the two hypotheses of Chapter 3 is shown in Figure 3-1.

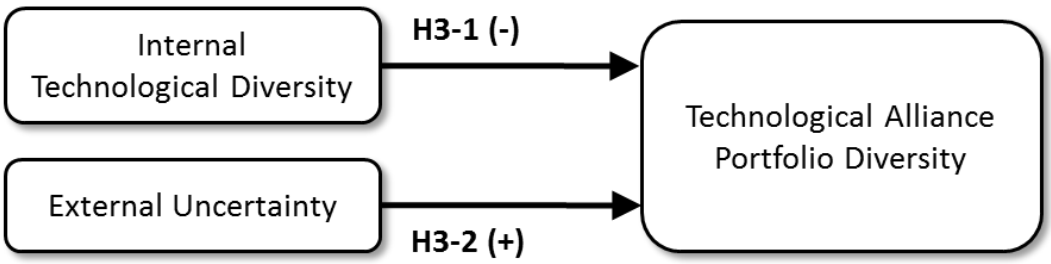

Figure 3-1. Conceptual Model for Chapter 3

3.3. Methods

3.3.1. Data and sample

For the empirical analysis I have compiled a dataset of firms in the semiconductor industry. The semiconductor industry is a high-tech industry that is known for its propensity to patent (Hall & Ziedonis, 2001) and networks of innovators (Kapoor & McGrath, 2014). It has also served as the background for a number of alliance related studies (Eisenhardt & Schoonhoven, 1996; Lahiri & Narayanan, 2013; S. H. Park, Chen, & Gallagher, 2002; Stuart, 1998, 2000). I began by identifying US listed firms with an Standard Industrial Classification (SIC) Code of 3674 (Semiconductors and Related Devices) from the Compustat North America database and collected information such as sales and R&D expense data for the 1990-2010 period. This time period was chosen to ensure a sufficient number of suitable samples. While firms in the semiconductor industry are very active in forming alliances, many of the alliances focus manufacturing or other services. Additionally, the semiconductor industry is dynamic and due to the constraints and filtering process described below, some firms only provided observable characteristics in a smaller number of observation years.

In the next step, I obtained information on the US patents granted to each of the firms by the United States Patent and Trademark Office (USPTO). The matching between the firms and its patents was performed using the matching data compiled by the Coleman

Fung Institute for Engineering Leadership at UC Berkeley (Fierro, 2014). Due to the fact that one of the independent variables as well as an important control variable are based on patents, all firms which had not been granted any patents are excluded from the dataset. This left a sample of 171 US semiconductor firms which had been granted at least one patent during the observation period. For each of those 171 firms, I compiled a list of strategic alliances they entered from 1988 to 2010 using information from the Thomson Reuters SDC Platinum database (Schilling, 2009). Using the provided alliance activity code, I decided to only include alliances which contained an R&D component, i.e., I excluded all alliances focusing purely on marketing, manufacturing or various services. Some of the alliances were formed between three or more firms and I have converted such alliances into sets of dyadic alliances. Due to the fact that not all of the semiconductor firm formed R&D-focused alliances during the sample period, at this point, the number of firms in the sample was reduced to 88 firms. These 88 semiconductor firms engaged in a total of 1142 R&D focused alliances with 646 different partner firms. The next step was to transform the list of alliance deals into the alliance portfolios of the 88 firms. As the SDC database does not contain complete information on when a given alliance ended, this study follows previous studies by assuming an alliance duration of three years (Schilling & Phelps, 2007; Srivastava & Gnyawali, 2011) when compiling the firms' alliance portfolios. For each of the 646 alliance partners, I obtained information on the patents granted using again the Fung Institute's patent data files but was unable to find patent information for 192 of the partner firms. These 192 firms without patents were either undisclosed partners or firms

which had not been granted any patents by the USPTO. For each of the firms in the sample I now calculated the technological diversity of the alliance portfolio for each year in which the firm had at least one active alliance. Due to the fact that, as mentioned above, some of the alliance partners had no patent information, at this point the sample was further reduced by excluding all firms whose alliance portfolios did not include at least one patent. This had to be done as without patents, it is not possible to calculate the dependent variable of this study.

The final sample contains observations from 68 distinct companies. Further accounting for the fact that many of these 68 firms in the sample did not exist for the whole observation period due to being incorporated later than 1990 or exiting the industry before 2010, and also excluding observations with missing values, the final dataset for this study contains 415 firm year observations.

3.3.2. **Dependent variable**

The dependent variable, *Alliance portfolio diversity,* is the technological diversity of the alliance portfolio. Technological diversity has often been measured using patent class data (e.g., Huang & Chen, 2010; D. J. Miller, Fern, & Cardinal, 2007). I follow previous literature (Garcia-Vega, 2006; Lin, Chen, & Wu, 2006; Quintana-García & Benavides-Velasco, 2008; Rao, Vemuri, & Galvin, 2004) in adopting a measure based on the Herfindahl Index.

Specifically:

$$\text{Alliance Portfolio Diversity} = \frac{N}{N-1}\left(1 - \sum_i {p_i}^2\right) \qquad (1)$$

Where N is the total number of patents held by the alliance partners and p_i is the proportion of the alliance partners' patents in the technical field i. The factor N/(N-1) is a correction for the bias introduced to Herfindahl Index-based measurements especially when they are based on a small sample size. The bias is corrected following the formula suggested by (Hall, 2005). Due to the high number of individual patent classes in the USPTO patent classification system which leads to some classes having a very low technological distance, in this study, a patent classification system based on Hall, Jaffe, and Trajtenberg (2001) is used which resulted in the patents being classified into one of 38 different fields. Due to the high depreciation rate of technological knowledge in high-tech industries (Gwangman Park, Shin, & Park, 2006), only patents applied for by the alliance partners within the five years before the alliance deal.

3.3.3. **Independent variables**

The operationalization for the independent variable *Technological diversity* followed a similar bias-corrected Herfindahl Index-based approach as the dependent variable. It is based on the patents applied for by the focal firm in the five years before the observation

year. For the classification I used the same 38 categories and calculated the diversity using the formula given above.

Technological uncertainty, which is exogenous to the firm, is often measured using the year-to-year changes in patenting activity on the industry level. Goerzen (2007) measured the percentage change in the number of patents of the industry between two years. A similar approach was used by Gilsing et al. (2014) who measured the relative change in the number of industry patents for a given year compared to the average of the three preceding years. Instead of basing a measure on the total patenting activity, Van de Vrande et al. (2009) introduced a measure based on the change of patenting activity in the patent classes that are most relevant for a given industry. To calculate the independent variable Uncertainty, I followed the procedure described in Van de Vrande et al. (2009). I began by identifying all the USPTO patent classes in which the focal firms in the sample had been granted patents during the observation period and narrowed the list down to the 22 classes which accounted for 80% of the patents. For each of the classes I then calculated the total number of US patent applications per observation year and calculated the Pearson correlation coefficient ρ for each pair of subsequent yearly patent distributions. Uncertainty is defined as $1- \rho$ and the variable is lagged by one year. The firms in the sample account for roughly 50 percent of all granted patents within the 22 key patent classes that were applied for during the observation period. The calculation of the variable revealed relatively small year-to-year differences, but a large uncertainty in the year 2005. This prompted me to also calculate the uncertainty following the above mentioned approaches of Goerzen

(2007) and Gilsing et al. (2014) which use the variation in the number of patents of the whole industry regardless of patent class.

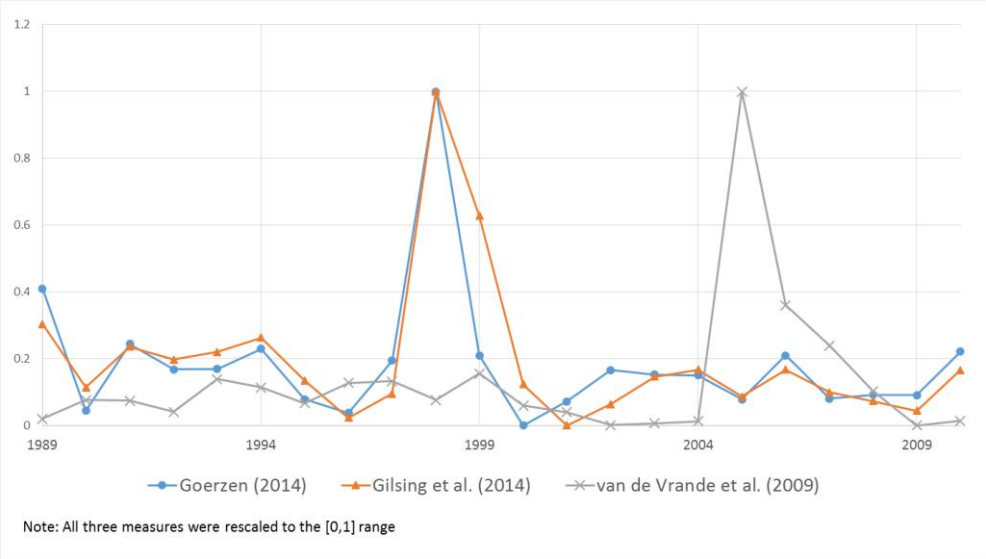

Figure 3-2. Comparison of Various Uncertainty Measures

A comparison of the results of these measures is given in Figure 1. The spike in the patent class based measure is due to especially a massive change in the patenting activity within US Patent Class 257, which covers active solid-state devices such as transistors. This spike is not seen in the other two measures which are based on the changes of the total number of patents. These two measures, however, exhibit a spike in 1998, which is the result of a general large increase in US patents that year.

3.3.4. **Control variables**

The empirical analysis includes a range of different control variables: portfolio size, similarity, R&D intensity, firm size, firm age as well as a number of time dummy variables. First, I control for the size of the alliance portfolio with the variable *Portfolio size*, defined as the number of alliances in the alliance portfolio in the observation year. The similarity of the focal firm's patent portfolio and the patent portfolio of the alliance partners is an important control variable as it might influence the alliance portfolio diversity in a number of different ways: On one hand, an increasing similarity between the knowledge and resources of the focal firm and its partners increases absorptive capacity (Cohen & Levinthal, 1990) and allows the focal firm to better access, transfer and incorporate the resources of its partners. This might result in firms pursuing more diversified portfolios. On the other hand, similar knowledge of focal firm and partners can increase the chance for redundancy and decrease the value of having a diversified portfolio. I calculate *Similarity* for each year and firm by calculating the Pearson correlation coefficient between the distribution of patents granted to both the focal firm and the firms in its alliance portfolio during the last five years based on the patent classification of Hall et al. (2001). As a firm's absorptive capacity in previous literature is often also approximated by the firm's R&D intensity (e.g., Stock, Greis, & Fischer, 2001; Tsai, 2001), I define *R&D intensity* as the firm's R&D expenses in a given year divided by the firm's total sales of the same year. Another variable that might have an effect on the firm's alliance portfolio is its

size. I define *Firm size* as the sales in each observation year and due to very high inter-firm differences, have log-transformed the variable. I also controlled for *Firm age*, defined as the number of years between the establishment of the company and the observation year. Semiconductor companies can be distinguished by their approach to manufacturing. Some larger companies such as Intel Inc. have their own manufacturing facilities which are often referred to as "fab", while other companies follow a "fab-less" business model and focus on the design of semiconductors but outsource the manufacturing to other companies (Balconi & Fontana, 2011; Hurtarte, Wolsheimer, & Tafoya, 2011). While this study specifically excluded alliances which just focus on manufacturing from the dataset, the choice of business model of the semiconductor companies might affect their alliance decisions. Consequently I have included a control variable *Fab*, which takes the value of 1 when the firm manufactures in-house and 0 if it follow the fab-less business model. I also introduced a series of year dummy variables.

3.3.5. **Empirical model specification**

This study's dependent variable, *Alliance portfolio diversity*, is continuous and limited to the [0,1] range. Without considering this characteristic, the predicted values could fall outside this range. For this reason, the dependent variable was logit transformed (C. F. Baum, 2008; Warton & Hui, 2011). As logit transformation does not work on values that are exactly 0 or 1, these values were first transformed using the methodology suggested by

Smithson and Verkuilen (2006). The unbalanced panel data was then analyzed using a linear regression model, both assuming random and fixed effects.

3.4. Results

Table 3-1 shows a summary of the descriptive statistics and the correlations among the variables used in this study. There are no high correlations between any of the variables. Nevertheless, in order to check for the presence of any multicollinearity problem, I performed an additional variance inflation factor (VIF) test (Mansfield & Helms, 1982). The results of this VIF test are shown in Table 3-2 and the low values (average of 1.78) indicate that this study does not have any problems with multicollinearity. Table 3-3 contains the results of the regression analysis using a random effects model. Model 1 contains all the control variables used in this study. The coefficients for Similarity, and Firm size are statistically significant, i.e., similar alliance portfolios tend to be more diverse and also larger firms tend to have more diverse alliance portfolios. Similar portfolios raise absorptive capacity and allow the firm to take better advantage also of diverse knowledge while large firms possess more resources to deal with the increasing complexity of managing highly diversified portfolios. Firm age is shown to be significant in three out of four models.

Table 3-1. Descriptive statistics and correlations matrix of the variables related to the determinants of alliance portfolio diversity

Variables	Mean	SD	1	2	3	4	5	6	7	8
Similarity	0.52	0.27	1							
Portfolio size	6.63	11.54	0.32	1						
Firm size	3117.97	6478.17	0.21	0.44	1					
R&D intensity	0.29	1.24	0.09	-0.05	-0.27	1				
Firm age	22.40	12.55	0.19	0.25	0.35	-0.08	1			
Technological diversity	0.75	0.16	0.19	0.18	0.09	0.04	0.16	1		
Uncertainty	0.01	0.02	0.05	-0.05	0.07	0.22	0.01	-0.07	1	
Alliance portfolio diversity	0.81	0.19	0.25	0.24	0.12	-0.02	0.02	-0.02	0.01	1

Table 3-2. VIF test results of the variables related to the determinants of alliance portfolio diversity

Variables	**VIF**
Similarity	1.19
Portfolio size	1.38
Firm size	1.57
R&D intensity	1.19
Firm age	1.27
Fab	1.33
Technological diversity	1.12
Uncertainty	1.10
Average	1.27

I originally included year dummies controlling for each observation year, but found that all year dummies for years in the 1990s were significant, which prompted me to create a new dummy variable, which takes the value 1 if the observation year is in the 1990s.

Model 2 tests Hypothesis 3-1, which predicted a negative influence of the internal technological diversity on the diversity of the alliance portfolio. The coefficient for *Technological diversity* is negative and highly significant in Model 2 as well as in Model 4, the full model. This strongly supports Hypothesis 3-1. Model 3 test Hypothesis 3-2, which predicted that increasing technological uncertainty leads to firms building up more

diverse portfolios. The coefficient for *Uncertainty* is neither significant in Model 3 nor in Model 4. I have retested Model 3 using the uncertainty definitions of Goerzen (2007) as well as of Gilsing et al. (2014), but in both cases (not shown in Table 3) failed to obtain statistically significant results. In summary, the empirical analysis did not support Hypothesis 3-2.

The results for the fixed effects model, which are presented in Table 3-4, are very similar to the results of the random effects model. Again one can see the significance of the Similarity, Firm size and Firm age control variables. The data also provides support for Hypothesis 3-1 but fails to support Hypothesis 3-2 using all three different definitions of *Uncertainty* (Table 3-4 only shows the baseline using the uncertainty definition of Van de Vrande et al. (2009)).

I also conducted an additional robustness test to rule out possible problems stemming from a 'reverse causality', i.e., the possibility that the internal technological diversity is not the cause of alliance portfolio diversity but its effect. To address this problem, I reversed the temporal order of the independent variable and dependent variable for Hypothesis 1. Specifically, I set Technological diversity [t+1] as the dependent variable, Alliance portfolio diversity [t] as the independent variable, and performed the regression analysis following the same procedure as for the original analysis. The results of the reverse-order regression analysis are shown in Table 3-5 and do not reveal any statistically significant relationships between the two lagged variables.

