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NOT INVENTED HERE

Managing Corporate Innovation in a New Era

Vareska van de Vrande

Not Invented Here

Managing Corporate Innovation in a New Era

PROEFSCHRIFT

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en
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Long before I even thought of pursuing a PhD, even long before I went to university, I remember my mother once explained to me the meaning of a PhD as "to write a thesis that addresses something new, something that has not been studied before". And I remember thinking: "By the time I get my university degree, this will have become impossible, because by that time, scientists will probably have discovered everything already..."

Could I possibly have been more wrong? For the past 4 years I have learned that the opposite is true. Moreover, I found that every answer leads to more questions in turn, and still I find doing research challenging, yet satisfactory.

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Chapter 1

Introduction to the study[1]

1.1 Introduction

The competitive landscape in which firms operate has changed considerably during the past decades. Companies are now facing an environment that is characterized by frequent, fast and unpredictable change (Bettis and Hitt, 1995). Technology and product life cycles shorten continuously and products are becoming more and more complex. Hence, sustaining competitive advantage is becoming a major challenge for companies. To cope with today's dynamic and turbulent environment, companies must not only focus on exploiting existing technologies, but also on exploring new technologies. In fact, the generation of new technologies and practices has become essential for survival, especially in fast changing environments (March, 1991).

Traditionally, the discovery and development of new business opportunities by firms was mostly realized through internal development. However, the external acquisition of knowledge has become a crucial part of companies' long-term growth strategy due to a number of factors (Chesbrough 2003; Grandstrand et al. 1992, 1997; Jones et al., 2001; Keil, 2002; Laursen and Slater, 2006; Tsai and Wang., 2007). First of all, as a result of the rapidly increasing speed of technological changes, technology-based new business development can no longer be achieved through internal ventures only (McGrath and MacMillan, 2000). Second, the increased mobility of employees and the growing number of workers with a higher education leads to a dispersion of knowledge among differently sized companies in various industries (Chesbrough, 2003). With knowledge being more spread around the globe, tapping into other firm's technologies becomes an important but also a more challenging strategic requirement to access new ideas. In addition, the availability of venture capital increased tremendously during the past decades, leading to an increase in the number of start-ups and university- and company spin-offs (Chesbrough, 2003). Taken together, these developments lead to a growth in the number of firms competing in the industry, with knowledge being more dispersed among these firms and competition becoming more severe. As a result, companies have

[1] Parts of this chapter are based on: Van de Vrande, V., Lemmens, C., and Vanhaverbeke, W. (2006) "Choosing Governance Modes for External technology Sourcing", R&D Management 36 (3): 347-363.

shifted from a closed innovation paradigm to a more open way of innovating, combining both internal and external sources of knowledge (Chesbrough, 2003). Open innovation and the external sourcing of new technologies are important vehicles to ensure corporate renewal (Dyer and Singh, 1998; Vanhaverbeke and Peeters, 2005) and hence to sustain the competitive advantage of firms. External technology sourcing can take a variety of forms, such as cooperation with lead-users, industry-university cooperation, or inter-organizational partnering. This study focuses on the particular role of different inter-organizational modes, such as M&As, strategic alliances, and corporate venture capital investments.

Traditionally, M&As and strategic alliances have received a lot of attention in the literature as means to source new technology externally. M&As have been stressed in the literature as a way to achieve firm growth through economies of scale and scope (Garette and Dussauge, 2000; Hoffmann and Schaper-Rinkel, 2001), or in order to gain fast entry into new markets (Vermeulen and Barkema, 2001). Although acquisitions are often referred to as mergers, previous studies point to the fact that most mergers are in fact acquisitions (World Investment Report, 2000). Prior studies furthermore note that an acquisition is often used when the need for strategic flexibility is low (Hoffmann and Schaper-Rinkel, 2001). Because of the vast amount of resources and people involved, mergers and acquisitions are highly irreversible and involve a high level of commitment from the investing firm.

Strategic alliances, on the other hand, are a much more flexible way to gain access to external knowledge. For years, strategic alliances have been a popular way to cope with the dynamism of the environment and to share the costs and risks associated with R&D with a partner (Duysters, 1996; Hagedoorn, 1993). Strategic technology alliances can take a variety of organizational forms, such as joint ventures, licensing agreements, distribution and supply arrangements, R&D partnerships, and technology exchange relationships. In addition, they can be either equity- or non-equity based (Inkpen, 1998; Zollo et al., 2002). Equity alliances, such as joint ventures and minority holdings, involve an equity investment in either the new firm, or in the partner firm. Hence, these kinds of alliances have high exit costs (Gulati, 1995) and are therefore less reversible than their non-equity counterpart. The largest share of the alliances that are created nowadays, however, are non-equity alliances that do not involve any equity investments. Non-equity alliances are more flexible than equity alliances, which in turn are more flexible than mergers and acquisitions.

Next to M&As and strategic alliances, the interest in corporate venture capital (CVC) investments as a way to get access to external knowledge has increased tremendously recently. CVC investments can be described as "equity investments by established corporations in entrepreneurial ventures" (Dushnitksy and Lenox, 2005c). Motives for corporate venture capital funds can be both financial (generating financial returns) and strategic, for instance to experiment with new capabilities, to develop a backup technology, to explore strategic white space, or to monitor market developments (Chesbrough, 2002; Keil, 2002; Siegel et al., 1988)). However, firms investing in corporate venture capital have explicitly mentioned scanning of the environment as one of the main objectives (e.g. Keil, 2002; Siegel et al., 1988; Sykes, 1990; Winters & Murfin, 1988). Because CVC investments are focused on the earlier stages of technology development, they serve as an interesting mechanism to enhance corporate entrepreneurial efforts (Dushnitsky and Lenox, 2005a). CVC investments thus provide the company with access to nascent technologies with highly uncertain future potential. When investing in these technologies, firms need to remain flexible in order to be able to withdraw from the commitment as soon as it seems not to be promising. CVC investments can thus be regarded as flexible, loosely coupled arrangements, with a low level of commitment from the investing company.

Taken together, these different modes for technology sourcing enable companies to assimilate and integrate technology in a flexible way and at different times in the new business development process. However, despite the apparent evidence that external technology sourcing is becoming more important over time, the literature has not yet addressed this issue in a full fledged manner. On the one hand there is the literature on alliances and networks, focusing largely on strategic alliances between companies (e.g. Hagedoorn, 1993; Stuart, 2000), sometimes also incorporating mergers and acquisitions (e.g. Folta and Leiblein, 1994; Garette and Dussauge, 2000; Hagedoorn and Duysters, 2002b; Hoffmann and Schaper-Rinkel, 2001; Lambe and Spekman, 1997; Roberts and Liu, 2001; Vanhaverbeke et al., 2002), and specific types of alliances, such as joint ventures and minority holdings (e.g. Gulati, 1995; Gulati and Singh, 1998; Santoro and McGill, 2005). On the other hand, there is the corporate entrepreneurship literature, focusing among other topics on the use of corporate venture capital as a means to get acquainted with novel technologies (e.g. Allen and Hevert, 2007; Chesbrough, 2002; Dusnithsky and Lenox, 2005a, 2005b, 2006; Wadhwa and Kotha, 2006). Although it is evident that innovating firms choose from a wide spectrum of technology sourcing and developing modes, including corporate venture capital investments, as well as strategic alliances and mergers and acquisitions, the literature streams as described above have been kept separate so far (notable exceptions are Keil, 2002, 2004; Schildt et al., 2005).