Table 3-3. Regression Results for Alliance Portfolio Diversity (Random Effects Model)

Variables	**Model 1**		**Model 2**		**Model 3**		**Model 4**	
	Coefficient	(S.E)	Coefficient	(S.E)	Coefficient	(S.E)	Coefficient	(S.E)
Control variables (at time t)								
Similarity	0.851***	(0.208)	0.876***	(0.206)	0.844***	(0.208)	0.871***	(0.206)
Portfolio size	0.007	(0.006)	0.006	(0.006)	0.007	(0.006)	0.006	(0.006)
Firm size	0.122*	(0.065)	0.119*	(0.065)	0.116*	(0.065)	0.114*	(0.066)
R&D intensity	0.013	(0.043)	0.016	(0.043)	0.006	(0.044)	0.011	(0.044)
Firm age	-0.016	(0.010)	-0.017*	(0.010)	-0.0158*	(0.010)	-0.017*	(0.010)
1990s dummy	0.702***	(0.143)	0.713***	(0.142)	0.704***	(0.143)	0.716***	(0.142)
Independent variables								
Technological diversity$_{t-1}$			-1.223***	(0.404)			-1.204***	(0.406)
Uncertainty$_{t-1}$					1.656	(2.364)	1.128	(2.343)
Constant	0.218	(0.412)	1.113**	(0.505)	0.231	(0.411)	1.104**	(0.503)
Fab dummy	included		included		included		included	
Number of observations	415		415		415		415	
R^2 (overall)	0.203		0.205		0.205		0.207	

* p < 0.1, ** p < 0.05, *** p <0 .01

Table 3-4. Regression Results for Alliance Portfolio Diversity (Fixed Effects Model)

Variables	**Model 1**		**Model 2**		**Model 3**		**Model 4**	
	Coefficient	(S.E)	Coefficient	(S.E)	Coefficient	(S.E)	Coefficient	(S.E)
Control variables (at time t)								
Similarity	0.762***	(0.221)	0.768***	(0.217)	0.747***	(0.221)	0.756***	(0.218)
Portfolio size	0.002	(0.006)	0.001	(0.006)	0.002	(0.006)	0.001	(0.006)
Firm size	0.274**	(0.109)	0.256**	(0.108)	0.261**	(0.110)	0.246**	(0.109)
R&D intensity	0.023	(0.046)	0.023	(0.046)	0.0134	(0.048)	0.016	(0.047)
Firm age	-0.082***	(0.020)	-0.085***	(0.020)	-0.084***	(0.020)	-0.087***	(0.020)
Independent variables								
Technological diversity$_{t-1}$			-1.562***	(0.455)			-1.538***	(0.457)
Uncertainty$_{t-1}$					2.289	(2.391)	1.704	(2.362)
Constant	1.192*	(0.644)	2.552**	(0.748)	1.301**	(0.654)	2.612**	(0.753)
1990s dummy	included		included		included		included	
Number of observations	415		415		415		415	
R^2 (within)	0.196		0.223		0.198		0.224	
R^2 (between)	0.003		0.001		0.002		0.001	
R^2 (overall)	0.023		0.0173		0.021		0.016	

* p < 0.1, ** p < 0.05, *** p <0 .01

Table 3-5. Reverse Causality Test (Regression Results for Technological Diversity$_{t+1}$)

Variables	Model 1 (fixed effects)		Model 2 (random effects)	
	Coefficient	(S.E)	Coefficient	(S.E)
Control variables (at time t)				
Similarity	0.1350**	(0.0652)	0.1410**	(0.0943)
Portfolio size	-0.0020*	(0.0018)	-0.0022	(0.0646)
Firm size	-0.0965***	(0.0296)	-0.0645**	(0.0260)
R&D intensity	-0.0116	(0.0140)	-0.0051	(0.0137)
Firm age	0.0084	(0.0065)	0.0096	(0.0062)
Independent variables				
Alliance portfolio diversity$_t$	0.0741	(0.0958)	0.0627	(0.0943)
Constant	1.4700***	(0.2150)	1.0300***	(0.2350)
Fab dummy			imcluded	
Year dummies	imcluded		imcluded	
Number of observations	410		410	
R^2 overall	0.0082		0.0913	

3.5. Discussion

This study investigates internal and external factors that affect the diversity of a firm's alliance portfolio. Specifically, focusing on technological aspects, I examined the effects of internal technological diversity and technological uncertainty on the technological diversity of alliance portfolios. The hypotheses were tested on a sample of US-listed semiconductor firms.

The empirical results confirm that increasing internal diversity of the technological

resources held by a firm negatively affects the diversity of its portfolio. In other words, firms that cover a wide range of technological fields within the firm are less likely to follow the same strategy in building their alliance portfolio. This result falls in line with a stream of research advocating for organizational ambidexterity. Ambidextrous organizations balance and pursue both exploration and exploitation (Raisch, Birkinshaw, Probst, & Tushman, 2009). Literature has acknowledged that this balancing does not just happen within a certain mode of operation such as internal activities or external alliance activities, but also between different modes (Rothaermel & Alexandre, 2009; Russo & Vurro, 2010; Stettner & Lavie, 2014). Diversification and variation can be interpreted as exploration of new possibilities, in contrast to exploitation, which is a focus on existing competencies (Lavie, Stettner, & Tushman, 2010; March, 1991). This relates to the firms in the sample as firms that focus on exploration within the firm's boundary, i.e., have a high internal technological diversity, achieve boundary crossing ambidexterity by limiting their external technology acquisition to focus on a smaller range of technologies. On the other hand, firms who focus on specific capabilities of their non-diverse internal knowledge complement this internal exploitation focus by having a diverse alliance portfolio, which can be seen as more exploration-oriented.

I also hypothesized that the technological diversity of a firm's alliance portfolio is affected by the technological uncertainty, i.e., the environment in which the firm operates. The hypothesis was based on the idea that increasing uncertainty makes it difficult for the firm to predict which technologies will become the next driving force of the industry and

will support the firm's competitive advantage. Consequently, I expected firms to build up a range of options by increasing the access to a more diverse range of technologies through their alliance portfolios. However, this chapter failed to find empirical evidence for such effect. Recently, Tao et al. (2015) investigated how firms in the telecom industry adapt their alliance portfolios to environmental jolts. They focused on two large scale disruptions to the firm's environment: the 1996 US Telecommunications Act and the 2000 dot.com crisis. While they were able to find evidence for changes of the alliance portfolio size as well as for changes to the alliance portfolio's functional and governance diversity, they found no evidence of changes in the partner diversity as a reaction to the changing environment. Their partner diversity measure was based on the partners' industrial background (as indicated by their SIC codes). This partner diversity measures serves as a proxy for the resources and capabilities offered by the partner firms and thus is closely related to the approach of this study, which defines the alliance portfolio diversity based on the technological resources of the partners, measured by their patents. Together, the results of Tao et al. (2015) and of this study indicate that alliance portfolio resource diversity is unaffected by year-to-year changes of the external uncertainty as well as by larger environmental jolts. The comparison of different measures for external uncertainty has also shown that the indicated uncertainty differs depending on whether the measures are based on all patents of an industry or just a selection of the most important ones. This opens up the question on how to best measure uncertainty. Previous literature (e.g., Milliken, 1987; Snyder & Glueck, 1982) has shown a long-running debate on whether uncertainty can be

measured objectively, as I have done in this study, or should be treated as a perceptual measure, i.e., the important factor is how the firm, or respectively its managers see and evaluate the external uncertainty (e.g., Bourgeois, 1985; Duncan, 1972; Jauch & Kraft, 1986; K. D. Miller, 1993; Song & Montoya-Weiss, 2001). It might well be that the change in resource-oriented dimensions of alliance portfolio diversity does not depend on objective, but rather subjective factors.

This study contributes to the research on strategic alliances, especially the research focused on the concept of alliance portfolio diversity. Previous research has extensively investigated the effects of alliance portfolio diversity on firm performance in a variety of settings but has paid little attention to investigating factors influencing the diversity. I extend previous research on this topic (Collins, 2013; Duysters & Lokshin, 2011; Golonka, 2015; Tao et al., 2015) which has recently begun to investigate the determinants of alliance portfolio diversity. Specifically, my research contributes by following a technological perspective and defining alliance portfolio diversity in terms of the diversity of the technological resources held by the firms in the alliance portfolio. This dimension of alliance portfolio diversity is important as the access to partners' resources is one of the key reasons for firms to enter into strategic alliances. The present study investigated the effects of both internal (internal technological diversity) and external (technological uncertainty) determinants on this alliance portfolio diversity. The choice of internal resource diversity as an independent variable also allows to complement the research of Srivastava and Gnyawali (2011). They investigated the moderating effect of internal resource diversity on

the relationship between alliance portfolio diversity and innovation performance. My research complements this by allowing to investigate a mediating effect: internal resource diversity directly affects alliance portfolio diversity, which in turn affects innovation performance. The investigation of environmental uncertainty complements previous work of Tao et al. (2015), who investigated how firms adapt their alliance portfolios after environmental jolts, by researching changes in alliance portfolio diversity in response to the year-by-year variation of the uncertainty in the firms' environment over longer time periods. Further setting this research apart from previous studies of the determinants of alliance portfolio diversity, which had mostly relied on survey results, the present study employs alliance and patent data and empirically tests its hypotheses on a dataset with a longer time duration.

As previous research has consistently demonstrated, the diversity of a firm's alliance portfolio has direct implications for its financial and innovation performance. Consequently it has stressed the need for managers to be aware of the composition of their alliance portfolios. This study further contributes to the understanding of this diversity by explaining the effects of internal resource diversity, which can be affected by a firm's spending on internal R&D.

Chapter 4. Dimensions and effects of alliance portfolio diversity

4.1. Introduction

In today's high-tech industries, changing technological paradigms create an uncertain environment which forces firms to continually innovate. To overcome the limitations of internal R&D and to acquire technologies and knowledge from outside sources firms are increasingly utilizing strategic alliances (Hagedoorn, 1993; Mowery et al., 1996). Often a single partner cannot provide all the required inputs and firms pursue more than one alliance at the same time, giving rise to the concept of alliance portfolios (Lavie, 2007). The increased importance of alliance portfolios resulted in research focusing on issues such as interactions between the individual alliances and the management of the portfolio (George et al., 2001; Parise & Casher, 2003; Wassmer, 2010). Within the alliance portfolio focused research, in recent years the concept of alliance portfolio diversity has been given increasing attention. Research has begun to investigate the origins and determinants of diverse alliance portfolios (e.g., Collins, 2013; Duysters & Lokshin, 2011; Golonka, 2015) and how they affect the performance of firms (e.g., De Leeuw et al., 2014; Faems et al., 2010; Van de Vrande, 2013). Prior literature on the link between alliance portfolio diversity and firm performance has dealt with different definitions of diversity but for the most part

focused on characteristics of the alliance partners when defining alliance portfolio diversity. This chapter follows prior studies in investigating the effect of alliance partner diversity on firm performance and also answers Wassmer (2010)'s call for pushing the boundaries of the research field by identifying new attributes to describe alliance portfolios. To do so, this study introduces a new alliance portfolio diversity measure based on the objective of the alliances in the portfolio. Previous literature has identified several factors that can moderate the relationship between alliance portfolio diversity and firm performance (e.g., Duysters et al., 2012; Oerlemans et al., 2013; Vasudeva & Anand, 2011), but has not yet given significant consideration to any interaction between different dimensions of alliance portfolio diversity itself (Wassmer, 2010). This research hypothesizes and tests the effects of alliance portfolios which are diverse in two different dimensions, based on partner- and alliance level attributes. In the case of this study, they are industrial background of the alliance partners and the aforementioned diversity of the alliance objectives. Together they allow to answer the question how a portfolio consisting of alliances with diverse objectives which are conducted with diverse partners affects the firm's innovation performance.

The hypotheses of this study are tested on a dataset of biopharmaceutical companies. The results of this empirical analysis confirm an inverted U-shape relationship between alliance partner diversity and innovation performance. They also confirm a negative interaction effect of alliance partner diversity and alliance objective diversity on innovation performance. This study contributes to strategic alliance literature by expanding the research on alliance portfolio diversity based on alliance characteristics by investigating

the effects of the diversity of the alliance objectives on innovation performance. Unlike previous studies (e.g., Jiang et al., 2010) which compare the effects of different dimensions of alliance portfolio diversity on innovation performance, this research studies the interaction between two of those dimensions, partner industrial background and alliance objectives.

The remainder of this chapter is organized as follows: First, I develop hypotheses which link alliance portfolio diversity, defined by either partner or alliance characteristics, with the firm's innovation performance. I also propose an interaction of the diversity of alliance partners and the diversity of the alliance objectives. Second, the hypotheses are tested using a dataset of US firms in the biopharmaceutical industry. Finally, the empirical results are presented and the chapter concludes with a discussion of the implications.

4.2. Research hypotheses

4.2.1. Different dimensions of diversity

Firms are forming alliances with their partners for various reasons such as to share risks, or quickly move into new markets. Among the motivations for alliances, the access to resources provided by the partners (Eisenhardt & Schoonhoven, 1996) is a key factor. The resources provided are not limited to physical resources but also include knowledge, routines and the partners' experience. The exact nature of the resources provided depends

on the partner, as different firms often possess different resources. This is especially the case when the partner firms belong to different industries which have distinct knowledge bases. When investigating the diversity of an alliance portfolio, following a resource-based perspective, the diversity of the resources provided presents itself as a logical starting point of investigation. While some research has investigated the diversity of the resources offered by the partners in the alliance portfolio by looking into the patents held by these firms (Srivastava & Gnyawali, 2011; Vasudeva & Anand, 2011), another approach is to look at the diversity of the partners' industrial background. As firms in the same industry are likely to possess similar resources, routines, knowledge and backgrounds, partners' industrial diversity is a useful proxy for the resources these partners can provide to the focal firm. Consequently, this research will also investigate the effects of alliance portfolio diversity, defined as the diversity of the partners' industrial background, on the innovation performance of the firm.

The resources available through the partners are a valuable dimension of alliance portfolio diversity and in fact are one of the most common definitions used in alliance portfolio research. However, alliance portfolio diversity cannot just be defined based on the characteristics of the partners, but, less commonly used in prior literature, also can be based on characteristics of the alliance deals. When firms make the decision to enter into an alliance, they make a number of decisions. One is whom to partner with; the results of this decision are captured by investigating the diversity of the alliance portfolio in terms of partner characteristics such as industrial background. Another decision is the objective of

the alliance. In which field should the alliance activities take place? The background of the alliance, which denotes objective and the knowledge background of the alliance deal has been previously studied on a dyadic level in the study of Wen and Chuang (2010). While investigating alliance governance-mode choices in strategic alliances, they considered different combinations of knowledge of the two alliance partners and the alliance itself. Knowledge background was defined as the SIC code of the partner firms and the alliance and possible combinations included co-exploration (when the alliance activity was in a field different from the industrial background of the partners), co-exploitation (when both the alliance partners and the alliance itself were assigned the same SIC code), and learning/teaching (when only one of the two firms shared the SIC code of the alliance). With the research focus on the alliance portfolio level, this study also investigates the industrial classification of the alliance as a key variable. However, similar to the partner characteristics, on the alliance portfolio level, this characteristic becomes a diversity measure. Analog to the alliance portfolio diversity, which is defined as the diversity of the partners' industrial background, I investigate alliance objective diversity, the diversity of the background of the alliance which hints at the objective and knowledge area of the alliances.

In this section, I will hypothesizes the direct effects of two important alliance portfolio diversities: First, alliance portfolio diversity defined as the diversity of the industrial background of the alliance partners, and, second, a diversity defined as the diversity of the alliances background. I will also look into the interaction between these

different dimensions of diversity which is especially interesting, as one is a partner –based characteristic, and the other is alliance-based.

4.2.2. Alliance Portfolio Diversity (Partners' Industrial Background)

The resource based view of the firm has long argued that resources form the basis for firms' competitive advantage (Mahoney & Pandian, 1992; Peteraf, 1993; Wernerfelt, 1984). Further extensions to the view have acknowledged the fact that these resources are not just internal to the firm, but span organizational boundaries and firms enter into alliances to access the resources of their partners (Das & Teng, 2000; Dyer & Singh, 1998; Lavie, 2006). At low levels of APD, partners are very similar in background, which means they are likely to possess similar resources and knowledge (L. Wang & Zajac, 2007). This increases the risk of redundancies of resources (Bruyaka & Durand, 2012) and limits learning. High levels of overlap have been shown to contribute little to the subsequent innovation of the firm (Ahuja & Katila, 2001). The correlation among the options in the portfolio is also known to reduce the value of the portfolio (Vassolo et al., 2004). With increasing diversity of the partners in the alliance portfolio, the firm gains access to more diverse resources which it can employ in its innovation generating processes. The diverse resources improve the firm's ability to innovate through resource recombination (Carnabuci & Operti, 2013) by increasing the possibility of developing useful combinations of knowledge (Katila &

Ahuja, 2002). Diverse resources in the alliance portfolio also strengthen the firm's strategic flexibility and allow it to better deal with uncertainties in its environment (Hoffmann, 2007). While an increasing diversity of the partners offers possibilities for innovation, it also brings about negative effects. These will require the firm to invest more of its valuable resources and prevent it from taking full advantage of the diverse portfolio. The issues related to high levels of diversity can be broadly classified into two major categories: issues resulting from increased transaction costs and issues resulting from attention allocation. Dealing with a more diverse set of alliance partners increases the potential for conflicts and increases the complexity of coordinating the alliances in the portfolio, leading to an increase in managerial costs (Jiang et al., 2010). Trust issues and lack of understanding of the partners will further increase monitoring costs (Goerzen & Beamish, 2005). In terms attention allocation, Koput (1997) summarizes some of the problems that occur when the firm tries process strongly diversified knowledge. The main difficulty is to identify useful knowledge, which can be further made more difficult due to too many ideas to process and ideas arriving at the wrong time and place.

In summary, alliance partner diversity positively contributes to the firm's innovation performance by enabling access to the resources of a diverse range of partners. As the partner's diversity increases, so does the diversity of the resources and knowledge held by them. Innovation requires constant new inputs to create novel combinations of different knowledge elements. On the other hand, dealing with more diverse partners places a burden on the firm and increases transaction costs due to more complex monitoring. At the same

time, the firm reaches the limits of its ability to acquire, process and use vast amounts of diverse knowledge, preventing it from taking full advantage of the diversity. These positive and negative effects of increasing alliance partner diversity lead to the following hypothesis:

Hypothesis 4-1: Alliance Portfolio Diversity (diversity of alliance partners' industrial backgrounds) has an inverted U-shape relationship with innovation performance

4.2.3. Alliance Portfolio Diversity (Alliance Objectives)

Besides the diversity of the partners' industrial background, the effects of alliance objective diversity, i.e., the dimension of alliance portfolio diversity defined as the diversity of the alliance objectives and knowledge background, also is expected to affect the firm's innovation performance. The pursuit of a wider range of objectives provides more learning opportunities to the firm. This is due to the fact that innovation can be realized by bridging fields. Galunic and Rodan (1997, p. 13) refer to these "recombinations that take place between competence areas, through the interaction or exchange of the underlying (input and knowledge-based) resources". Fleming (2001) has argued that familiarity with the combinations of an invention, the invention's usefulness increases. Being involved in more diverse alliances, i.e., forming alliances spanning more diverse fields, helps the firm to become more familiar with a wider range of technologies and combinations, further

increasing their innovation performance.

On the other hand, firms have only limited capabilities and capacities to handle increasingly diverse bodies of knowledge (Cohendet & Llerena, 2009) and face problems being engaged in diverse alliances at the same time. Firms who try to cover too many objectives at once, i.e., have alliance portfolios with a high level of alliance portfolio diversity (objectives), will suffer from an information overflow and find it hard to allocate their attention (Koput, 1997).

In summary, I expect the diversity of the alliance objective to positively contribute to the firm's innovation performance as diverse alliance objectives allow for a greater recombinative potential. As the diversity increases, however, the firm suffers from increasing problems with attention allocation. The combination of these two effects leads to the following hypothesis:

Hypothesis 4-2: Alliance Portfolio Diversity (diversity of alliance objectives) has an inverted U-shape relationship with innovation performance

4.2.4. **The Interaction between Partner and Objective Diversity**

The alliance portfolio perspective advocates the understanding that the different alliances a firm is undertaking at the same time should not be viewed separate from each other.

Rather than being stand-alone activities of the firm, there is an interaction between them. While firms may enter the individual alliances to pursue different objectives with different partners, knowledge and resources can be shared between the individual alliances in the portfolio (Khanna, Gulati, & Nohria, 1998). Literature has stated that the ease of transferring knowledge and resources is closely related to the concept of absorptive capacity (Cohen & Levinthal, 1990). Absorptive capacity is increased when the knowledge and experiences overlap with each other. Consequently firms will find it easier to transfer and share knowledge between alliances from similar fields, i.e., in an alliance portfolio with a low level of objective diversity. On the other hand, a high diversity of the alliance objectives, showing that the individual alliances in the firm's alliance portfolio focus on many different objectives, will decrease the absorptive capacity and impede knowledge sharing across alliances.

The absorptive capacity argument also holds for resource diversity. An increasing level of resource diversity also lowers the absorptive capacity (Cohen & Levinthal, 1990; Cui & O'Connor, 2012; Sampson, 2007). Firms with a highly diverse alliance portfolio in terms of partners' industrial background already find it hard to transfer and benefit from the diverse resources offered by their partners due to increasing costs and complexities. If they simultaneously face a highly diversified alliance portfolio in terms of alliance objectives, the reduced levels of absorptive capacity will further impede their ability to transfer knowledge from partners and across alliances and will weaken their capabilities to innovate.

Another possible explanation is that a focus on a small number of areas, i.e., a small alliance portfolio diversity in terms of alliance objectives, could act as a filter for resources and information. Firms overwhelmed by the knowledge of their diverse partners can better select knowledge which corresponds to and fits with a smaller number of objectives. This filtering can reduce the problems associated with high levels of alliance portfolio diversity such as those resulting from knowledge overflow. The interaction of alliance portfolio diversity (partners) and alliance portfolio diversity (objectives) leads to the following hypothesis:

Hypothesis 4-3: The diversity of the alliance objectives negatively moderates the relationship between Alliance Portfolio Diversity (partner industrial background) and innovation performance.

For an easier understanding, Figure 4-1, presents the conceptual model and shows the linkages between the three hypotheses of this chapter.

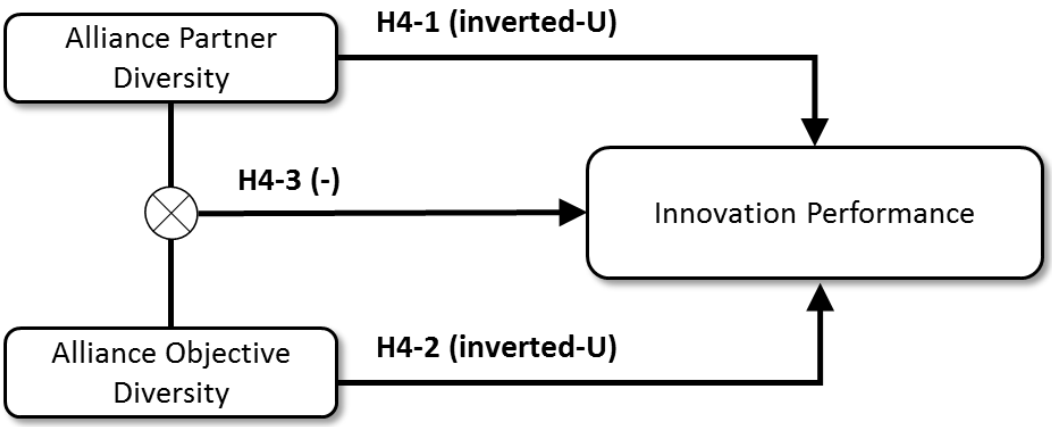

Figure 4-1. Conceptual Model for Chapter 4

4.3. Method

4.3.1. Data and sample

For the empirical analysis I have compiled a dataset of US biopharmaceutical firms. The biopharmaceutical industry is knowledge-intensive and recognized for its high rate of alliance activity (Hagedoorn, 1993). Pharmaceutical industries also exhibit a high propensity to patent their innovation outcomes (Arundel & Kabla, 1998; Danguy, De Rassenfosse, & de la Potterie, 2014). Due to these characteristics, the biopharmaceutical

industry has served as the setting for a number of previous studies on alliances (e.g., Reuer & Devarakonda, 2015; Rothaermel, 2001; Xia & Roper, 2008; Zhang et al., 2007) and alliance portfolios (e.g., J. A. Baum et al., 2000; George et al., 2001; Shan, Walker, & Kogut, 1994; Vassolo et al., 2004).

This study focuses on the time period from 1998 to 2002. This time period was chosen for two main reasons: First, owing to technological progress and the emergence of new dedicated biotech companies, the rate of R&D focused collaboration peaked during the late 1990s and early 2000s (Riccaboni & Moliterni, 2009). The selection of this period ensures a sufficient number of alliances in the sample to calculate the diversity of firms' alliance portfolios. Second, the chosen time period ends before the stagnation of growth experienced by the biopharmaceutical industry during the mid-2000s, until which the industry had averaged yearly sales growth rates of over 10% (Gassmann, Reepmeyer, & Von Zedtwitz, 2008).

In collecting the dataset used in this study, I adhered to the following procedure: First, I compiled the alliance portfolios of US biopharmaceutical firms using the alliance data available from the Thomson Reuters SDC Platinum database. In this study, biopharmaceutical firms are those with an assigned SIC code of 283. Following the established time frame of this study, I collected information on alliances formed between 1998 and 2002. Focusing on R&D alliances, I excluded all alliances whose Activity Code and Activity Description section, i.e., the section which describes the general purpose of the alliance, did not contain any mention of research and development. This limited the

final selection to pure R&D alliances as well as multi-purpose alliances with an R&D element, for example, manufacturing and R&D alliances. Further information about the focal firms, such as firm size or R&D expenditures were collected from the Compustat North America database. To assess the innovation performance of the firms, for which I employ a patent-based indicator, as well as for the construction of some of the control variables, I collected information on the patents granted to the focal firms from the database of the US Patent and Trademark Office (USPTO). The use of US patent data also explains this study's focus on US biopharmaceutical companies, as non-US firms might patent their innovations in other countries first or at higher rates. A number of companies and related alliance deals had to be excluded from the final dataset for a number of reasons: First, during the observation period financial and patent data for some, mostly small, target firms was unavailable. This concerned a number of small, mostly privately owned firms as well as some firms which were the target of some of the frequent mergers & acquisitions (M&As) in the biopharmaceutical industry. Second, alliance and patenting activities were in some cases carried out by subsidiaries of a firm. I follow the approach taken in previous studies (e.g., C.-S. Kim & Inkpen, 2005; Van de Vrande, 2013) and consolidated the available patent and alliance data at the level of the parent corporation. The final dataset contains the information on 70 firms which conducted R&D-focused alliance deals during the observation period. These numbers fall well in line with previous research using datasets from the biopharmaceutical industry (e.g., Hoang & Rothaermel, 2005; Van de Vrande, 2013).

4.3.2. **Dependent variable**

The dependent variable of this study is the innovation performance of the firms. Previous literature has used patent count as a measure of innovation performance (e.g., Ahuja & Katila, 2001; Henderson & Cockburn, 1996; Penner-Hahn & Shaver, 2005). This method, however, has limitations as it treats all patents the same, while in reality the importance of individual patents can vary (Lanjouw, Pakes, & Putnam, 1998). Consequently, literature has found ways to compensate for these variations by including other measures such as the number of citations a patent received. The use of patent citations is a suitable approach as they have been shown to be correlated with technical importance (Albert, Avery, Narin, & McAllister, 1991; Carpenter, Narin, & Woolf, 1981), value of the patent (Harhoff, Narin, Scherer, & Vopel, 1999) and firms' market value (Deng, Lev, & Narin, 1999; Hall, Jaffe, & Trajtenberg, 2005). This study uses an approach based on a combination of the number of granted patents as well as the number of citations these patents received. Specifically, I use a measure based on the linear weighted patent count suggested by Trajtenberg (1990). The formula used to calculate the weighted patent count for each firm is shown below, with n_j being the total number of granted patents applied for by firm j during the observation period and C_i the number of forward citations received by patent i.

$$\mathrm{WPC}_j = \sum_{i=1}^{n_j} (1 + C_i) \qquad (2)$$

Following other literature which used a weighted patent count-based approach (Sampson, 2007), this study adopts a four year difference between alliance and patent observation periods to account for the time it takes for the knowledge gained through alliances to become patented knowledge. This time lag is the result of the time it takes to transfer the knowledge, adapt and process it, and apply it to new innovation as well as the time it takes to prepare a patent for application. Patents applied for before the year 2002 thus are unlikely to be the result of the firm's alliance activity during the observation period. Patents were collected for the 2002-2006 timeframe and citations were considered until the year 2010. This leads to a truncation of the citations received for especially the patents applied for late in the observation period. As patent citations are known to peak within the first three years (Mehta, Rysman, & Simcoe, 2010), however, this effect can be neglected and longer observation periods for forward citations are not considered necessary (Lanjouw & Schankerman, 1999).

4.3.3. Independent variables

The independent variable, *Alliance portfolio diversity (partner),* is the diversity of the alliance partners' industrial backgrounds. The partners' industrial background is a good proxy for the resources, technology, routines, capabilities of the partners as firms in the same industry are likely to be able to offer similar resources to the focal firm (L. Wang & Zajac, 2007). Similar approaches of defining partner diversity using the SIC code have

been used in a number of previous studies (e.g., Cui & O'Connor, 2012; Jiang et al., 2010). To calculate the diversity of the alliance portfolio, I employ a measure based on the Herfindahl Index. Specifically:

$$\text{Alliance Portfolio Diversity} = 1 - \sum_{i} {p_i}^2 \qquad (3)$$

where p_i is the proportion of the alliance partners with a primary SIC code of *i.* The variable ranges from 0 to 1, with 0 showing that all alliance partners have the same industrial background, i.e., the same SIC code, and 1 showing that the partners are fully diverse with each partner firm belonging to a different industry.

The operationalization for the independent variable *Alliance portfolio diversity (objective)* followed a similar Herfindahl Index-based approach. It is based on diversity of the objectives of the alliances in a firm's alliance portfolio. The objective is indicated by the alliance main SIC code assigned by the experts at Thomson Reuters to each alliance in the SDC Platinum database.

4.3.4. **Control variables**

The empirical analysis includes five control variables: firm size, R&D intensity, patent stock, alliance experience, and number of alliances during the patent observation period. The size of a firm might be an indicator as to the amount of resources it can use to arrange

alliances, manage them, and gain advantages which translate into an increased firm performance. I define *firm size* as the average amount of sales from 1998-2002 and, due to large inter-firm differences, have log-transformed the variable.

The firm's capabilities to perform in-house R&D can be expected to affect the results in two ways: First, increased R&D can directly lead to an improved innovation performance. Second, a firm's R&D capabilities are often seen as a proxy for the firm's absorptive capacity (Cohen & Levinthal, 1990) which influences the firm's ability to identify, transform and assimilate external knowledge from its alliance portfolio. I define *R&D intensity* as the average of the firm's R&D expenses in the 1998-2002 period divided by the average of the sales during the same period. This study also controls for the firm's recent patenting activity, a proxy for experience and capabilities, that can be expected to affect the quality and quantity of subsequent patents. In this study, *Knowledge stock,* is defined as the number of patents applied for by the firm from 1998-2001.

As firms enter into more alliances, they increase their alliance related experience, which can help them to obtain better outcomes through improved alliance management. While some studies have defined alliance experience as being accumulated prior to the observation period (De Leeuw et al., 2014; Sampson, 2007), the variable *Alliance portfolio size* of this study does not just capture size effects but can also be understood as the contemporary experience, i.e., the experience obtained during the measurement period of the alliance portfolio diversity (Duysters et al., 2012; Heimeriks, 2010). *Alliance portfolio size* is defined as the number of alliances of each firm in the 1998-2002 timeframe. Finally,

Sampson (2007) argues that the number of ongoing alliances is likely to affect the patenting activities of a firm. To control for this effect, I define *Alliance during obs period* as the number of alliances the focal firm is conducting during the patent observation period (2003-2006).

4.3.5. Empirical model specification

The dependent variable of the study, *innovation performance*, is based on the concept of the weighted patent count and is a non-negative count variable. A closer look at its characteristics reveals that it suffers from over-dispersion, i.e., its variance is larger than its mean value. This violates a basic assumption of the Poisson regression model, which is often used to analyze count data. As a result, this study adopts a negative binomial regression model (Barron, 1992; Cameron & Trivedi, 2013).