In order to fill this gap, this thesis aims to integrate the different governance modes into a broader framework of external technology sourcing. More specifically, we intend to answer the following research question:

How do firms choose between the different modes for external technology sourcing and how do these modes affect the performance of innovating firms?

As noted earlier, the literature streams about CVC investments on the one hand and strategic alliances and M&As on the other hand, have often been kept separate. Moreover, most studies focusing on external technology sourcing modes have limited their attention to one or two governance modes in particular. However, since most large, diversified companies do not limit their external sourcing strategies to one or two governance modes, incorporating a broader set of different governance modes is necessary to explain how the external sourcing of new knowledge and technologies impacts the performance of firms. Moreover, including CVC investments as an alternative to strategic alliances and M&As is the only way in which the choice companies have between different governance modes can be fully understood.

In order to answer this research question, we will start with an investigation of the determinants of governance mode choice, focusing specifically on the role of uncertainty. Next, the focus will shift to the role of different technology sourcing modes and their relationship with firm performance. Because the use of external technologies is to a large extent driven by the need to innovate, we study the outcomes of the innovation process. More precisely, we will explain how different technology sourcing modes affect the innovative performance of firms and the creation of pioneering technologies. The following sections will describe the different sub questions in more detail.

1.2 The role of uncertainty when choosing governance modes for external technology sourcing

There are a number of governance modes that can be used for external technology souring. As mentioned earlier, each of these governance modes has its own characteristics. As a result, the choice between different modes is likely to be contingent upon the circumstances that surround the investment decision. Although prior studies have pointed to different drivers for governance mode choice, including frequency, asset specificity and uncertainty (e.g. Folta, 1998; Mahoney, 1992; Sutcliff and Zaheer, 1998), the role of uncertainty as a central driver for sourcing decisions seems to be a recurrent issue in the context of new business development. Despite its well-recognized importance, systematic empirical studies on the role of uncertainty in governance mode choices for external venturing have been relatively sparse. In particular, previous studies have not taken into account the impact of different forms of uncertainty on governance mode choice (Mahoney, 1992; Sutcliff and Zaheer, 1998). Moreover, prior research on governance mode choice have not yet explicitly addressed the role of CVC investments as an alternative to strategic alliances and M&As. Because the choice companies have between different governance modes determines their flexibility to adapt to changing markets and technological developments, the first question that needs to be answered is:

What is the effect of uncertainty on the choice between different external technology sourcing modes?

In the context of new business development, uncertainty takes on a central role as a driver for investment decisions. Uncertainty can be roughly divided into two groups: exogenous and endogenous uncertainty (Folta, 1998). Exogenous uncertainty is unaffected by a firm's actions, and primarily resolves over time. *Environmental turbulence* and *technological newness* are both aspects of exogenous uncertainty. Environmental turbulence refers to the technological change over time, whereas technological newness refers to the average age of the technology portfolio of the partner firm. When a partner firm is working primarily on recent technologies, the technological newness is thus higher than when a firm is working more on older technologies. Turbulence in the environment and newness of technology are both sources of uncertainty that are exogenous to the focal firm and thus affect the decision-making process.

Endogenous uncertainty, on the other hand, is embedded in the technology-sourcing relationship and can be reduced by actions of the firm. Endogenous uncertainty includes the *(technological) distance* between firms and (the lack of) *prior cooperation*. Technological distance is the relative overlap between the technology portfolios from two partnering firms. A smaller overlap of technology portfolios indicates a higher technological distance between the firms. This leads to two types of problems: First, a higher technological distance makes it more difficult to recognize and absorb the partner's knowledge (Cohen and Levinthal, 1990; Lane and Lubatkin, 1998). Second, a larger technological distance might also lead to adverse selection due to information asymmetries (Williamson, 1975). Another source of endogenous uncertainty is the lack of prior cooperation between the partnering firms. Prior cooperation can be a powerful tool to reduce uncertainty between the partners. Endogenous uncertainty is thus also affected by the existence of prior ties between the focal firm and its partner.

Prior studies on the organization of inter-firm agreements have suggested ranking different governance modes along a continuum between arms-length market transactions and full integration (Gulati and Singh, 1998; Hagedoorn and Sadowski, 1999; Nielsen, 2002; Santoro and McGill, 2005; Villalonga and McGahan, 2005; Williamson, 1975). Following the rankings used in earlier studies, we order the different governance modes used in this study along a continuum between less and more integration; non-equity alliances come closest to market transactions and are hence the least integrated solution followed by respectively CVC investments, minority holdings, joint ventures, and M&As.

1.3 The added value of CVC investments in explaining innovative performance

Another aspect in explaining the role of different governance modes in the new business development process is to determine how they affect innovative performance. Prior studies have already indicated how mergers and acquisitions (e.g. Ahuja and Katila, 2001; Hitt et al., 2001; Koenig and Mezick, 2004), strategic alliances (e.g. Baum et al., 2000; Stuart, 2000), and corporate venture capital (CVC) investments (e.g. Dushnitsky and Lenox, 2005a; Kortum and Lerner, 2000) affect the innovative performance of firms. However, most of these studies are limited to one or two governance modes (an exception is Nicholls-Nixon and Woo, 2003), thereby neglecting the fact that most innovative firms do *not* limit their attention to the use of one or two external sourcing modes in particular. Rather they invest in a portfolio of projects in different stages of development using a broad range of different governance modes. Especially since the diverse characteristics of the governance modes under study enable access to various types of technologies in different stages of development, this raises the question as to what extent different governance modes substitute or reinforce each other. The interaction between external sourcing modes is thus an aspect that needs further attention when looking at the role of different governance modes in the new business development process. More specifically, since CVC investments receive a growing amount of attention in the academic literature as well as in practice, is it worthwhile to investigate how CVC investments interact with other modes for external technology sourcing. Therefore, we formulate a second sub-question:

What is the added value of corporate venture capital investments, next to the other modes of external technology sourcing, in explaining innovative performance?

In order to answer this question, we discuss the added value of CVC investments as a means to source new technologies and the effect on a company's subsequent innovative performance. CVC investments enable access to new technologies in the earliest stages of technology development, while other modes seem to be more appropriate for later stages or less explorative technology acquisition (Van de Vrande et al., 2006). As a result, the different governance modes can be considered as alternatives, though complementary from a longitudinal perspective. Within each stage of the new business development process, however, they can also be regarded as substitutes, as for every technology sourcing decision; the company chooses either the one *or* the other. In response to the main research question, this chapter focuses on the interaction between CVC investments and other modes for external technology sourcing when explaining innovative performance of firms.

1.4 The creation of pioneering technologies

Finally, prior studies have acknowledged the importance of both exploitation and exploration for firms' long term survival (March, 1991; O'Reilly and Tushman, 2004). However, the role they play in the innovation process is quite different. Exploitative innovation is incremental by nature and builds on the existing knowledge base of the firm (Benner and Tushman, 2003). Exploitative innovation involves the search for technologies that are closely related to the company's current technological domains. Explorative innovation, on the other hand, aims at the creation of technologies that are distant from the existing technological capabilities of the firm. One specific type of explorative innovations is the concept of pioneering technologies. Pioneering technologies are defined as technologies that do not refer to any prior patents. They do not build on prior art and thereby are characterized by a highly explorative nature.

Although prior studies have acknowledged the role of pioneering technologies in overall firm success (Kim and Mauborgne, 2004; Kleinschmidt and Cooper, 1991), the creation of breakthrough inventions (Ahuja and Lampert, 2001) and the generation of economic returns (Achilladelis et al., 1990), the role of external sources of knowledge in the discovery of pioneering technologies is still an understudied phenomenon. Rosenkopf and Nerkar (2001) indicated that looking beyond both organizational and technological boundaries will lead to the development of radical innovations. However, the authors did not include the particular role of *different* inter-organizational relationships in this respect. Although a number of studies have investigated the impact of different external technology sourcing modes on innovative performance (e.g. Ahuja and Katila, 2001; Dushnitsky and Lenox, 2005a; Nicholls-Nixon and Woo, 2003; Stuart, 2000), the way in which these strategies affect the generation of *pioneering technologies* has not yet been studied in a full-fledged manner. We intend to fill this gap in the last empirical chapter of this thesis, by answering a third sub-question:

What is the effect of the different governance modes on the creation of pioneering technologies?

In response to this question, we analyze the effect of corporate venture capital investments, non-equity alliances, equity alliances and M&As on the generation of pioneering technologies. Strategic alliances are flexible contracts that allow firms to share the costs and risks associated with the R&D process (Hagedoorn, 1993). This makes them very suitable to be used in the early stages of the new business development process. The same holds for CVC investments. Being regarded as a 'window on new technology' (Ernst et al., 2005; Keil, 2002; Siegel et al., 1988; Sykes, 1990), CVC investments are targeted at technologies in early stages of development. Mergers and acquisitions, on the other hand, are more appropriate when the need for flexibility is low (Garette and Dussauge, 2000).

Additionally, prior studies have indicated the importance of technological newness (Katila, 2002; Nerkar, 2003) and technological distance (Nooteboom, 2000) in the creation of knowledge. Both technological newness and technological distance increase the need for flexibility and a loosening of linkages (Nooteboom, 2004). This chapter will therefore also explore the interactions between technological newness and technological distance on the one hand and different modes for external technology sourcing on the other hand.

1.5 Contribution

The main contribution of this thesis lies in the combination of strategic alliances, mergers and acquisitions and corporate venture capital investments as means of technology acquisition. Corporate venture capital investments and minority holdings are becoming strategically more important means to access new technologies and only by incorporating these modes into the broader framework of external technology sourcing, a full picture of how diversified firms are growing can be obtained. By including CVC investments as an alternative to strategic alliances and M&As, we contribute to the existing alliance literature and to the current debate about inter-organizational relationships. Moreover, our focus on the effect of uncertainty on the choice between different governance modes has implications for both transaction costs economics and real options reasoning regarding their predictions of inter-organizational organizing under uncertainty. Additionally, we add to the innovation literature by investigating the interaction between different governance modes for external technology sourcing and their effect on innovative performance and by specifically studying the relationship between different sourcing modes and the creation of pioneering technologies.

This study thus has important implications for academic literature, but there are also a number of contributions to the management literature. Recent trends in open innovation show the growing importance for firms to engage in external technology sourcing. However, many firms struggle with the choice they have among a broad spectrum of inter-organizational governance modes. By incorporating a broad range of different governance modes managers have at their disposal when sourcing new technologies externally, we shed light on the aspects managers need to take into account when choosing between different modes. Moreover, our investigation of how different external technology sourcing modes affect various types of innovation outcomes encourages managers to think about the desired outcome of their innovation process before entering a technology-sourcing relationship. This might help them to cope with changing market and technology conditions by making investments with the right level of commitment and flexibility.

1.6 Outline

The remainder of this thesis is organized as follows. Chapter 2 will describe the data that was collected to analyze the questions raised in this project. Chapter 2 describes the data collection process, the sources that were used and the dataset that was compiled for the analyses in this study. Chapters 3, 4 and 5 will then each tackle one of the sub-questions as described earlier. Chapter 3 will go into the role of environmental and relationship-specific uncertainty when choosing between CVC investments and other modes for external technology sourcing. Chapter 4 will focus on the role of CVC investments, next to the more traditional governance modes, in explaining innovative performance of firms. Chapter 5 will show how different governance modes enhance the creation of pioneering technologies. The particular role of technological distance between the focal firm and its partner, as well as the role of technological newness will be addressed in order to analyze how they affect the relationship between external technology sourcing and the creation of pioneering innovations. Finally, Chapter 6 synthesizes the results, followed by a discussion on how these results have contributed to answering the sub-questions and the main research question as raised in this chapter. The chapter concludes with a number of limitations to the study and an outlook on future research on this topic.

Chapter 2

Data and sample

2.1 Introduction

For the purpose of this research project, I have collected secondary data to construct the database used in this thesis. Using secondary data from existing data sources enables researchers to quickly gather a large amount of information. Nevertheless, the use of existing data sources to collect data is also subject to some debate as the data is originally collected for a different purpose and may hence be subject to certain biases that affect its reliability. Moreover, using secondary data-sources does not enable the researcher to obtain insight in the decision-making processes underlying certain investments. However, a large amount of data as collected during this study does allow researchers to conduct large-scale, quantitative analyses, aiming at results that can be generalized across firms or even across industries. For this thesis, the pharmaceutical industry has been selected as a setting to answer the research questions. The chapter starts with a brief description of the pharmaceutical industry and the reasons to choose this industry. After that, the different data sources that were used for data collection and the data collection process will be addressed. The chapter concludes with a discussion on the methodologies used in this study.