4.4. Results

Table 4-1 shows a summary of the descriptive statistics and the correlations among the variables used in this study. Of interest is the correlation between the diversity of the alliance partners and the diversity of the alliance objectives (0.34), which shows that the decision about partnering with firms of a certain industrial background and the decision of the alliance objective are made quite independent of each other. It can also be seen that the

highest levels of correlation are found between firm size and innovation performance as well as between knowledge stock and innovation performance. Larger firms who also have a larger knowledge stock, produce more and/or higher cited patents. To check for possible problems due to multicollinearity, I performed a variance inflation factor (VIF) test. The results of this test are shown in Table 4-2 and the low values (average of 1.74) indicate that this study does not have any problems with multicollinearity (Craney & Surles, 2002; O'brien, 2007).

Table 4-1. Descriptive statistics and correlations matrix of the variables related to the effects of alliance portfolio diversity

Variables	Mean	SD	1	2	3	4	5	6	7	8
Firm size	5.53	3.01	1							
R&D intensity	1.32	2.14	-0.61	1						
Knowledge stock	157.27	228.79	0.63	-0.24	1					
Alliance portfolio size	2.96	1.76	0.17	-0.06	0.40	1				
Alliance during obs period	4.8	7.73	0.50	-0.21	0.51	0.24	1			
Alliance portfolio diversity (partner)	0.48	0.25	0.37	-0.28	0.34	0.29	0.36	1		
Alliance portfolio diversity (objectives)	0.45	0.23	0.26	-0.22	0.23	0.26	0.17	0.34	1	
Innovation performance	819.03	1238.08	0.64	-0.28	0.70	0.36	0.54	0.34	0.17	1

Table 4-2. VIF test results of the variables related to the effects of alliance portfolio diversity

Variables	**VIF**
Firm size	2.90
R&D intensity	1.74
Knowledge stock	2.15
Alliance portfolio size	1.30
Alliance during obs period	1.52
Alliance portfolio diversity (partner)	1.36
Alliance portfolio diversity (objective)	1.20
Average	1.74

contains the results of the regression analysis using the negative binomial regression model. Model 1 contains all the control variables used in the study. Two of the control variables, firm size and knowledge stock, show consistently significant results, not just in Model 1, but in all the models. It shows that large firms in the biopharmaceutical industry produce more and/or more influential patents. The significance of knowledge stock, which is defined as the number of patent applied for by the firm between 1998 and 2001, shows that firms who had a high innovation output in that time period, also performed well in the patent observation period of 2002-2006. All other control variables did not show any significant results in any of the models.

Models 2 and 3 test Hypothesis 1, which predicts an inverted U-shape relationship between the diversity of the alliance partners' industrial background and the innovation performance of the firm. While the linear term is not significant in Model 2, in Model 3, which tests the predicted curvilinear relationship, both alliance portfolio diversity (partner) as well as alliance portfolio diversity (partner) squared are significant. The positive sign of alliance portfolio diversity (partner) and the negative sign of alliance portfolio diversity (partner) squared show the inverted U-shape relationship, thereby confirming Hypothesis 4-1.

Models 4 and 5 test Hypothesis 4-2, which predicts an inverted U-shape relationship between the diversity of the alliance objectives and the innovation performance of the firm. While the linear term alliance portfolio diversity (objective) shows a low level of significance in Model 4, both it and the quadratic term alliance portfolio diversity (objective)

squared are insignificant in Model 5 as well as in the full Model 7. Summarizing the results for alliance portfolio diversity (objective) and alliance portfolio diversity (objective) squared, it can be seen that Hypothesis 4-2 about the direct effect of alliance portfolio diversity defined in terms of alliance objective on the firms' innovation performance is not supported.

Model 6 tests Hypothesis 4-3, which predicts a negative interaction of the alliance portfolio diversities based on partner and objectives on the innovation performance. As can be seen in Table 3, the coefficient for APD (partner) × APD (objective) is negative and significant in Model 6 as well as in Model 7. This supports Hypothesis 4-3. The interaction of alliance portfolio diversity and alliance objective diversity and their effect on innovation performance is plotted in the 3D-graph in Figure 4-2. In this graph, one can clearly see the inverted U-shape relationship between alliance portfolio diversity and innovation performance as well as the negative effect of increasing alliance objective diversity.

Model 7 is the full Model which contains all the control variables and independent variables used in the empirical analysis. Alliance portfolio diversity (partner), alliance portfolio diversity (partner) squared as well as the interaction term APD (partner) x APD (objective) show significance and the predicted direction of the effect, further lending support for Hypotheses 4-1 and 4-3.

Table 4-3. Negative binomial regression results for innovation performance (different dimensions of alliance portfolio diversity)

Depend variable: Innovation performance	Model 1		Model 2		Model 3	
	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.
Control variables						
Firm size	0.3070***	0.0746	0.3040***	0.0744	0.2880***	0.0761
R&D intensity	0.0652	0.0931	0.0684**	0.0924	0.0391	0.0913
Knowledge stock	0.0023**	0.0009	0.0022**	0.0009	0.0025**	0.0010
Alliance portfolio size	0.0572	0.0740	0.0510	0.0739	0.0569	0.0738
Alliances during obs. period	-0.0042	0.0235	-0.0067	0.0235	0.0097	0.0251
Independent variables						
Alliance portfolio diversity (partner)			0.4570	0.635	3.6240**	1.5890
Alliance portfolio diversity (partner) squared					-4.7500**	2.2290
Alliance portfolio diversity (objective)						
Alliance portfolio diversity (objective) squared						
APD (partner) × APD (objective)						
N	70		70		70	
Log likelihood	-490.334		-490.084		-487.923	
Pseudo *R*^2[a]	0.0650		0.0654		0.0696	
LR Chi^2	68.14		68.64		72.97	

[a] McFadden's pseudo R-squared.

Notes: *p < 0.10; **p < 0.05; ***p < 0.01

Table 4-3 (Continued) Negative binomial regression results for innovation performance

(different dimensions of alliance portfolio diversity)

Depend variable:	Model 4		Model 5		Model 6		Model 7	
Innovation performance	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.
Control variables								
Firm size	0.3220***	0.0719	0.3240***	0.0708	0.301***	0.0697	0.2870***	0.0697
R&D intensity	0.0256	0.0914	0.0314	0.0915	-0.0140	0.0858	-0.0204	0.0863
Knowledge stock	0.0023**	0.001	0.0024***	0.0009	0.0024***	0.0009	0.0025***	0.0009
Alliance portfolio size	0.0924	0.0748	0.0979	0.0746	0.1100	0.0726	0.1050	0.0717
Alliances during obs. period	-0.0050	0.0225	-0.0065	0.0222	0.0092	0.0233	0.0092	0.0231
Independent variables								
Alliance portfolio diversity (partner)					4.6250***	1.5560	5.1320***	1.5670
Alliance portfolio diversity (partner) squared					-4.3110**	2.0880	-3.8490*	2.2340
Alliance portfolio diversity (objective)	-1.120*	0.5820	0.2420	1.6790			1.6780	1.5900
Alliance portfolio diversity (objective) squared			-2.0770	2.4030			-0.6470	2.6150
APD (partner) × APD (objective)					-3.2000***	1.1230	-5.3310**	2.4790
N	70		70		70		70	
Log likelihood	-488.432		-488.069		-483.686		-482.840	
Pseudo *R*^2	0.0686		0.0693		0.0776		0.0793	
LR Chi^2	71.95		72.67		81.44		83.13	

Notes: *p < 0.10; **p < 0.05; ***p < 0.01

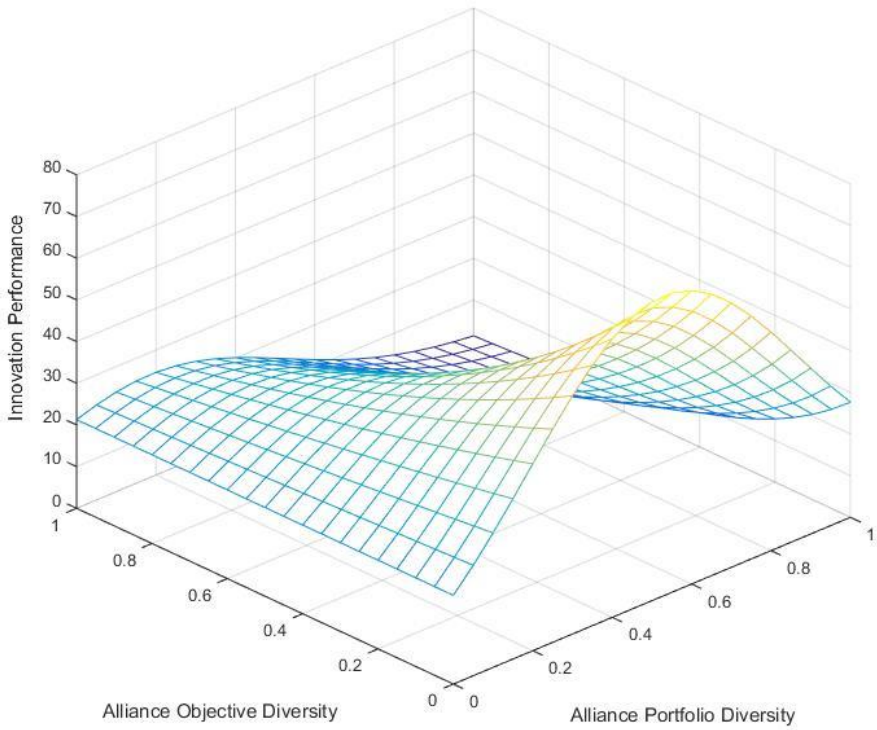

Figure 4-2. The interaction of alliance portfolio diversity (partner) and alliance portfolio diversity (objective) on the innovation performance of the firm

4.5. Discussion

This study investigates the effects of alliance portfolio diversity on firms' innovation performance. Specifically, focusing on various definitions of alliance portfolio diversity, it examined the effects of diversity in terms of alliance partners' industrial background and

in terms of alliance objectives as well as the interaction between these two dimensions. The hypotheses were tested on a sample of R&D focused alliances formed by US biopharmaceutical companies.

The empirical results confirm that the alliance portfolio diversity, defined as the diversity of the partners' industrial background, has an inverted U-shape relationship with innovation performance. While increasing diversity first improves the innovation performance of the focal firm by providing access to a broader range of resources whose recombinations with each other and with the resources held by the focal firm can increase innovation output, firms are not able to profit as well from too high levels of diversity. At higher levels of diversity, the firms face increasing costs and complexities in managing the portfolio. Managers of alliance portfolios need to be aware of the relationship between alliance portfolio diversity and innovation performance. They should strive to find the optimal level of diversity that allows access to sufficiently diverse resources, but at the same time be careful not to increase diversity to the point where the firm is unable to handle the diverse partners.

The present research failed to confirm direct effects of the diversity of the alliance objectives, but confirmed the important interaction between alliance portfolio diversity and alliance objective diversity. Previous studies have focused on one dimension of diversity at a time, but have generally not considered interaction effects. This study finds a significant negative interaction effect of alliance portfolio diversity in terms of partner background and in terms of alliance objectives. Together, high diversities significantly affect the

innovation performance of the firm. The major implication of this finding is that managers need to be aware that not just partners can be diverse, but also diverse objectives of the alliances in the portfolio need to be considered. The negative interaction shows that especially firms who are already dealing with a highly diverse range of partners in their portfolio need to be careful not to pursue a too diverse range of objectives at the same time. Both diverse partners and diverse alliance objectives lead to drastically reduced innovation performance. Firms with diverse partners should thus focus on a smaller number of objectives, i.e., ensure that the alliances pursue objectives in similar business fields.

This study contributes to the research on strategic alliances, especially the research focused on the effects of alliance portfolio diversity. Previous research has begun to investigate the effects of alliance portfolio diversity on firm performance in a variety of settings and has focused to a large part of describing the effects of partner characteristic-based diversities. Following this research, this study confirmed an inverted U-shape relationship between the partners' industrial background and the focal firm's innovation performance. The present research compliments the results of Jiang et al. (2010) who found a similar relationship between the industrial background of alliance partners and firms' financial performance in the automotive industry. Alliance decisions are, however, not limited to selecting partners, and the focus on the diversity of partner characteristics does not allow for a complete understanding of the effects of diversified alliance portfolios. I address this issue and contribute to the ongoing research by introducing a diversity measure based on the objective of the alliances in the portfolio, which is measured by employing

the SIC code associated with each alliance. To my knowledge, my research is the first to investigate this alliance-based characteristic, which so far has been studied in the dyadic perspective of alliances, on the alliance portfolio level. I further extend previous research on the effects of alliance portfolio diversity by investigating the interaction between two different dimensions of alliance portfolio diversity, the diversity of the partners' industrial background and the diversity of the alliance objectives. The findings of this dissertation demonstrate that focusing on a smaller number of objectives in an alliance portfolio can improve the innovation performance and that especially firms with a high diversity of alliance partners need to be careful of not engaging in a too diverse range of objectives at the same time as firms' capabilities to innovate are severely impeded when the diversity of both partners and objectives is high.

Chapter 5. Moderating the relationship between alliance portfolio diversity and innovation performance

5.1. Introduction

Strategic alliances are important tools for firms to access the knowledge and resources of other firms (Grant & Baden-Fuller, 2004; Mowery et al., 1996; Simonin, 2004). Rather than pursuing a single alliance at a time, firms often are engaged in multiple alliance deals with multiple partners. The phenomenon of firms assembling such a portfolio of alliances (Gulati, 2007; Lavie, 2007; Wassmer, 2010) has been well recognized by the academic literature in the field of alliances and an increasing number of studies has focused effects of multiple alliances being operated together such as embeddedness issues (M. J. Kim, Park, & Kang, 2015; Gunno Park, Kim, & Kang, 2015) or the additive effects of pursuing multiple alliances (Vassolo et al., 2004). Research has investigated various characteristics of alliance portfolios and how they influence the innovation of the firm. The most basic characteristic of alliance portfolios is their size (Deeds & Hill, 1996; Shan et al., 1994), however research has shown that its effect might be outweighed by other characteristics (Wassmer, 2010). Consequently, research has focused also on other characteristics such as quality (Stuart, 2000) or efficiency (J. A. Baum et al., 2000). In recent years, an increasing

number of studies has focused on the diversity of the alliance portfolio. Approaching the issue from various perspectives, literature has investigated the effects of alliance portfolio technological diversity (e.g., Srivastava & Gnyawali, 2011; Vasudeva & Anand, 2011), alliance portfolio partner diversity (e.g., De Leeuw et al., 2014; Faems et al., 2010; Jiang et al., 2010; Oerlemans et al., 2013) and the diversity of alliance-deals related aspects such as the type of alliance (Jiang et al., 2010) or mode of governance (Van de Vrande, 2013). Treating the alliance portfolio diversity as an exogenous factor, the research mostly focuses on the effect of diverse alliance portfolios on the innovation and financial performance of the firm. A number of studies has investigated factors that influence and moderate the relationship between alliance portfolio diversity and firm performance. This research has uncovered the moderating effects of alliance experience (Duysters et al., 2012), the use of technology management tools (Oerlemans et al., 2013) or technological distance between the firm and its alliance portfolio (Van de Vrande, 2013; Vasudeva & Anand, 2011).

This chapter investigates the moderating effects of a number of firm characteristics which are all related to the firm's internal R&D capabilities and activities. A wide stream of literature has investigated the relationship between external knowledge sourcing and internal R&D activities of the firm (e.g., Arora, Belenzon, & Rios, 2014; Berchicci, 2013; Cassiman & Veugelers, 2006; Denicolai, Ramirez, & Tidd, 2014; Grimpe & Kaiser, 2010). Gambardella (1992) found that firms with better in-house science-related capabilities are better at identifying and integrating external knowledge and also other research has investigated the role of the firm's R&D expertise in the external knowledge acquisition

process (Caloghirou, Kastelli, & Tsakanikas, 2004). This chapter investigates three firm characteristics related to internal R&D. The first one is the internal technological diversity, i.e., the diversity of the existing knowledge base. The diversity of the resources used in the innovation process has direct effects on the innovative output (Carnabuci & Operti, 2013). Previous research conducted on R&D alliances of US semiconductor firms by Srivastava and Gnyawali (2011) has shown that the internal technological diversity of a firm also affects its ability to profit from diverse alliance portfolios. This chapter presents two competing hypotheses: one arguing for a positive role of internal technological diversity due to its role in increasing the absorptive capacity and raising the potential for innovative recombinations of knowledge and technologies. The counter-hypothesis builds up on changing perception of external knowledge and predicts a negative influence of a diverse knowledge base. The next factor investigated is the absorptive capacity of the firm, i.e., its ability to identify, transfer and use external knowledge. This study considers both the classical absorptive capacity, which is a characteristic of the target firm, as well as the newer, relative absorptive capacity, a dyadic concept, which had been previously studied in the context of technological alliance portfolio diversity by Vasudeva and Anand (2011). The final characteristic investigated in this chapter is the firm's level of organizational slack. While a number of previous studies have confirmed the relationship between organizational slack and firms' innovation and financial performance (e.g., Huang & Chen, 2010; Nohria & Gulati, 1997; Su, Xie, & Li, 2009) and argued for the role of organizational slack in easing capital restrictions and increasing the propensity to take risks, to my knowledge, this

is the first study investigating the effect of organizational slack on the link between alliance portfolio diversity and innovation performance, where these characteristics can be expected to support the firm's efforts to turn the resources offered by a diverse alliance portfolio into innovation. This chapter also contributes to the research on the relations between alliance portfolio diversity and innovation performance by testing the hypotheses on a multi-industry sample of R&D alliances conducted by US firms from nine different high-tech industries. Previous research has usually tested in a single-industry setting which limits the generalization of the results.

The remainder of this chapter is organized as follows: First, I develop a base-hypothesis on the relationship between alliance portfolio diversity and innovation performance. Then I will introduce a number of hypotheses which propose moderating effects of R&D-related factors on this relationship. The hypotheses of this chapter are empirically tested using a dataset of R&D alliances conducted by high-tech firms in 9 different industries between 1993 and 2004. The final section of this chapter presents the results of this empirical analysis and concludes with a discussion of the results.

5.2. Research hypotheses

5.2.1. Alliance portfolio diversity and innovation performance

Innovation is derived by recombining resources and knowledge (Fleming, 2001; Hargadon

& Sutton, 1997; Kogut & Zander, 1992). These resources can be the existing resources of the firm as well as the externally acquired resources such as those of its alliance partners (Lavie, 2006) . The diversity of the resources available for this recombination has a direct effect on the innovation output as the availability of more diverse resources increases the chance of finding impactful combinations (Carnabuci & Operti, 2013; Katila & Ahuja, 2002). Alliance portfolios with a low level of diversity cannot provide access to diverse resources as the knowledge and technologies held by the firms in the alliance portfolio are very similar. This similarity of the partners leads to them providing redundant resources and does not allow the foal firm to gain benefits in term of externally sourced inputs for its innovation process. As the alliance portfolio diversity increases, these negative factors lessen and the firm gains access to a more diverse range of resources. Using these resources for innovative purposes by either directly applying them or by recombining them with existing internal knowledge leads to an increasing innovation performance.

While a number of studies (e.g., Faems et al., 2010; Srivastava & Gnyawali, 2011) hypothesize or test such a positive effect of alliance portfolio diversity on innovation performance, most prior literature on the relationship between alliance portfolio diversity and innovation performance (e.g., De Leeuw et al., 2014; Duysters et al., 2012; Oerlemans et al., 2013; Sampson, 2007) sees the diversity as a double-edged sword and hypothesizes an inverted U-shape relationship. The common view of these studies is that beyond a certain level of alliance portfolio diversity negative effects come into play and diminish the positive effects of the diversity. These negative effects stem from the increasing complexity

of managing a diverse alliance portfolios. In a diverse portfolio, the alliance partners are very heterogeneous, and the lack of a common background increases the potential for trust issues and conflicts of interest (Goerzen & Beamish, 2005) which can prevent alliance partners from efficiently combining their knowledge and resources (Sarkar, Aulakh, & Madhok, 2009). Arguing from another perspective, highly diverse alliance portfolios make it difficult for the focal firm to process the offered knowledge. Being overwhelmed by the diverse resources of its alliance partners, the firm finds it difficult to identify which knowledge would be useful for its innovation processes (Koput, 1997). The vast amount of resources on offer preoccupy the firm and its innovation performance suffers as a consequence.

Combining the resource-based perspective, which sees a positive effect of alliance portfolio diversity due to the access to diverse resources as inputs of the innovation process and the transaction-cost and attention-based-view perspective which focuses on the negative effects of high levels of diversity, this study arrives at the following hypothesis:

Hypothesis 5-1: Alliance portfolio diversity has an inverted U-shape relationship with innovation performance

5.2.2. **The moderating effect of internal technological diversity**

The access to the resources of the partner firms in the alliance portfolio is an important motivation to enter alliance deals. The focal firm accesses the resources of its alliance partners to either directly use them to create innovation or recombines them with resources already available within the firm to work towards innovative outcomes. Consequently, the resources already held by the focal firm can be expected to have an influence on the firm's ability to turn the resources offered in diverse alliance portfolios into innovative outcomes. The internal technological diversity of the firm influences the relationship between alliance portfolio diversity and innovation performance in two major ways: First, it provides opportunities for combining the firm's existing knowledge and technologies with those sources from the alliance partners to create innovation. Second, it increases the firm's absorptive capacity, allowing it to benefit more from diverse external knowledge.

As stated in the logic of the base hypothesis of this study, the availability and nature of the resources available to the firm, both internally and externally (Das & Teng, 2000), play an important role in the innovation process. Especially the diversity of the resources is important to foster recombinations which constitute new innovation. Consequently, a larger internal technological diversity allows for more variations in combining the internal knowledge of the firm with the knowledge of its alliance partners. This potential for recombination is maximized when the diversity of the resources both within the firm as well as in the alliance portfolio are at a high level.

A large internal technological diversity shows that the firm has amassed knowledge in a wide range of different fields. This knowledge plays an important role in the acquisition process of external knowledge and technologies. Cohen and Levinthal (1990)'s absorptive capacity concept refers to the firm's ability to recognize, assimilate, and apply the value of new information to innovations. A firm with a large internal technological diversity possesses a larger absorptive capacity (H. Schildt, Keil, & Maula, 2012; Zahra & George, 2002) and uses its knowledge in a wide range of fields to identify, absorb and recombine useful knowledge of its partners. In diverse alliance portfolios which provide a wide range of resources, firms can suffer from attention allocation problem (Koput, 1997). Under these circumstances, firms with a larger internal technological diversity and thus larger absorptive capacity will have a benefit in identifying suitable knowledge and technology and can alleviate some of the attention allocation problems, leading to higher innovative performance.

The increased potential for novel recombinations of the alliance partners' knowledge with the diverse internal technological knowledge of the focal firm as well as the increased absorptive capacity of internally diverse firms, which at any given level of alliance portfolio diversity should result in improved innovation performance, lead to the following hypothesis on the moderating effect of internal technological diversity:

Hypothesis 5-2a: Internal technological diversity positively moderates the relationship between alliance portfolio diversity and innovation performance

While Hypothesis 5-2a is focused on a positive moderating effect of internal technological diversity, one could argue that a broad knowledge base of the firm has negative effects on the relationship between alliance portfolio diversity and innovation performance. Srivastava and Gnyawali (2011) hypothesize and test such a negative moderating effect in their study on the US semiconductor industry.

A firm with a high level of internal technological diversity possesses knowledge in a wide range of fields, and consequently has access to a variety of resources in-house. This availability of knowledge and resources within the firm can affect how the firm sees, evaluates and ultimately uses knowledge sources which in contrast to the internal base are located outside the firm. Firms with a high internal technological diversity do not feel the same pressure to access outside sources of knowledge and might feel encouraged to continuously rely on their diverse internal knowledge. This can lead to the situation of relaying on outdated or ill-fitting technologies and knowledge while at the same time ignoring the new development which might happen outside the firm's boundary. This phenomena is often referred to as the firm falling into a "competency trap" (Levitt & March, 1988; Liu, 2006; Locke & Jain, 1995). Another negative side effect of being able to rely on the internal knowledge base is the "not-invented-here (NIH) syndrome" (Hussinger & Wastyn, 2015 (forthcoming); Katz & Allen, 1982). It refers to the unwillingness to consider and use knowledge that comes from other sources (Lichtenthaler & Ernst, 2006). According to Mehrwald (1999), the NIH syndrome manifests itself in a wrong evaluation, non-optimal

use or even the neglect of external All together it is found to strongly disturb the knowledge transfer between organizations (Kathoefer & Leker, 2012) and prevents the firm from taking advantage of the resources in its alliance portfolio.

The change in perception and willingness to acquire and use the knowledge provided by diverse alliance partners as a result of internally diverse firms falling into a competency trap and suffering from the not-invented-here-syndrome leads to the following hypothesis, which is based on the understanding that the negative effects of internal technological diversity at any given level of alliance portfolio diversity shift the curve of the relationship between alliance portfolio diversity and innovation performance in a downward direction:

Hypothesis 5-2b: Internal technological diversity negatively moderates the relationship between alliance portfolio diversity and innovation performance

5.2.3. **The moderating effect of absorptive capacity**

Cohen and Levinthal (1990) introduced the concept of absorptive capacity to the literature on learning and innovation. They define it as "the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends" (Cohen & Levinthal, 1990, p. 128) and stress its importance for the innovative capabilities of the firm. The R&D performed by a firm plays an important role in increasing its absorptive capacity.

In turn, the increased absorptive capacity will enable the firm to better identify external knowledge of its alliance partners that it wants to transfer, transfer it, and apply it to generate innovation. The R&D intensity of the firm, Cohen and Levinthal (1990)'s operationalization of absorptive capacity, can be also seen as an indicator for its innovation intent, i.e., how important innovation is for the firm's strategy (Lin, Lee, & Hung, 2006). A firm that places a high importance on innovation can be expected to also intensify its efforts to transfer and use externally sourced knowledge from the alliance portfolio. The positive role of absorptive capacity in strengthening the firm's ability to identify, transfer and use the diverse external knowledge provided by the partner firms in its alliance portfolio leads to the expectation that at any given level of alliance portfolio diversity, the curve describing the relationship between alliance portfolio diversity and innovation performance will be shifted upwards. This leads to the following hypothesis:

Hypothesis 5-3a: General absorptive capacity positively moderates the relationship between alliance portfolio diversity and innovation performance

The absorptive capacity concept as used in the above hypothesis is solely based on the R&D capabilities and intentions of the focal firm and does not characteristics of the source of external knowledge context and relative characteristics into account (Camisón & Forés, 2010; Lane, Salk, & Lyles, 2001). Lane and Lubatkin (1998) extended the works of Cohen and Levinthal (1990) to introduce the relative aspect (Lane, Koka, & Pathak, 2006). From

the perspective of knowledge and similarities, it argues that similar background of the firm and the source of the knowledge will facilitate the transfer of knowledge due to shared similar structures and language. On the other hand, if the background, routines and knowledge of the firm differs by a large degree, the efficiency of the transfer is reduced and the focal firm finds it harder to benefit from the diverse knowledge of its partners. A number of studies have applied this concept of relative characteristics to the research on alliances and have found that alliance partners that are similar show a performance (Ahuja, 2000b; Lane & Lubatkin, 1998). In a study on the fuel cell industry, Vasudeva and Anand (2011) hypothesized and tested the effects of absorptive capacity on the firms' ability to generate innovation from technologically diverse alliance portfolios. Using a novel definition of absorptive capacity that involves the firm's ability to identify, transfer and employ diverse knowledge (referred to as latitudinal absorptive capacity) and the ability to do so with technologically distant knowledge (referred to as the longitudinal absorptive capacity). The results of their study that firms whose alliance portfolio is technically similar can allocate more of their limited resources on absorbing diverse knowledge from their alliance partners.

Similarity between the knowledge, technologies and capabilities of the firm results in a higher relative absorptive capacity, which I expect to support the firm's ability to benefit from the resources offered by its diverse alliance portfolio. At any given level of alliance portfolio diversity, this should improve the innovation performance of firms with a higher level of relative absorptive capacity, i.e., shift the curve depicting the relationship

between alliance portfolio diversity and innovation performance upwards. This leads to the following hypothesis:

Hypothesis 5-3b: Relative absorptive capacity positively moderates the relationship between alliance portfolio diversity and innovation performance

5.2.4. The moderating effect of organizational slack

Geiger and Makri (2006, p. 97) refer to organizational slack as the "resources available to an organization that are in excess of the minimum necessary to produce a given level of organizational output". Based on the works of James March, Bourgeois (1981, p. 30) offers a definition focusing on the roles played by organization slack as he characterizes it as a "cushion of actual or potential resources which allows an organization to adapt successfully to internal pressures for adjustment or to external pressure for change in policy, as well as to initiate changes in strategy with respect to the external environment". There is a general agreement in literature that organizational slack is related to experimentation and how firms fund innovative projects (Herold, Jayaraman, & Narayanaswamy, 2006), to the exploration of ideas before their actual need (Rosner, 1968) and that slack resources facilitate innovation (Singh, 1986).

Firms operate with constrained financial and organizational resources. However, the transfer and incorporation of knowledge and resources of the alliance partners is a complex

and costly process (Oxley, 1997; Teece, 1977). Especially in the case of highly diversified alliance portfolios, attention allocation problems (Koput, 1997) make it difficult for the firm to identify and characterize the available resources of the partners. Consequently, the firm finds it difficult to accurately plan and budget the external knowledge acquisition process. In the case of a firm with a zero level of organizational slack, the lack of available resources forces the firm to focus on its short term performance (Nohria & Gulati, 1996). However, literature has argued that in order to stay on top and produce impactful innovation, firms need to take a certain amount of risks, which might only pay off in the long term (Carlisle & McMillan, 2006; Singh, 1986; Tushman, 1997). Being unable and/or unwilling to pursue risky opportunities, firms without organizational slack forego opportunities to innovate.

Increasing the level of organizational slack has two key effects on the firm and its ability to innovate (George, 2005). First, organizational slack eases capital restrictions. This allows firms to pursue a wider range of projects to obtain and use more of the resources of their alliance partners at any given level of alliance portfolio diversity. Second, increased levels of organizational slack increase the risk taking of the firm (Bromiley, 1991). Increased levels of slack thus increase the experimentation and number of new projects (Nohria & Gulati, 1996). Having organizational slack as a buffer, the managers of the firm feel free to pursue projects which are novel, but carry a larger risk of failure (Geiger & Makri, 2006). As innovation is often derived from novel ideas, the additional risk-taking of the firm as a result of increased slack resources can increase its innovation performance.

Also this effect is expected at any given level of alliance portfolio diversity, leading to organizational slack shifting the curve depicting the relationship between alliance portfolio diversity and innovation performance in an upward direction. This leads to the following hypothesis:

Hypothesis 5-4: The firm's level of organizational slack positively moderates the relationship between alliance portfolio diversity and innovation performance

The hypotheses of this chapter are summarized in **Figure 5-1**, with Hypothesis 5-1 being the base hypothesis on the relationship between alliance portfolio diversity and innovation performance and Hypotheses 5-2 to 5-4 focusing on various factors moderating this relationship.