2.2 Pharmaceutical industry

The history of the pharmaceutical industry can be traced back to the invention of aspirin at the end of the 18th century. Since then, numerous scientific and technological breakthroughs have shaped the pharmaceutical industry as we know it today. Major breakthroughs include the discovery of arsphenamine (also known as Salvarsan) in 1908, a highly effective drug against syphilis, and sulfanilamide in 1935 (which stops the growth of bacteria). Further developments include the introduction of penicillin in the 1940s, and the development of "The Pill" (the first oral contraceptive) and valium in the 1960s. Alongside these developments in drug discovery, pharmaceutical companies emerged throughout the world, often having their roots in the chemical industry. Among the first pharmaceutical companies were Bayer (who patented and commercialized Aspirin back in 1899) and Hoechst (both Germany), Roche and Ciba-Geigy (Switzerland), Beecham and Glaxo (UK), and Abbott Laboratories, Eli Lilly, Merck and Pfizer (US).

While the discovery of new drugs intensified, the competitive landscape changed dramatically after the raise of biotechnology and genetic engineering during the 1980s. Although large, established firms still played an important role in the drug discovery process, they failed to seize the opportunity that was provided by biotechnology. This left room for the emergence of numerous small, biotech start-ups, aiming to develop and commercialize drugs based on biotechnology. Eventually, the growing significance of biotechnology for drug discovery, the high R&D costs, and the importance of networks to test and commercialize new drugs, resulted in an increased need for cooperation. During the last decades of the 20th century, many inter-firm partnerships were established between incumbent firms and with biotech companies and a large number of M&As have taken place. Besides, corporate venture capital investments have played a significant role in the funding of small, biotech start-ups.

There are a number of reasons why the pharmaceutical industry is an interesting and relevant setting for this study. First of all, the pharmaceutical industry is a typical high-tech sector characterized by a high level of dynamism and internationalization. Furthermore, the pharmaceutical industry plays an important role in shaping the economic and social environment. Due to the enormous amount of activity in this industry in terms of inter-organizational relationships that resulted from the increased competition on the one hand and the increasing R&D costs on the other hand, this industry is particularly suitable to study the phenomenon of external technology sourcing. Additionally, a high amount of activity ensures the availability of the data necessary to answer the research questions provided in Chapter one. Moreover, since the empirical analyses to answer the research questions require working with patent data, it is important to focus on an industry were patent data can be regarded as a reliable source of information, which is the case in the pharmaceutical industry.

2.3 Data sources

The database used in this thesis is established using existing sources of secondary data. The data sources are described hereafter.

MERIT-CATI

The MERIT database on Cooperative Agreements and Technology Indicators (Hagedoorn, 1993) is a relational database, including information on technology cooperation agreements. Data is collected using newspapers, journal articles, books and specialized technical journals and goes back to the early 1970s. MERIT-CATI contains information on cooperative agreements and the partners involved in this agreement, including both equity and non-equity strategic alliances, such as joint R&D agreements, licensing agreements, and joint ventures among others. A large body of prior empirical research on technology partnerships is based on the MERIT-CATI database (e.g. Hagedoorn, 1993; Hagedoorn and Schakenraad, 1994; Duijsters and Hagedoorn, 1996, 2000, 2002; Gulati, 1995; Gulati and Singh, 1998; Roijakkers, 2003).

Thomson ONE banker

Thomson ONE Banker is a major financial database including financial indicators on public companies, merger and acquisition information, and market data. Thomson ONE Banker contains the complete version of SDC Platinum, VentureXpert and Worldscope. SDC Platinum provides detailed information on M&As, including minority investments. Venture Xpert contains information on venture funds, private equity firms, executives, venture-backed companies, and limited partners, and Worldscope is a major source of financial information, such as income statements, balance sheets, statements of cash flows, etc. A considerable amount of prior empirical research on mergers and acquisitions and (corporate) venture capital, is based on the data sources provide by Thomson (e.g. Hagedoorn and Cloodt, 2003; Cloodt, 2005; Dushnitksy and Lenox, 2005, 2006a, 2006b; Porrini, 2005; Schildt et al., 2005; Villalonga and McGahan, 2006).

US PTO

The United States Patent and Trademark Office patent databases include full-text information for all patents applied for in the US, including the application date, year the patent was granted, inventor and company information, citations to prior patents, and detailed technological information. Patent data has for long been subject to discussion regarding its biases and shortcomings (e.g. Archibugi and Pianta, 1996; Griliches, 1998). Despite this long-standing debate, patent indicators have been used in many prior studies, as indicators of the technological knowledge base (e.g. Jaffe and Trajtenberg, 2002) and to measure knowledge flows (e.g. Mowery et al., 1996). US patent data are used for both US and non-US firms. Although these US data could imply a bias in favor of US companies against non-US firms, it is mentioned in the literature that non-US companies often need to file patent in the US, given the importance of the US market, the 'real' patent protection offered by US authorities, and the level of technological sophistication of the US market (Patel and Pavitt, 1991).

Who Owns Whom

Who Owns Whom by Dun & Bradstreet offers details of corporate linkages on companies and its subsidiaries worldwide. The information is collected by a specialist team of editors, from different sources including questionnaires, telephone interviews with companies, secretaries (or equivalent authority), company annual reports, major business newspapers and selected trade journals. D&B Who Owns Whom has been used by a number of previous studies in order to accumulate data from different organizational level onto the parent company level (e.g. Pavel and Pavitt, 1997, Mowery et al, 1996).

Worldscope

Worldscope provides detailed accounts information on over 40,000 public companies in more than 50 developed and emerging markets. Worldscope data goes back to 1980 and is collected through various sources such as annual reports and press releases. The information provided by Worldscope includes company profile information (e.g. SIC codes and country codes), financial statements data (e.g. income statements), financial ratios (e.g. growth rates and profitability), and security and market data (e.g. stock market price). For this research project, we collected annual sales, employees and R&D expenditures data, as well as some business information data like SIC codes and country codes.

2.4 Database used for this project

Setting up the database

The first step in setting up the database was the selection of firms used to focus the research on. To select the focal firms, patent data was used rather than other industry measures such as industry descriptions or SIC-codes. Patent data can be regarded as a reliable indicator for the technological activity of firms, and the use of patent data also allows one to select both private and public firms. First, we have selected the largest companies in the pharmaceutical industry between 1990 and 2000. The sample was selected based on companies' prior patents in the industry. For each year of the observation period, the 200 companies with the largest cumulative number of patents in the industry were collected. Selection was based on patents filed in the following 3-digit technological classes: 424, 435, 436, 514, 530, 536, 800, and 930. Focusing on the largest companies in the industry is necessary in order to have a consistent set of firms over that observation period. Moreover, small (or privately held) firms do not disclose the relevant information. Prior research on alliances and acquisitions has for that reason also been focused on the largest companies in the industry (Ahuja, 2000; Gulati, 1995; Gulati and Garguilo, 1999; Hitt et al., 1991, 1996).