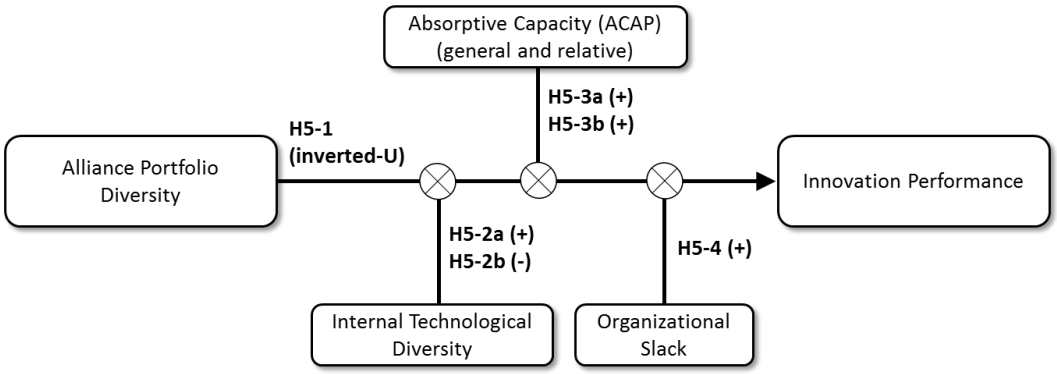

Figure 5-1. Conceptual Model for Chapter 5

5.3. Method

5.3.1. Data and sample

The empirical analysis is based a multi-industry dataset of firms operating in 9 different high-tech industries. I began by identifying all US high-tech firms within the Financial Times Top 500 companies list of 2006. Financial and corporate information on these firms, such as data on sales, employees, or R&D expenses was collected from the Compustat database as well as from the Datastream database. In the next step, I compiled a list of all alliances that involve one of the sample firms in the 1993-2013 timeframe. This alliance information was obtained from the Thomson Reuters SDC Platinum database. The SDC Platinum database contains detailed information on each alliance deal, including information on the participants (including their SIC code), starting date of the alliance as well as a description of the type of alliance. In terms of type of alliance, the database classifies alliances into several categories including marketing alliances, licensing, manufacturing, research and development, and a number of services such as computer or transportation services. A single alliance can have more than one function, so it can be classified into more than one of the above-mentioned categories. As the focus of this dissertation is on R&D alliances, I have excluded all alliance deals which do not involve research and development as one of their alliance types, i.e., an alliance focusing on R&D and manufacturing would be included while an alliance purely focusing on manufacturing

would be excluded from the dataset. As alliances can be formed between more than two partners, I have transformed all multi-partner alliances into sets of dyadic alliances, i.e., An alliance firm A enters with firm B and firm C is transformed into the two alliances of A and B, and A and C. In total, at this stage the sample consisted of 1741 alliance deals of 82 firms. For each firm and each year between 1995 and 2013 I now compiled the information on their alliance portfolio. Due to the fact that for many alliances no reliable information on the duration of the alliance deal is available, I assumed an alliance duration of three years. This approach is consistent with previous literature (e.g., Schilling & Phelps, 2007; Srivastava & Gnyawali, 2011; Stuart, 2000), which generally assumes an alliance duration of three to five years. For the resulting alliance portfolios, I calculated the alliance portfolio diversity based on the methodology introduced by Jiang et al. (2010).

In the next step, patenting information was obtained from the USPTO patent database. The patenting information contains information on all patents applied for and granted to the firms in the sample as well as information on how often these patents were cited by other patents. Using the information on the number of granted patents and the information on the number of citations received by these patents allowed the calculation of the weighted patent count, the dependent variable of this study. Due to the lag required for the patent analysis and the lack of some independent and control variables for some of the firm year observation, the sample was further reduced. The final sample consists of 366 firm year observations of 69 firms between 1995 and 2004. An overview of the composition of the final sample by industry is given in Table 5-1.

Table 5-1. Multi-industry sample composition

Industry	Frequency	Percent
Technology hardware and equipment	111	30.3
Pharmaceutical and Biotechnology	98	26.8
Software and Computer services	46	12.6
Chemicals	42	11.5
Aerospace and Defense	33	9.0
Automobiles and Parts	16	4.4
General Industrials	9	1.6
Industrial Engineering	6	1.4
Electronic and Electrical equipment	5	2.20
Total	366	100

5.3.2. Dependent variable

The dependent variable in the present study is the firm's innovation performance. Previous literature has investigated a range of different indicators which each have distinct advantages and disadvantages (Cordero, 1990; Kleinknecht, Van Montfort, & Brouwer, 2002). Amongst the different indicators, patents (Ernst, 2003) have become one of the most common indicators. The use of patents has the advantage of directly providing an indication of research output and their management by an independent patenting authority guarantees that unlike firm-level financial indicators such as R&D spending, they are not influenced by individual accounting practices of firms (Correa & Ornaghi, 2014).

Innovation measures obtained from patent data are often based on the number of patents granted to the firm within a certain time period (e.g., Ahuja, 2000a; Beneito, 2006). However, this approach disregards the fact that not all patents have the same influence on the innovation of a firm (Lanjouw et al., 1998). To address this shortcoming, patent indicators which also take into account the citations received by the patents have been developed. The forward citations received by a patent have been proven to be an important and value-relevant indicator for patent quality (Hirschey, Richardson, & Scholz, 2001; Karki, 1997; Lanjouw & Schankerman, 2004). The weighted patent count (Katila, 2007; Trajtenberg, 1990) is a commonly used innovation performance indicator combining information on the firm's number of granted patents with the information on the number of forward citations. While it has the advantage of capturing information on the perceived value of the patents, the need to include a time period of patent citation in the analysis means that it cannot be applied to the study of recent data. In spite of this disadvantage, this study uses the weighted patent count as the dependent variable of Innovation performance. This also fits well with previous literature on the effects of alliance portfolio diversity on innovation performance. The studies of Sampson (2007), Vasudeva and Anand (2011), and Srivastava and Gnyawali (2011) all were based on patent indicators that not just captured the raw number of patents but also their impact.

The method to calculate the weighted patent count in this study is following Trajtenberg (1990) and is given below:

$$\text{WPC} = \sum_{i=1}^{n} (1 + C_i) \tag{4}$$

Where C_i is the number of forward citations received by each patent *i* of the firm. I have considered all patents granted to the firm that were applied for between year 2 and year 4 after the focal year. The reason for the one year delay is the time required for the knowledge being obtained from the alliance partners, being incorporated into the firm and then used for innovation. Selecting the timeframe in which citations are considered requires to find a balance between allowing sufficient time to allow for a clear picture of the impact of a patent and the need to keep the duration short to allow the analysis of more recent data. As research by Mehta et al. (2010) has shown that the majority of citations are received within the first few years, in this study, Patent citations are collected over a 5 year timeframe.

5.3.3. Independent variables

Alliance portfolio diversity

Previous literature has used different characteristics of both the partner firms and the alliances themselves to define the diversity of the alliance portfolio. Among the most commonly used definitions are those related to the different capabilities and resources

provided by the firms in the alliance portfolio. Previous literature has captured these capabilities and resources using two key methods: the patents held by the alliance partners (e.g., Srivastava & Gnyawali, 2011; Vasudeva & Anand, 2011), and the industrial background of the alliance partners (e.g., Cui & O'Connor, 2012; Jiang et al., 2010; Tao et al., 2015). For this study, I define alliance portfolio diversity based on the industrial background of the firms in the alliance portfolio. Specifically, I follow the procedure introduced by Jiang et al. (2010). The procedure is based on assigning a code expressing the similarity in industrial background between the focal firm and the partner firm to each of the alliance partners. The basis for the code is the overlap in digits of the SIC codes of focal and partner firm. Table 5-2 shows the relationship between the SIC overlap and the assigned code.

Table 5-2. Diversity Measurement coding following Jiang et al. (2010)

SIC code overlap	Assigned code
4-digit overlap	4
3-digit overlap	3
2-digit overlap	2
1-digit overlap	1
No overlap	0

Alliance portfolio diversity is then calculated using the above mentioned codes and the Herfindahl-Index based diversity measure of Hall (2005) using the following formula:

$$\text{Alliance portfolio diversity} = \frac{N}{N-1}\left(1 - \sum_{i=0}^{4}\left(\frac{n_i}{N}\right)^2\right) \qquad (5)$$

with N being the total number of alliance partners in the portfolio and n_i the number of alliance partners assigned code *i*.

Internal Technological diversity

The independent variable *Internal technological diversity* is a diversity measure based on the technological background of the patents held by the firm. All US patents are organized into groups of technologically similar patents through the use of the US Patent Classification System (USPC). Patents are assigned one of more than 450 classes, which are further subdivided into a total of more than 150,000 subclasses (USPTO, 2012). Due to this large number of possible classifications, patents in different classes might still be of a very similar nature. To overcome this problem, Hall et al. (2001) suggested a new patent classification system which is comprised of 36 different categories and provide a classification table to match USPC classes to their classification system. I have amended Hall et al. (2001)'s classification system, which focuses on utility patents, and added two additional categories to capture design patents and patent classes missing from the conversion table. The resulting 37 categories are used to calculate a Herfindahl-Index based

measure of diversity. The measure is based on Hall (2005) and includes a correction for the bias introduced when calculating the index using a low number of categories. The exact formula used to calculate *Internal technological diversity* is:

$$\text{Internal technological diversity} = \frac{N}{N-1}\left(1 - \sum_i {p_i}^2\right) \qquad (6)$$

in which N is the total number of patents held by the firms in the alliance portfolio and p_i is the proportion of their patents in category *i*. Some of the firms in the sample have long histories and have decades of patenting history. However, in high-tech industries, the value and usefulness of technological knowledge has been shown to have high depreciation rates (Gwangman Park et al., 2006) and knowledge from patents applied years ago cannot be considered to have a large impact on the current activities of the firm. To account for this knowledge depreciation, the calculation of *Internal technological diversity* is based on only patents applied for within the last five years before the observation year.

Absorptive Capacity

This study considers two different kinds of absorptive capacity. The first one is the "classical" absorptive capacity following the concept and definitions of Cohen and Levinthal (1990) while the second one is the relative absorptive capacity of Lane and Lubatkin (1998). Following previous literature (Cantner & Pyka, 1998; Rocha, 1999; Schmidt, 2010), I have defined the classical absorptive capacity by using the firm's R&D

intensity, i.e., its R&D expenses divided by the sales. For the operationalization of relative absorptive capacity I resort to the use of the alliance partner coding scheme of Jiang et al. (2010), which is summarized in Table 5-2. It captures the distance between the focal firm and each of the firm in its alliance portfolio based on the overlap of the two firms' SIC codes. The average of this codes for the complete alliance portfolio thus gives an indication of the similarity or distance between the focal firm and its alliance portfolio.

Organizational Slack

Organizational slack in this study is related to the amount of resources of the firm that are available in the short term. Following previous literature (Geiger & Cashen, 2002; Geiger & Makri, 2006; Herold et al., 2006; Singh, 1986) this study uses the "quick ratio" as a measurement for the amount of organizational slack. Based on the information available in the Compustat database, the quick ratio is defined as current assets (not including inventories) divided by the firm's current liabilities. In this definition, assets include all assets that can be quickly used for business purposes or turned into cash, while current liabilities are defined as financial obligations that the firm has to cover within the timeframe of one year (Herold et al., 2006).

5.3.4. **Control variables**

This study includes a range of control variables. Due to the fact that the dependent variable is the innovation performance of the firm, it is important to control for factors that might influence the innovative activities of the firms in the sample. Large firms find it easier to invest more into R&D efforts than smaller firms, making the size of the firm a logical choice for a control variable (Cohen & Klepper, 1996). In this study *Firm size* is defined as the number of employees of the firm in the observation year. Another control variable, *Knowledge stock*, captures the size of the firm's knowledge base, i.e., the number of patents held in the observation year. Due to the quick depreciation of technological knowledge (Gwangman Park et al., 2006), only patents applied during the last five years are considered in the calculation of this variable. This study also controls also for the size of the alliance portfolio. The variable *Alliance portfolio size* is defined as the number of active alliances of the firm in the observation year, i.e., due to the assumed three year duration of alliances, it includes all alliances formed in the observation year or the two years before. In addition to these control variables, I also control for the direct impact the firm's *R&D intensity, Similarity*, and *Organizational Slack*. I have also included two sets of dummy variables. One set controls for year-specific effects during the eleven year span of the dataset and another set of dummy variables controls for the different industries (listed in Table 5-1) within the dataset.

5.3.5. Empirical model specification

The dependent variable of this study is the firm's innovation performance. The detailed operationalization is the weighted count following the method proposed by Trajtenberg (1990), which is based on a count of both the number of patents granted to the firm and also the number of citations received by these patents. Consequently, the dependent variable takes the characteristics of a positive integer count variable. For count variables, Poisson regression is an often used analysis method. A closer look at the dependent variable *Innovation performance* reveals that it is over dispersed, i.e., its variance is larger than its mean value. This violates a basic assumption of the Poisson regression model. Previous literature has found different methodologies to analyze patent counts (e.g., Hausman, Hall, & Griliches, 1984; P. Wang, Cockburn, & Puterman, 1998) with many patent-related studies adopting negative binomial regression models (e.g., Fleming & Sorenson, 2001; C. Kim & Song, 2007; Maurseth & Verspagen, 2002). Also this study uses negative binomial regression to analyze the unbalanced panel dataset.

5.4. Results

Table 5-3 provides a summary of the descriptive statistics and the correlations among the variables used in this chapter. The highest correlation is found between *Knowledge stock* and Innovation performance, i.e., firms which had a high patenting activity within the last five years continue to patent a large number of (impactful) patents. In order to rule out any problems as a result of multicollinearity (Gunst & Webster, 1975) in the dataset, I have

performed an variance inflation factor (VIF) test (Craney & Surles, 2002; Mansfield & Helms, 1982). Table 5-4 presents the results of this VIF test. The low values for all variables (average value of 1.28) indicate that the dataset does not have any problems related to multicollinearity.

Table 5-3. Descriptive statistics and correlations matrix of the variables related to moderating effects on the alliance portfolio diversity-performance relationship

Variables	Mean	SD	1	2	3	4	5	6	7	8	9
Firm size	48.47	73.51	1								
Knowledge stock	684.52	1035.38	0.43	1							
Alliance portfolio size	8.26	13.47	0.13	0.22	1						
Internal diversity	0.75	0.21	0.33	0.32	0.15	1					
R&D intensity	0.33	1.13	-0.16	-0.13	-0.10	-0.15	1				
Similarity	1.66	1.16	-0.07	-0.14	-0.05	-0.22	-0.05	1			
Organizational Slack	2.28	2.90	-0.34	-0.22	-0.17	-0.33	0.44	0.20	1		
Alliance portfolio diversity	0.47	0.37	0.26	0.26	0.26	0.14	-0.22	0.10	-0.27	1	
Innovation performance	4678.06	8269.40	0.13	0.61	0.30	0.22	-0.11	-0.03	-0.13	0.23	1

Table 5-4. VIF test results of the variables related to moderating effects on the alliance portfolio diversity-performance relationship

Variables	**VIF**
Firm size	1.36
Knowledge stock	1.34
Alliance portfolio size	1.11
Internal diversity	1.27
R&D intensity	1.28
Similarity	1.14
Organizational slack	1.51
Alliance portfolio diversity	1.24
Average	1.28

The results of the negative binomial regression analysis are presented in Table 5-5. Model 1 contains all the control variables used in this study. Of the control variables included, only firm size shows a significant positive effect. This shows that larger (in terms of the number of their employees) firms produce more and/or more impactful innovation and can be explained by the larger amount of resources that larger firms can invest into creating innovation.

Model 2 tests Hypothesis 5-1, which predicts an inverted U-shape relationship between *Alliance portfolio diversity* and *Innovation performance*. The linear coefficient for Alliance portfolio diversity in Model 2 is highly significant and positive while the squared term is highly significant and negative. These results confirm Hypothesis 5-1, which serves as the baseline hypothesis of this study. Model 2 tests Hypotheses 5-2a and 5-2b, which predict a positive and negative moderation effect of *Internal diversity* on the relationship between *Alliance portfolio diversity* and *Innovation performance*. The interaction term *APD x Internal diversity* in Model 3 is significant and positive, confirming Hypothesis 5-2a and simultaneously rejecting Hypothesis 5-2b. Hypotheses 5-3a and 5-3b focus on the moderation effect of absorptive capacity on the relationship between the diversity of the alliance portfolio and the firm's innovation performance. Hypothesis 5-3a is testing classical absorptive capacity defined as the firm's R&D intensity and Hypothesis 5-3b is testing the moderation effect of relative absorptive capacity, defined as the similarity between the industrial background of the focal firm and the alliance portfolio. The interaction term *APD x R&D intensity* in Model 4 is not statistically significant, thus failing to provide support for Hypothesis 5-3a. The interaction for *APD x Similarity* in Model 5, on the other hand, is positive and significant. This supports Hypothesis 5-3b on the moderating effect of relative absorptive capacity. Model 6 tests the final hypothesis, Hypothesis 5-4, which predicts a positive moderating effect of *Organizational slack* on the relationship between *Alliance portfolio diversity* and *Innovation performance*. The interaction term *APD x Organizational slack* is not significant and does not support

Hypothesis 5-4. Finally, Model 7 presents the full model of all the variables used in this study. The positive interaction terms of *APD x Internal diversity* and *APD x Similarity* lend further support to Hypotheses 5-2a and 5-3b.