After selecting the companies with the largest cumulative number of patents in the relevant patent classes, research institutes and universities were removed from the sample. Next, the remaining sample was manually checked for parents and affiliates using Dun & Bradstreet's "Who Owns Whom". In case the listed companies belonged to the same parent company, we combined the different affiliates with the parent firm. After checking for duplicates, this leads to 149 independent companies to be included in the sample. A list of these companies can be found in Appendix I. Hereafter, we will refer to these independent companies as "focal firms", to distinguish them from their partner companies.

After selecting the focal firms, several sources of secondary data were used to collect information regarding their inter-organizational relationships. All venture capital investments, non-equity alliances, minority holdings, joint ventures, and merger and acquisitions that were entered during the period 1985-2000 were gathered, as well as patent data and financial information. Corporate venture capital data was derived from the Thomson VentureXpert database, data concerning alliances and joint ventures was obtained from the MERIT-CATI databank on Cooperative Agreements and Technology Indicators (Hagedoorn, 1993), and we used Thomson ONE Banker to collect information regarding the companies' M&A activity and minority holdings. A minority holding is defined as an investment in another firm with less then 50% of the shares owned after the transaction. Because both the collected alliances and corporate venture capital investments have a strong technology component, we also included only technological M&As and minority holdings in our sample, following the method by Ahuja and Katila (2001).This method requires technological M&As to meet one of the following criteria: technology has been reported as a motivating factor for the acquisitions or technology was part of the transferred assets, or the acquired firm had any patenting activity in the five years prior to the acquisition. The method employed in this thesis is slightly different than the one used by Ahuja and Katila (2001). Since we had no access to press releases concerning the M&A deals, we could only include deals in which the partner has applied for at least one patent.

Financial data was gathered using Worldscope, including sales, research and development expenses and number of employees. In addition to that, patent information until 2003 was collected for all firms included in our sample using data from the US Patent and Trademark Office. Because the US Patent and Trademark Office grants patents both on subsidiary as well as on parent company level (Patel and Pavitt, 1997), and the organizational level on which patents are applied for differs between companies, the patents were manually consolidated on parent company level for each observation year, using *Who Owns Whom* by Dun & Bradstreet. Patent information used in this study are patent applications and patent citations data. As mentioned earlier, patents can be used an indicator of the technological knowledge base (e.g. Jaffe and Trajtenberg, 2002). Patent applications, in that respect, can be used to measure technological output, or innovative performance (e.g. Ahuja and Katila, 2001). Patent citations, on the other hand, can be used to measure knowledge flows between firms (e.g. Mowery et al., 1996; Schildt et al., 2005) or as a determinant of the value of innovations (e.g. Trajtenberg, 1990).

Description of the data

Appendix I shows an overview of the respective activity of all the focal firms. On average, the focal firms in this study have been involved in 10 technology alliances, 2 CVC investments, 2 minority acquisitions, 2 joint ventures, and 6 mergers and acquisitions. However, the high standard deviations show that these numbers vary greatly between the firms in the sample and it should be noted that for some of the firms in this sample, no activity has been recorded in any of the data sources used. Overall, it can be concluded that for the firms included in this database, non-equity alliances are the most popular means of external technology sourcing, followed by M&As, equity alliances (minority holdings and joint ventures), and CVC investments respectively (Figure 1).

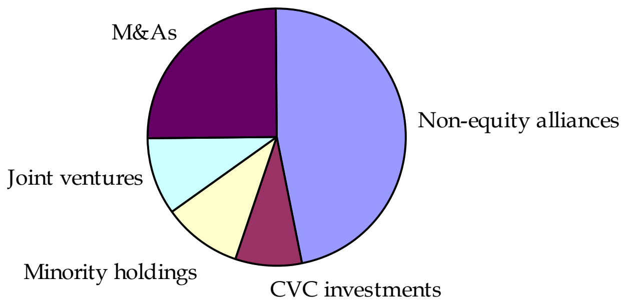

Figure 1 Distribution of different governance modes

Because it is expected that larger firms are more diversified and hence involved in more different types of inter-organizational agreements, it is also interesting to take a closer look at the average characteristics of firms that are involved in a certain set of governance modes. Appendix II shows the distribution among the different organizational modes, and the average characteristics of firms in each group.

Note that the larger share of the firms in the dataset used for this thesis is involved in non-equity and equity alliances and M&As, and a smaller group is also involved in CVC investments. Interestingly, the firms in the groups including M&A activity seem to have significantly lower R&D intensity (R&D expenditures divided by sales) than the firms in other groups. Another remarkable finding from Appendix II is that while the firms that are involved in all types of inter-organizational agreements under study in this thesis (non-equity and equity alliances, M&As and CVC investments) have on average significantly less sales than the firms involved in non-equity and equity alliances and M&As (and not in CVC investments), but their patenting output is much higher. However, one should be careful interpreting these results, as all data is aggregated over a longer period of time, and outliers might easily cause a large disturbance when calculating the mean.

2.5 Variables

Throughout this study, a considerable number of variables have been defined and developed in order to test the hypothesized relationships. An overview of these variables can be found in Appendix III. Because prior research has pointed towards the fact that technological knowledge depreciates sharply over time (e.g. Grilliches, 1979), losing most of its value within five years, a five year moving window is used to calculate most of the variables used in this thesis. Other studies using patent data as an indicator for technological knowledge have for that reason also used five years moving windows (e.g. Katila and Ahuja, 2002; Stuart, 2000). A more detailed description of the calculation of these variables can be found in the respective empirical chapters.

Chapter 3

The Effect of Uncertainty on Governance Mode Choice[2]

3.1 Introduction

This chapter discusses the effect of exogenous and endogenous uncertainty on the choice between different governance modes for external technology sourcing. As described in Chapter 1, companies that co-develop technology or in-source external technology to set up new business can choose from a myriad of different sourcing modes, such as strategic alliances, joint ventures, license agreements, mergers and acquisitions, and corporate venture capital (CVC) investments. Innovating companies can choose between these external technology sourcing modes in order to react in a flexible way to new technological developments and changing market conditions. CVC investments have gained increasingly attention in the academic literature recently. However, in studies on external technology sourcing this organizational mode has not yet been incorporated as an alternative compared to strategic alliances and/or M&As. Therefore, to get the full picture of how companies use different modes of external corporate venturing, it is important to address the issue raised here in a more comprehensive way, incorporating CVC investments as a distinct strategy.