Table 5-5. Negative binomial regression results for innovation performance (effects of alliance portfolio diversity and moderators)

Dependent variable: Innovation performance	Model 1		Model 2		Model 3	
	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.
Control variables						
Firm size	0.0018**	0.0009	0.0019**	0.0009	0.0011	0.0010
Knowledge stock	-0.0001	0.0001	-0.0001*	0.0001	-0.0001*	0.0001
Alliance portfolio size	-0.0001	0.0015	-0.0006	0.0015	0.0008	0.0015
R&D intensity	0.0188	0.0276	0.0201	0.0281	0.0201	0.0278
Similarity	-0.0168	0.0258	-0.0164	0.0266	-0.0165	0.0262
Organizational slack	0.0070	0.0119	0.0085	0.0121	0.0085	0.0120
Independent variables						
Alliance portfolio diversity			0.7740***	0.293	0.192	0.3570
APD squared			-0.8690***	0.306	-0.903***	0.3020
APD x Internal diversity					0.806***	0.2940
APD x R&D intensity						
APD x Similarity						
APD x Organizational slack						
N	366		366		366	
Year dummies	included		included		included	
Industry dummies	included		included		included	
Log likelihood	-3000.435		-2996.245		-2991.861	
Wald Chi^2	79.22		92.15		92.74	

Notes: *p < 0.10; **p < 0.05; ***p < 0.01.

Table 5-5 (Continued) Negative binomial regression results for innovation performance (effects of alliance portfolio diversity and moderators)

Dependent variable: Innovation performance	Model 4		Model 5		Model 6	
	Coefficient	S.E.	Coefficient	S.E.	Coefficient	S.E.
Control variables						
Firm size	0.0019**	0.0009	0.0019**	0.0009	0.0019**	0.0009
Knowledge stock	-0.0001*	0.0001	-0.0001*	0.0001	-0.0001*	0.0001
Alliance portfolio size	-0.0006	0.0015	-0.0007	0.0015	-0.0006	0.0015
R&D intensity	0.0198	0.0279	0.0133	0.0288	0.0202	0.0281
Similarity	-0.0170	0.0267	-0.0479	0.0312	-0.0164	0.0266
Organizational slack	0.0098	0.0122	0.0081	0.0121	0.0084	0.0131
Independent variables						
Alliance portfolio diversity	0.8030***	0.2980	0.6520**	0.2960	0.7730***	0.2970
APD squared	-0.8700***	0.3070	-0.992***	0.3120	-0.8700***	0.3070
APD x Internal diversity						
APD x R&D intensity	-0.1690	0.3130				
APD x Similarity			0.137**	0.0691		
APD x Organizational slack					0.0009	0.0311
N	366		366		366	
Year dummies	included		included		included	
Industry dummies	included		included		included	
Log likelihood	-2996.094		-2994.258		-2996.245	
Wald Chi^2	92.27		97.46		92.15	

Notes: *p < 0.10; **p < 0.05; ***p < 0.01.

Table 5-5 (Continued) Negative binomial regression results of Chapter 5

Dependent variable: Innovation performance	Model 7	
	Coefficient	S.E.
Control variables		
Firm size	0.0011	0.0010
Knowledge stock	-0.0001	0.0001
Alliance portfolio size	-0.0008	0.0015
R&D intensity	0.0122	0.0283
Similarity	-0.0528*	0.0313
Organizational slack	0.0087	0.0131
Independent variables		
Alliance portfolio diversity	0.0771	0.3670
APD squared	-1.0550***	0.3100
APD x Internal diversity	0.8380***	0.3000
APD x R&D intensity	-0.3700	0.4050
APD x Similarity	0.1530**	0.0697
APD x Organizational slack	0.0135	0.0404
N	366	
Year dummies	included	
Industry dummies	included	
Log likelihood	-2989.183	
Wald Chi^2	99.10	

Notes: *p < 0.10; **p < 0.05; ***p < 0.01.

As can be seen in Table 5-5, for the hypotheses concerned with the moderation effects, I only test the moderation of the linear term, for example, *APD x Internal diversity*, and do not include the moderation for the quadratic term, which for example, would be *APD squared x Internal diversity*. The hypotheses of this chapter lead to the expectation of an up/down shift of the inverted U-shape curve, which can be detected with the linear moderation term. Nevertheless it is generally advised to also include the quadratic term.

However, in this analysis, adding the quadratic moderation term results in insignificant results of the key variables, *APD, APD squared,* and the both moderators in all models tested.

5.5. Discussion

This chapter investigates various factors moderating the relationship between alliance portfolio diversity and innovation performance. Specifically, focusing on factors related to the internal R&D activities and capabilities of the firm, I examined the moderating effects of internal technological diversity, two different kinds of absorptive capacity and of organizational slack. The hypotheses were tested on a multi-industry sample of US high-technology firms.

The empirical results confirm that alliance portfolio diversity, which in this study is defined in terms of partner firms' industrial background following the definition of Jiang et al. (2010), has an inverted U-shaped relationship with the firms innovation performance. It shows that up to a certain level of diversity, firms benefit from the increasing diversity of resources offered by their alliance partners. These diverse resources are the inputs for the firm's innovation creating processes and are either directly applied or recombined with the existing resources. However, increasing alliance portfolio diversity brings about negative effects which beyond a certain point diminish the positive contributions of resource diversity. Dealing with a diverse range of partners increases the complexity and

cost of the alliance portfolio management process and gives rise to trust and coordination issues. Firms are also limited in how much diverse information, knowledge and technologies of their alliance partners they can handle and being confronted with too diverse portfolios find it difficult to identify, transfer and incorporate the right resources.

The above mentioned relationship is moderated by a variety of factors. The first factor tested is the internal technological resource diversity. This chapter finds a positive moderating effect of internal resource diversity. This shows that firms which possess knowledge in a diverse range of fields are better equipped to benefit from diverse alliance portfolios. I argued that this is due to two key facts: the increased absorptive capacity which makes the identification, transfer and application of knowledge easier and the increased potential for recombining diverse externally sourced knowledge with the diverse internal knowledge base of the firm to create innovation. I have also presented a competing hypothesis, which theorized that firms which already possess a large range of technologies within the firm have a different attitude towards the knowledge of their alliance partners as a result of falling into a capability trap and suffering from the not-invented-here syndrome. This hypothesis was not confirmed in the empirical analysis. This is in contrast to the study conducted by Srivastava and Gnyawali (2011), who found a negative moderating effect of internal technological diversity. However, there are some differences in the study design between their research and this chapter, which might explain the different results. Srivastava and Gnyawali (2011) employed slightly different definitions of alliance portfolio diversity and innovation performance. Their alliance portfolio diversity measure

was based on the diversity of patent classes amongst the patents held by the firms in the alliance portfolio, while this study uses the alliance partners' industrial background. Their measure for innovation performance was the rate of breakthrough innovation, defined as the number of patents which fall into the top three percent of patents in terms of forward citations received. In contrast, my study employs the concept of the weighted patent count proposed by Trajtenberg (1990), which does not consider a very narrow sample but counts all granted patents and their received citations. Finally, the setting of the studies is different. The study of Srivastava and Gnyawali (2011) uses a dataset of US-listed semiconductor firms. The semiconductor industry is increasingly following a trend towards specialization, which has been recognized in literature (e.g., Brown & Linden, 2009; Kapoor, 2013). This trend might influence the attitude of internally diverse firms and the level of not-invented-here syndrome that they experience.

I also test the moderating effect of absorptive capacity. The hypothesis testing the moderating effect of R&D intensity, a classical measure for absorptive capacity as found in Cohen and Levinthal (1990), was not supported by the empirical analysis. However, another hypothesis, testing the moderation effect of relative absorptive capacity (Lane & Lubatkin, 1998) and using the similarity of the business field of focal firm and alliance portfolio as a measure, was confirmed. The results show that simply increasing the amount of R&D spending in relation to the sales of the firm does not help to take advantage of diverse alliance portfolios. It rather shows that firms are better able to turn the resources offered by diverse alliance portfolios into innovation when the similarity between the firm

and the portfolio is high. A high similarity leads to more shared knowledge, languages and organizational routines and improves the identification, absorption and use of the knowledge.

The final hypothesis tested the moderating effect of organizational slack. I hypothesized that firms with a larger level of organizational slack are less constrained in their activities to transfer and use the diverse resources available to them in their alliance portfolios. Previous literature had found that increased organizational slack leads to more experimentation and increases the likelihood of firm also pursuing risky but potentially very rewarding projects. I expected this behavior to increase the innovation performance of the firm as it would try to incorporate more of the diverse resources and try to turn them into innovation. However, this hypothesis could not be confirmed and the influence of organizational slack on the relationship between alliance portfolio diversity and innovation performance in the dataset of the present study was found to be not significant. While a significant part of previous literature on organizational slack and innovation has used the quick ratio used also in this chapter to measure organizational slack, there is a variety of different conceptual and empirical definitions (Bourgeois, 1981), which might affect the relationship between alliance portfolio diversity and innovation performance in various ways. The risky projects supposedly undertaken by firms with a high level of organizational slack might also not be well captured by this studies operationalization of innovation performance due to lower impacts or delayed impacts on the innovation output.

In discussing the results of the moderating effects, it should be noted that due to the

limitations in the empirical analysis described in the previous section, only an up/down shift could be measured, internal technological diversity and relative absorptive capacity might also have the effect of shifting the curve showing the relationship between alliance portfolio diversity and innovation performance left/right, i.e., there might be an yet untested effect of the moderated maximum innovation performance being obtained at lower or higher levels of alliance portfolio diversity.

Chapter 6. Conclusive remarks

6.1. Summary and contributions

In conclusion, this dissertation contributes to a better understanding of alliance portfolio diversity, a key characteristic of alliance portfolios. Alliance portfolio diversity is known to effect the firm's financial and innovation performance, but previous research has left gaps in the understanding of the concept itself, its effects and in how to moderate these effects. This dissertation makes a number of important findings: First, unlike previous research which often treated alliance portfolio diversity as an exogenous concept, it investigates determinants of technological alliance portfolio diversity and finds that it is influenced by the firms' internal technological diversity. Second, it investigates the effects of different dimensions of alliance portfolio diversity on innovation performance. It confirms an inverted U-shaped relationship between alliance portfolio diversity defined in terms of alliance partners' industrial background and innovation performance. It also finds an important negative interaction effect of alliance portfolio diversity in terms of partners and the diversity in terms of alliance objectives. Third, this dissertation investigates the moderating effects of three key characteristics of firms' internal R&D on the link between alliance portfolio diversity and innovation performance and finds positive effects of internal technological diversity and similarity. Each of those contributions has not only an

academic value but also provides managerial implications for firms trying to maximize the benefits they derive from their R&D alliance portfolios.

The research in Chapter 3 on the determinants of alliance portfolio diversity reveals an influence of internal technological diversity. It also confirms that firms tend to balance their internal and external R&D activities and follow the ambidextrous strategy suggested by previous research. Firms that focus on diversity in their internal R&D (explore internally) tend not to do so in their external knowledge acquisition strategy through R&D alliances and rather focus on (exploit) fewer areas, and vice versa.

Chapter 4 investigates different dimensions of alliance portfolio diversity. It demonstrates an inverted U-shape relationship between the diversity of the alliance partners' industrial background and the innovation performance. Firms need to be careful when adding new partners to the alliance portfolio. While at first the innovation performance will increase, beyond a certain level of diversity, the firm's inability to manage diverse partners and identify, transfer and apply the diverse resources they offer will lead to a decreased innovation performance. The best course of action for the firm is to slowly add more diverse partners to its portfolio and carefully evaluate the resulting performance to identify the maximum level of diversity the firm can handle without any negative effects. It is also important for managers who are concerned with planning and coordinating the firm's alliance strategy to understand that portfolios can be diverse in many ways. Even a portfolio of alliances formed exclusively with firms from a single industry can be diverse in terms of the governance mode of the alliances, the type of alliance, or, as tested in Chapter 4, the

objective of the alliance. While the diversity of the alliance objectives was not found to have a statistically significant influence on the innovation performance, managers need to be aware of the interaction between different dimensions of alliance portfolio diversity. As the results of Chapter 4, which are plotted in Figure 4-2, demonstrate, high levels of partner and objective diversity have a large negative effect on the innovation performance. I thus advise alliance managers to use caution when trying to pursue diverse alliance objectives with a diverse range of alliance partners.

The relationship between alliance portfolio diversity and innovation performance described in Chapter 4 is moderated by a variety of factors. Chapter 5 tests the moderation effect of some of these factors to investigate how firms can improve their innovation performance while benefiting from diverse alliance portfolios. The chapter finds that internal technological diversity positively moderates the relationship between diversity of the portfolio and innovation due to the increased possibilities for knowledge and resource recombinations. The internal technological diversity can be actively influenced by the firm through their internal R&D activities and through the acquisition and incorporation of knowledge from external sources. This dissertation also finds a positive moderating effect of relative absorptive capacity, measured by the similarity between the firm and its alliance portfolio. Assembling an alliance portfolio that has a similar background, helps the firm mitigate some of the negative effects of the diversity of their partners and improve the innovation performance. In summary, trying to diversify the internal knowledge base and keeping an eye on the similarity between the firm's field of business and the alliance

portfolio will improve the firm performance. Altogether, this dissertation highlights the need to understand the diversity of alliance portfolios to increase the firm's innovation performance.

6.2. Limitations and future research

Despite making valuable contributions to the research on alliance portfolio diversity and helping to improve the understanding of the determinants and effects of diverse R&D alliance portfolios, this dissertation has a number of limitations, which might be overcome by future research.

Some of the limitations stem from the use of single-industry datasets in Chapter 3 and 4. Chapter 3's empirical analysis uses a dataset of R&D alliances of US-listed firms in the semiconductor industry (SIC code 3674) while Chapter 4 uses a dataset of R&D alliances of US biopharmaceutical firms (SIC code 283). It is known that the findings from such single-industry study can be difficult to apply to other industries. However, even considering the problem of generalizing the results, the chosen industries present themselves as worthwhile targets for an empirical analysis on alliance portfolios. The semiconductor industry is a well-known high-tech industry which is known to form networks of collaboration (Kapoor & McGrath, 2014) and due to rapid technological progress, firms are entering technology-driven strategic alliances at a large rate (Yasuda, 2005). This ensures a sufficient alliance sample size to derive meaningful conclusions about

alliance portfolios. The semiconductor industry is also known for firms actively protecting their innovations through patenting (Hall & Ziedonis, 2001, 2007). This is important as a number of key variables in Chapter 3 are defined based on patenting information. However, there are characteristics of the semiconductor industry that create difficulties for studies on R&D alliances. For example, while some semiconductor firms such as Intel design and manufacture their products in-house, while some companies, including well-known large firms such as Nvidia or Broadcom only design the semiconductors but outsource their production to other firms who either have excess production capacities or are focused on production such as TSMC who most famously produces the processors for Apple smartphones and tablets. These outsourcing arrangements lead to a large number of alliance which are focused on pure manufacturing, which, for example, this dissertation excluded as no flow of knowledge can be assumed.

Also the biopharmaceutical industry used in Chapter 4 has certain characteristics that make it an attractive setting for alliance-related studies. This is further supported by the large number of previous studies who tested alliance and alliance portfolio related hypotheses using datasets from this industry. The biopharmaceutical industry is very active in forming strategic alliances (Hagedoorn, 1993) with diverse partners. As these alliances also cover a broad variety of objectives, the industry is suitable to test the hypotheses in Chapter 4 which focuses on various dimensions of alliance portfolio diversity. A major limitation of datasets from the biopharmaceutical industry is the relatively low number of samples as evidenced by the data of Chapter 4 and previous literature (e.g., Hoang &

Rothaermel, 2005; Van de Vrande, 2013).

Different from the single industry datasets of Chapters 3 and 4, Chapter 5 is based on the empirical analysis of a multi-industry dataset composed of US firms from nine different high-tech industries. While this should support the generalization of the results, multi-industry datasets suffer from the differences between the individual industries, for example, their likelihood to form R&D alliances, their propensity to patent their innovations, and others. While the study in Chapter 5 controls for the different industries using dummy variables and includes other control variables including the knowledge stock which provides information on the firm's recent patenting activities, there might be other factors which this study does not control for but which could influence the results.