Prior studies have pointed to different drivers for governance mode choice, including frequency, asset specificity and uncertainty (e.g. Folta, 1998; Mahoney, 1992; Sutcliff and Zaheer, 1998). Although all of these factors are important to consider, the role of uncertainty as a central driver for sourcing decisions seems to be a recurrent issue in the context of new business development. Despite its well-recognized importance, systematic empirical studies on the role of uncertainty in governance mode choices for external venturing have been relatively sparse. In particular, previous studies have not taken into account the impact of different forms of uncertainty on governance mode choice (Mahoney, 1992; Sutcliff and Zaheer, 1998). Uncertainty with respect to governance mode decisions can roughly be divided into two types: exogenous and endogenous uncertainty (Folta, 1998). Exogenous or environmental uncertainty is unaffected by firm actions and predominantly resolves over time as new technologies

[2] This chapter is based on Van de Vrande, V., Vanhaverbeke, W. and Duysters, G. (2007) "External Technology Sourcing: The Effect of Uncertainty on Governance Mode Choice", forthcoming in Journal of Business Venturing.

become mature. Technology sourcing often occurs for the purpose of new business development, in which the future potential of the technologies being acquired is still unknown. In addition to that, the technological environment is turbulent, making predictions about the future even more difficult. Hence, exogenous uncertainty might take the form of *environmental turbulence* or *technological newness*. Endogenous or relational uncertainty on the other hand can often be found as taking the shape of relationship-specific uncertainty when firms are sourcing technologies externally for new business development. This type of uncertainty is typically represented by dissimilarities among partners which can be caused for instance by *different knowledge bases* or by the lack of *prior cooperation* to overcome information asymmetries.

In this chapter we offer a detailed analysis of the role of uncertainty in government mode choice, focusing specifically on technology sourcing, which has become an important driver to enhance the development of new business. We will draw on both transaction cost economics (TCE) and real options theory (RO) to develop our arguments. We distinguish among corporate venture capital investments, non-equity technology alliances, joint ventures, minority holdings, and mergers and acquisitions. Although other technology sourcing modes exist, these are most important from an external corporate venturing perspective (Keil, 2002; Schildt et al., 2005). In addition, the modes listed here incorporate a full range of options that can be ranked along the continuum between arms-length transactions and a fully integrated solution (Gulati and Singh, 1998; Hagedoorn and Sadowski, 1999; Nielsen, 2002; Santoro and McGill, 2005; Villalonga and McGahan, 2005). In the remainder of this chapter the terms less and more integrated governance modes will be used, referring to the continuum discussed here, ranging from non-equity alliances as the less integrated mode of governances, respectively followed by CVC investments, minority holdings, joint ventures, and M&As, the latter being the mostly integrated governance mode.

This chapter is organized as follows. First, we will provide a more detailed background to develop some hypotheses on how different types of uncertainty affect the choice for more or less integrated governance modes. Second, we will test the hypotheses using a longitudinal dataset comprising data on inter-organizational relationships of the largest companies in the pharmaceutical industry. This section includes a description of the data, the variables included in the study and the methods used. Next, we present and discuss the results, followed by the conclusions and some suggestions for further research.

3.2 Theoretical Background

The continuum of governance modes

Traditionally, organizational theory has distinguished between markets and hierarchies, where firms are regarded as hierarchical entities, interacting with other firms through market transactions (Williamson, 1975). However, as noted by Powell (1990), the existing boundaries of firms are blurring as they engage in different types of interorganizatinal contracting that falls between arms-length market transactions and vertical integration. These arrangements can take the form of joint ventures, strategic alliances, or other forms of interorganizational collaboration. Previous studies have argued that these modes of collaboration can be ranked along the continuum between arms-length transactions and a fully integrated solution (Gulati and Singh, 1998; Hagedoorn and Sadowski, 1999; Nielsen, 2002; Santoro and McGill, 2005; Villalonga and McGahan, 2005). For example, Gulati and Singh (1998) distinguish between joint ventures, minority holdings and strategic alliances, ranking joint ventures at the hierarchical end of the continuum, followed respectively by minority holdings and strategic alliances towards the market-transaction end. Santoro and McGill (2005) distinguish and rank a number of alliance governance modes, ranging from licensing at the market end of the continuum, followed by cross-licensing, bilateral alliances, and minority equity alliances, to equity joint ventures at the hierarchy end.

In a similar vein, we argue that the governance modes used in this chapter (non-equity technology alliances, CVC investments, minority holdings, joint ventures and M&As) can also be ranked along the same continuum. Non-equity technology alliances have few hierarchical controls and are hence the most flexible form of cooperation, entailing a relatively low level of control over its partner. Moreover, non-equity alliances represent low levels of irreversible commitment due to the lack of equity involved. As a result, non-equity technology alliances come closest to market transactions. CVC investments and minority holdings, in which the investing company takes a minority share in another firm, are also a flexible form of cooperation, though the level of control is greater than in strategic alliances, partly because of the equity participation. Although both types of investments are in fact minority holdings, a clear distinction between the two exists. CVC investments typically occur in start-up firms and are normally organized in the focal firm by means of the establishment of a separate organizational unit with allocated funds. In addition to that, interaction between the venture and the investing firm usually occurs via the CVC unit (Schildt et al, 2005). Minority holdings, on the other hand, are usually carried out by a business unit and often occur as a means to gain control in a strategic alliance or as a first step towards a merger or acquisition. Hence, it can be argued that in terms of commitment and flexibility, CVC investments are more flexible and involve less commitment and as a result are positioned more towards the arms-length end of the continuum, followed by minority holdings. Joint ventures represent a higher level of integration, due to the increasing involvement of equity and the establishment of a new organizational entity. Finally, M&As represent the highest level of vertical integration as the partner (or target) company is fully controlled by the investing firm.

3.3 Hypotheses

Exogenous and endogenous uncertainty

When estimating the effect of uncertainty on the use of different governance modes, it is important to note that uncertainty exists in many forms and that each form may have a different impact on the governance mode choice (Mahoney, 1992; Sutcliff and Zaheer, 1998). Uncertainty affecting governance mode decisions can roughly be divided among two groups: exogenous and endogenous uncertainty (Folta, 1998). Exogenous uncertainty refers to uncertainty that 'is largely unaffected by firm actions' (Folta, 1998: 1011) and predominantly resolves over time. Exogenous uncertainty might take the form of *environmental turbulence*, but also *technological newness* is exogenous to the investing firm. Real options theory mainly deals with exogenous uncertainty, where the value of the option is determined by the uncertainty surrounding the investment. Endogenous uncertainty on the other hand refers to uncertainty that 'can be decreased by actions of the firm' (Folta, 1998: 1010). Endogenous uncertainty can often be found as taking the shape of relationship-specific uncertainty when firms are sourcing technologies externally for new business development. This type of uncertainty is typically represented by dissimilarities among partners which can be caused for instance by *different knowledge bases* or by the lack of *prior cooperation* to overcome information asymmetries. Both TCE and RO can be applied to decision-making under endogenous uncertainty, since they both stress a different perspective. RO stresses the value that is embedded in the uncertainty about the opportunity and gradually decreases as a result from learning investments. TCE takes on a different perspective in which hierarchy is presented as a way to circumvent the costs that are associated with the writing of contracts under higher levels of uncertainty.