A common characteristic of the datasets in all three chapters is that they focus on US firms. The main reason for this choice is the availability of the data. US-listed firms are required to annually publish a range of financial data, which forms the basis for the commercially available databases such as Compustat or Datastream, which are heavily used in this dissertation. Many of the indicators in this dissertation are based on patent data and make use of the publicly available patent database of the USPTO. As foreign firms might have a different propensity to patent their innovations in the US compared to US-listed or US-based firms, the focus was placed on the US. In many technological fields such as the semiconductor industry, most, if not all of the major firms have operations in the US and thus are included in the data. Another reason for selecting US firms is that the SDC Platinum database, which is the source of the alliance data in this dissertation is known to

have a bias towards information on alliances which is available in English (Schilling, 2009), so selecting US firms should increase the reliability and completeness of the employed alliance data. Previous literature has also either relied on US data, or, in the case of CIS datasets on European data. Nevertheless, future research could, given the availability of the required data, investigate alliance portfolio diversity in previously unstudied setting to further enhance the general applicability of the research results.

Another set of limitations of this dissertation is the result of the choice of variables and their definitions. Many of the variables in all three chapters are based on patenting information. While Patent-based indicators are a widely accepted measure in technology management contexts (Ashton & Sen, 1988; Ernst, 2003), they can suffer from possible variations of propensity to patent over time or between different industries (Pavitt, 1985; Scherer, 1983) and the fact that they disregard innovations that are not patented (Arundel & Kabla, 1998; Basberg, 1987; Kleinknecht et al., 2002). The studies presented in this dissertation use either a single-industry dataset or control for different industries and additionally control for trends over time which reduces the likelihood and impact of these effects. Nevertheless, future research can try to find other concepts that are not based on patenting data or better control for different industries' propensity to patent and other choices of protecting their intellectual property.

Alliance data in this study is obtained from the Thomson Reuters SDC Platinum Database. As Schilling (2009) writes in her investigation of different alliance databases, it is the largest and most inclusive database in terms of industries covered and contains a wide

range of information on the individual alliance deals, as well as containing not only inter-firm deals but also alliances with universities and other organizations. However, it is widely known and acknowledged in the academic literature that the database has a number of shortcoming. Due to the information coming from a wide range of data source such as firms' press releases, newspaper articles, etc. not all information is correctly interpreted and coded. It also does not provide complete data on the ending time of alliances, prompting the use of an assumed alliance duration in the chapters of this dissertation to compile the alliance portfolios which are defined as the alliances of a firm ongoing at a certain moment in time. Nevertheless, the SDC Platinum database is widely used in prior literature on alliances and alliance portfolios. Future research might want to take advantage of smaller, more specialized databases such as the Bioscan database for bio-technology firms.

One major limitations of studies on alliance portfolio diversity is the difficulty to control for characteristics of individual alliances or alliance partners, as at the level of the alliance portfolio the absolute value of the characteristics of the individual partner or alliance are lost, as the common understanding of diversity is the distribution of differences, either measured as the number of elements with differing characteristics, or more common, as one minus the concentration of different elements, measured using a Herfindahl-index based measure. This limits the options to control for characteristics to either calculating the average or diversity of the characteristic for all elements in the alliance portfolio or to exclude all alliances or partners with a certain characteristic. This dissertation is limited in its inclusion of variables which are usually controlled for in previous alliance related

studies which were conducted in a dyadic setting. A major limitation, especially of Chapters 4 and 5 is the lack of a control for the governance mode of the alliance. Alliances can be formed as loose collaboration agreements, or as more permanent collaborations with equity stakes in a joint venture. A number of previous studies in the context of alliance portfolio diversity have demonstrated that the mode of governance, or on a more detailed level the equity stake, can influence the benefits firms derive from diverse alliance portfolios. This can be due to complex and diverse information being better transferred between firms in joint ventures due to a dedicated management and control function (Sampson, 2007) or the fact that majority equity stake owning firms can exert more pressure on alliance partners to share information and technologies (Cui & O'Connor, 2012). I expect future research to overcome the limitation found in many studies and find ways to control for the influence of different government forms on the relationship between alliance portfolio diversity and firm performance and also introduce the concept of modes of governance and equity stake to the increasing research on the determinants of alliance portfolio diversity.

Chapter 3 investigates the effects of internal technological diversity and external uncertainty on the technological alliance portfolio diversity of semiconductor firms. The definition of internal technological diversity and alliance portfolio diversity is based on applying the Herfindahl index to the distribution of patents in various patent categories. As described in Chapter 3, the more than 450 classes of the US patent classification system do not allow for an accurate calculation due to their high similarity between some of the classes. As a consequence, this dissertation joins previous literature in using a patent

classification system proposed by Hall et al. (2001) which groups the US patent classes into around 40 aggregated categories. Another similar attempt had been made by Jaffe (1986), whose unpublished system classified US patents into 49 categories. This shows a factor of 10 difference in the number of categories in the available classification systems. While Hall et al. (2001, p. 13) wrote that "… there is always an element of arbitrariness in devising an aggregation system and in assigning the patent classes into the various technological categories, and there is no guarantee that the resulting classification is "right", or adequate for most uses.", future research could revisit the choice of classification system and investigate the effect of various definitions on the outcome of the research.

Chapter 4 investigates the effects of different dimensions of alliance portfolio diversity on the innovation performance of firms. Innovation performance in the context of that study is measured by using Trajtenberg (1990)'s concept of the weighted patent count, which combines the information on the number of granted patents with the number of forward citations received by these patents. While this is a commonly used measure for innovation performance, future research could use other kinds of operationalization. Previous literature has used concepts such as the number of drugs or components that advance to the level of clinical testing (e.g., Danzon, Nicholson, & Pereira, 2005), the number of new products introduced to the market (e.g., Artz, Norman, Hatfield, & Cardinal, 2010; Rothaermel, 2001), or patenting productivity (e.g., Yamin & Otto, 2004).

Chapter 4 defines the objective of each alliance using the main SIC code assigned to each alliance deal in the Thomson Reuters SDC Platinum database. This code is assigned

based on publicly available information on the alliance deal such as official announcements or press releases. Previous research on the scope of R&D alliances (Khanna, 1998; Oxley & Sampson, 2004) has stated that scope is a multi-dimensional concept and is hard to define, which in part explains the relative lack of literature on the subject. This dissertation's use of the main SIC code might not paint a complete picture of the alliances' objectives if the scope of the alliance is wide. Future research on the effects of alliance characteristic-based diversity measures should try to investigate more in-depth definitions of the scope and objectives of the individual alliance deals.

Chapter 5 investigates the moderating effects of various firm characteristics on the relationship between alliance portfolio diversity and innovation performance. The definition of alliance portfolio diversity is based on the industrial background of the alliance partners (Jiang et al., 2010) which also can be seen as a proxy for their experiences and resources. However, in reality firms operating within the same industry can possess different resources. While this makes the approach of Chapter 3, to define the diversity based on the firms' patents very attractive, it has the problem of not being able to capture the information from firms which either do not have any patents, or whose patents cannot be linked to the firm, for example, in the case of alliance partners whose exact name is not disclosed.

Chapter 5 also investigates the moderating effect of organizational slack. This dissertation follows previous literature on organizational slack and innovation and defines it using the quick ratio. Some previous literature (Bourgeois, 1981; Geiger & Cashen, 2002) has

stressed the multi-dimensional characteristic of organizational slack. I expect future research to investigate the different dimensions of organizational slack and test their effect on the ability of the firm to benefit from diverse alliance portfolios. The results of Chapter 5 confirm a positive moderating effect of internal technological diversity. Chapter 3 also used the same concept and demonstrated its negative effect on the technological alliance portfolio diversity. At a first glance, it seems as if internal technological diversity is a double edged sword. While it reduces the diversity of the firm's alliance portfolio at the same time it helps the firm to benefit from the diversity. Further research on the role and interactions of the internal technological diversity are necessary to clarify how firms can best use it to improve their performance.

In the chapters focusing on the effects of alliance portfolio diversity on the firm, this dissertation focuses on the innovation performance of the firm, rather than other definitions of performance such as financial performance or measures related to efficiency and productivity. One of the key reasons is that this dissertation focuses on R&D alliances in high-tech industries. In these industries, innovations can be patented years before they are turned into sales or affect other metrics observable in the firm. As a result, it is very difficult to find a suitable timing to observe the effects of R&D alliance portfolio diversity on the performance measure. Previous literature on strategic alliances has established time lags for measuring the effects of alliances on firms' patenting activity which have been implemented in the empirical studies of my dissertation. Future research can extend the perspective of the effects of diverse alliance portfolios to other aspects of the firm such as

its financial performance, survival, or efficiency.

Last, while this dissertation and previous research have discussed and empirically demonstrated the negative effects of highly diverse alliance portfolios due to increased costs to manage them and attention allocation problems, the general perspective is that strategic alliances are positive for the firm. Research such as that of (Gunno Park & Kang, 2013) has begun to address negative effects of alliances, for example, their ability to weaken internal R&D capabilities under certain conditions. Future research on alliance portfolio diversity should thus not just investigate the negative effect of certain alliance portfolio characteristics but critically examine the role of the alliances themselves. I hope that this dissertation serves as another stepping stone and encourages others to further investigate diversity aspects of alliance portfolios.

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국문초록

전략적 제휴는 기업들의 기술 교환, 공동 R&D 수행 및 혁신 과정에 필요한 위험과 비용을 분산하는데 기여한다. 이러한 장점으로 인해 여러 하이테크 산업에서 기업은 점점 더 많은 제휴를 맺고 있다. 개별 파트너가 기업에 필요한 모든 요소를 제공해 줄 수 없기 때문에, 기업들은 동시에 하나 이상의 제휴를 맺게 되는데 이러한 현상은 제휴 포트폴리오라는 개념을 낳게 되었다. 제휴 포트폴리오가 중요하게 여겨지면서 개별 제휴와 포트폴리오의 전체 사이의 상호작용 등을 다루는 연구들이 등장하기 시작했다. 그러한 가운데 최근 연구에서는 제휴 포트폴리오 다양성이 큰 주목을 받고 있다. 제휴 포트폴리오 다양성의 기원 그리고 이러한 다양성이 어떻게 결정되고 기업 성과에 어떠한 영향을 미치는 지가 주목을 받고 있다. 그렇지만 이들 연구에서는 제휴 포트폴리오에 대한 충분한 이해가 이뤄지지 못했다. 대부분의 기존 문헌이 제휴 포트폴리오 다양성의 효과에 주목하고 있지만 마치 제휴 포트폴리오 다양성을 각 기업에게 애초부터 주어진 조건으로 여기고 그 결정요인에 대해 다루지 않았다. 일부 최신 연구들이 제한된 정의와 맥락 하에서 제휴 포트폴리오 다양성의 결정요인에 대해 다루고 있지만 아직 이러한 시도가 R&D 중심의 기술 제휴

포트폴리오까지 미치지는 못했다. 본 학위 논문은 제휴 포트폴리오 다양성에 대한 이해를 증진시키는데 목적을 두고 “제휴 포트폴리오 다양성을 결정하는 요인은 무엇인가?”, “제휴 포트폴리오의 서로 다른 측면이 어떻게 혁신 성과에 영향을 미치나?”, 그리고 “제휴 포트폴리오 다양성과 혁신 성과 사이의 관계를 촉진하는 요인은 무엇인가?”라는 세 가지 주요 질문을 다룬다.

구체적으로 3장에서는 기술 제휴 포트폴리오 다양성을 결정하는 요인을 고찰한다. 제휴 네트워크의 진화가 내생적인 영향과 외생적인 영향에 의해 이루어진다는 점에 착안하여 내부 요인과 외부 요인 양쪽 모두를 조사하였다. 내부 요인으로는 기업이 보유하고 있는 지식과 기술의 다양성을 주로 다루었다. 외부 요인으로는 기존 문헌이 제휴 포트폴리오 다양성과 외부 환경을 연관시켜 다룬 것처럼 본 논문 역시 외부 환경의 불확실성에 초점을 맞춰 산업 내의 기술적 변화를 연 단위로 측정하였다. 이러한 방식은 단순히 산업 내의 거대한 이벤트만을 불확실성으로 다룬 기존 연구 방식을 보완한다. 본 연구의 가설은 미국에 등록된 반도체 기업들의 R&D 제휴 데이터를 통해서 검증하였다. 3장의 결과를 통해 기업 내부의 기술적 다양성이 기술 제휴 포트폴리오 다양성을 확대하는데 부정적인 영향을 끼친다는 점을 확인할 수 있었다. 이러한 결과는 조직의 양손잡이 속성을 대변하는 연구들과 그 맥을

같이한다. 그러나 기술적 환경 변화는 기술 제휴 포트폴리오 다양성에 특별한 영향을 미치지 못했다.

4장은 제휴 포트폴리오 다양성의 여러 측면을 조명하며 제휴 포트폴리오 다양성의 서로 다른 측면이 혁신 성과에 미치는 영향을 확인한다. 기존 문헌은 파트너 측면 및 제휴 측면에서 제휴 포트폴리오의 다양성을 구분하였다. 본 학위 논문 역시 제휴 포트폴리오 다양성을 파트너 측면(파트너가 속한 산업의 다양성)과 제휴 측면(제휴 목적의 다양성)으로 구분하고 있다. 그렇지만 서로 다른 측면의 다양성이 혁신 성과에 미치는 영향을 비교했던 기존 문헌과 다르게 본 연구에서는 파트너 측면의 다양성과 제휴 측면의 다양성의 상호작용에 좀 더 집중하고 있다. 본 연구의 가설은 1998년부터 2002년까지 미국 바이오제약 산업의 R&D 제휴 데이터를 통해 검증되었다. 4장의 결과는 다양한 파트너를 보유한 기업들이 동시에 너무 다양한 제휴 목적을 갖지 말아야 함을 시사하고 있다.

5장에서는 제휴 포트폴리오 다양성과 기업의 혁신 성과 사이의 관계를 조절하는 요인을 조명한다. 기업은 내부 R&D 역량을 활용하여 외부 지식 습득을 뒷받침해야 한다. 그러므로 기업의 현존하는 지식 기반, R&D에 대한 집중도 및 추가적인 투자는 기업의 제휴 포트폴리오 내에 포진한 다양한 기술적 자원을 혁신 성과로

전환시키는데 영향을 미친다. 본 연구의 가설은 포브스 500 리스트 중 다양한 산업의 하이테크 기업들을 대상으로 검증되었다. 기본적으로 제휴 포트폴리오의 다양성은 기업의 혁신 성과와 역-U자의 관계를 보임이 확인되었다. 그러한 가운데 제휴 포트폴리오 다양성과 기업 내부 기술 다양성의 상호작용은 혁신 성과를 증진시키는 것으로 나타났다. 제휴 포트폴리오의 다양성과 기업의 흡수역량 사이의 상호작용 역시 기업의 혁신 성과를 증진시키는 것으로 나타났다. 5장의 결과는 기업들이 다양한 기술 분야의 지식을 보유하거나 그들과 유사한 배경을 가진 파트너들을 거느릴 때 제휴 포트폴리오 다양성으로부터 더 큰 혜택을 볼 수 있다는 것을 시사한다.

전체적으로, 본 학위 논문은 포괄적인 접근을 통해 R&D 제휴 포트폴리오 다양성에 대한 이해를 높이는데 그 목적을 두고 있다. 구체적으로 다양성을 결정하는 요인이나 제휴 포트폴리오 다양성이 혁신 성과에 미치는 영향에 대해 개별적인 장에서 다루고 있다. 본 학위 논문의 가설들은 반도체 및 바이오 제약 산업 등 다양한 하이테크 산업에서의 R&D 제휴 데이터를 활용해 검증되었다. 기업 내부의 기술적 다양성은 제휴 포트폴리오의 다양성을 축소시키는 것으로 나타났지만 한 편으로는 제휴 파트너의 자원을 혁신 성과로 전환시키는 데는 긍정적인 역할을 하는 것으로

나타났다. 제휴 포트폴리오의 다양성은 파트너 기업 혹은 제휴의 특성에 따라 다양한 방식으로 정의되었다. 본 학위 논문은 제휴 포트폴리오 다양성에 대한 여러 가지 측면이 서로 상호 작용함으로써 혁신 성과에 지대한 영향을 미치는 것을 보임으로써 이들이 개별적으로 인식되지 말아야 함을 강조하고 있다.

주요어: 전략적 제휴, 제휴 포트폴리오, 제휴 포트폴리오 다양성, 혁신 성과, 외부 지식 습득

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