Environmental turbulence

High-technology environments are typically characterized by unpredictable change fostered by radical innovations and therefore entail a rather high level of environmental turbulence. When the environment is turbulent, it becomes more valuable for innovating firms to keep their options open. Hence, they will prefer to maximize flexibility in this stage while uncertainty decreases and a possible follow-on investment can be decided upon (Van de Vrande et al., 2006). Therefore, under these circumstances, innovating firms will typically choose for less integrated governance modes with a lower level of financial commitment to reduce the potential costs associated with environmental turbulence in general and technology changes in particular (Sutcliffe and Zaheer, 1998). Not only can these types of investment be reversed more easily once outcomes are not satisfying, they also allow the investing company to bet on more than one horse at the same time. By investing simultaneously in different arrays of (competing) technology, the firm reduces the risk of being locked in a limited few (Moon, 1998). Moreover, such a strategy enhances the firm's ability to respond quickly to changing environments.

Previous research has indicated the preference among companies facing turbulent or uncertain environments to favor flexibility over control. In support of this, Hagedoorn and Duysters (2002a) find that industries that are characterized by rapid technological change ask for flexible forms of organization that enable quick strategic response. In their analysis, they find firms to favor alliances over of M&As. Following RO arguments, Folta (1998) and Moon (1998) found that technological turbulence leads to a preference for equity collaborations over acquisitions, whereas Santoro and McGill (2005) show how the dynamism of the technological subfield of an alliance negatively affects the use of more hierarchical alliance forms. Balakrishnan and Wernerfelt (1986), furthermore, show how integration is negatively affected by the frequency of technological change, an effect that holds specifically if the degree of competition is high. This view to delay financial commitment when uncertainty is high is also confirmed in studies investigating entrepreneurial entry (O'Brien et al., 2003) and partner buyouts (Folta and Miller, 2002).

To sum up, environmental turbulence seems to be a forceful driver to delay commitment and to keep different investment options open. The flexibility generated by real options allows firms to cope with unforeseen contingencies and facilitates reversibility of actions in combination with low degrees of financial commitments. Hence, we hypothesize that when environmental turbulence is high, companies are more likely to use less integrated governance modes that are more flexible, and involve a lower level of commitment.

> *Hypothesis 1. Environmental turbulence has a negative effect on the use of more integrated governance modes.*

Technological newness

Another important source of uncertainty within new business development projects is the uncertain business potential of the product or technology the firm invests in. Uncertainty with respect to the technological characteristics and the market feasibility of products or technologies cannot easily be reduced by the investing firm, but typically decreases over time as the technology matures and the innovating firm gets a better understanding of the technology and its market potential thanks to subsequent R&D or learning investments. When a technology is in an early stage of development, its basic concepts stem from practice, thereby raising the uncertainties associated with it (Ahuja and Lampert, 2001). Additionally, the possible success of the innovation is more uncertain in nascent technologies (Sahal, 1985). Hence, the high uncertainty surrounding new technologies makes it more valuable for the investing firm to make small, initial investments reducing the uncertainty about the business opportunity. Those early (and small) investments can be regarded to as learning investments (Janney and Dess, 2004) and intent to bring down the uncertainty through technological and market feasibility studies. Therefore, when the technology of the partner is rather new, companies will be more likely to pursue agreements that are more towards the market-transaction end of the continuum, such as strategic alliances and corporate venture capital investments, in order to remain flexible (Vanhaverbeke et al., 2002).

Previous studies have also pointed to the use of less integrated governance modes under conditions of technological newness. Pisano (1990), for instance, found that in the early days of biotechnology, technological uncertainty has played a critical role in established firms' decision to acquire biotechnology R&D from the outside. In addition to that, Lambe and Spekman (1997) argue that in the early stages of the technology life cycle where industry uncertainty is high, alliances take precedence over the two other options (make and buy) for acquiring new technology. Moreover, Steensma and Fairbank (1999) find that under conditions of high uncertainty (with respect to technological and commercial success), arms-length arrangements such as licensing are more likely to being pursued than joint development or acquisitions.

To sum up, when the technology of the partner firm is rather new and hence its success is unpredictable, it becomes more valuable for the investing firm to make small, learning investments. Therefore, we hypothesize that in the case of technological newness, the investing firm will be more likely to use less integrated governance modes that are highly reversible and involve a lower level of commitment.

> *Hypothesis 2. Technological newness has a negative effect on the use of more integrated governance modes.*

Technological distance

Dissimilarities between the knowledge bases of two partners might have an effect on the choice of the governance mode to shape their cooperation. Larger dissimilarities lead to two types of problems; the first one is related to he limited capability to detect, assimilate and integrate technology that is quite different from a firms' core technologies. Next, larger technological distance between two partners may also lead to relational uncertainty forcing them to safeguard against opportunistic behavior of the other.

The first type of problem is typically related to the absorptive capacity of firms. The more dissimilar the knowledge bases of two partners, the larger the probability that the absorptive capacity of the investing firm falls short, affecting the extent to which a firm can recognize and absorb its partner's technological capabilities (Cohen and Levinthal, 1990; Lane and Lubatkin, 1998). One can argue that partnering firms will choose governance modes that are more integrated in order to facilitate the effective transfer of distant knowledge (Cantwell and Colombo, 2000; Gulati and Singh, 1998; Mowery et al., 1996; Sampson, 2004). For instance, Colombo (2003) finds support for the hypothesis that divergence in partner's technological specialization increases the propensity to use equity alliances over non-equity alliances.

Second, larger technological distance between the partners and its associated absorptive capacity problems also leads to endogenous or relational uncertainty, i.e. the uncertainty within the technology sourcing relationship or the uncertainty between the partners which is typical for the TCE approach (Williamson, 1975, 1985)[3]. Large technological distance between two partners might lead to adverse selection. When the technological distance between the partners is high, information asymmetries emerge, which might result in the selection of inferior technologies. It can be argued that in order to overcome the danger of adverse selection, a higher level of integration is favorable to cope with information asymmetries and to protect the investing against for opportunistic behavior from its partner. Moreover, higher levels of technological distance between partners imply higher levels of uncertainty, which makes it more costly and more complicated to write complete contracts. As a result, a higher level of integration becomes a more attractive alternative (Williamson, 1975).

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[3] According to TCE logic, three types of problems typically arise during the transaction: adverse selection, moral hazard, and hold-up. In this section, we limit our attention to the danger of adverse selection, since adverse selection is typically an issue that might result from technological distance. Moral hazard and hold-up on the other hand are more related to the transaction and the threat of opportunistic behavior in general and will be discussed in relation to prior cooperation.

To sum up, when the knowledge bases of the firms involved in a technology sourcing partnership are dissimilar, a higher level of integration is necessary to increase the efficient transfer and accumulation of knowledge. Moreover, dissimilar knowledge bases increase the danger of adverse selection and make it more difficult to write contracts, hence making a higher level of integration more favorable. As a measure for dissimilarity among technological competences, we use technological distance between the firms. We hypothesize that when technological distance is high, companies will use more integrated governance modes entailing a higher level of hierarchical control.

> *Hypothesis 3a. Technological distance between the focal firm and its partner has a positive effect on the use of more integrated governance modes.*

On the other hand, the greater the knowledge base dissimilarities, the longer it will take before the uncertainty about the opportunity will be resolved, making a higher level of commitment less attractive. Instead, it is better to first build familiarity through small, educational investments or through alliances or joint ventures (Roberts and Berry, 1985). In this way, the investing company creates an option while learning about the opportunity ahead (Van de Vrande et al., 2006). When the knowledge bases are more converged, a higher level of integration becomes more attractive. In addition, Nooteboom (2004) argues that exploration requires a loosening of linkages with large cognitive distance, whereas exploitation should be conducted through more integration and small cognitive distance, hence stressing the likelihood of combining large technological distance with less integration and vice versa. Moreover, opportunistic behavior is not a real threat as long as the business potential of the technology is not crystallized into a viable business model. In other words, firms that are not yet familiar with the technological capabilities of its partners will first have to learn from each other before being able to accumulate the knowledge. Thus, greater technological distance makes unintended spill-over of knowledge less likely, decreasing the threat of opportunistic behavior (Colombo, 2003).

Supporting this view, Folta (1998) finds that in case of dissimilar business operations between partners, equity collaboration is preferred over acquisitions, whereas Villalonga and McGahan (2005) come to the conclusion that the relatedness between the focal firm and its partner is associated with the choice of acquisitions over alliances and alliances over divestures. Hagedoorn and Duysters (2002a) furthermore find support for their hypothesis that M&As are more likely when the external source of innovative capability is related to the company's core business (thus, when technological distance is small), and that strategic alliances are more likely for non-core businesses. In addition to that, Vassolo et al. (2004) find that lower technological distance enhances the likelihood of that an alliance partner is being acquired.

In sum, when the partnering firms have dissimilar knowledge bases, the need for learning and flexibility prevails over the need for administrative control. Technological distance between the firms is used as a measure for dissimilarity of technological competences between the partners. When technological distance is high we expect that companies will use less integrated governance modes to increase learning effects that might result from the relationship. Moreover, the use of less integrated governance modes enables those same firms to reverse their commitments at lower sunk costs at any point in time. Therefore, we hypothesize an alternative to Hypothesis 3a: technological distance has a positive effect on the use of more flexible governance modes that involve a lower level of commitment, and hence are less integrated.

> *Hypothesis 3b. Technological distance between the focal firm and its partner has a negative effect on the use of more integrated governance modes.*

Prior cooperation

In the case of new business development, technology sourcing partnerships often take multiple forms over time. As new technologies are developed and commercialized, subsequent inter-organizational transactions should be in line with the decreasing external uncertainty and the need to increase the level of commitment. As a result, different governance modes will be preferred as an innovation proceeds through the development and commercialization stages.

As discussed above, technological distance between the innovating firm and its partners is an important indicator of endogenous uncertainty. Another important indicator for endogenous uncertainty is the existence of prior cooperation between the partners. Prior cooperation can be used to overcome information asymmetry among partners (Reuer and Koza, 2000; Vanhaverbeke et al., 2002; Williamson, 1985). Information asymmetry occurs when firms do not have access to all the relevant information to make an investment decision. As mentioned before, the uncertainty within the technology partnership might be decreased by using small, initial investments to learn about the partner and its technology. This facilitates more familiarity with the technologies and practices of the partner firm. Real options reasoning suggests that under circumstances of uncertainty, these initial investments are also a way to put off commitment until the potential of the opportunity has become more tangible. If we extend this logic to the choice between different governance modes given prior cooperation, this leads to the suggestion that the inter-organizational transaction entails a higher level of commitment.

This point of view is supported by Duysters and De Man (2003) in their concept of transitory alliances, which are flexible alliance forms that might be intensified and become a more traditional alliance when the opportunity seems promising. Information asymmetry can be decreased substantially through prior cooperation. Furthermore, Garette and Dussauge (2000) draw attention to the fact that scale alliances might be the first step towards a merger. Some empirical evidence stresses this perspective, arguing that prior cooperation is an effective way to overcome information asymmetries that might exist among partners in a technology sourcing relationship. Balakrishnan and Koza (1993) argue that when information asymmetries exist, joint ventures are preferred over acquisitions, because information asymmetry strongly increases the costs of valuing the target. Vanhaverbeke et al. (2002) found empirical evidence for this argument, suggesting that as soon as the information asymmetry has been resolved as a result from the interaction within the alliance, a firm will move from a strategic alliance to an acquisition. Additionally, Kogut (1991) describes how joint ventures may be acquired later on. Following the arguments presented above, we expect that prior cooperation enhances the willingness of companies to enter into a relationship that is less reversible and that involves a higher level of commitment. Or, alternatively, if there is no prior cooperation we expect companies to opt for a governance mode that is less integrated and hence easier to reverse. We therefore hypothesize:

> *Hypothesis 4a. Prior cooperation has a positive effect on the use of more integrated governance modes.*

On the other hand, there is also a body of literature suggesting the opposite. Endogenous problems such as moral hazard and hold-up can be reduced through prior cooperation. Moral hazard refers to the threat of opportunistic behavior which occurs under circumstances of tacit knowledge. Prior cooperation is one way to learn about that knowledge and reduces the threat of opportunistic behavior. The problem of opportunistic behavior in contractual relations that require transaction specific investments – referred to as hold-up – can also be mitigated by prior and thus recurrent cooperation. In fact, more prior cooperation creates trust, which in turn reduces the fear for opportunistic behavior, thereby decreasing the need for control. Gulati (1995) found empirical evidence supporting this view. In his study about the choice among different governance structures for alliances, he finds evidence that prior ties between the partners reduces the likelihood that the next alliance between them will be equity based. Moreover, Reuer et al. (2006) show that trust leads firms to use non-equity alliances over equity alliances, whereas Villalonga and McGahan (2005) find support for the hypothesis that prior alliances positively affect the choice for alliances over acquisitions. In addition to that, Santoro and McGill (2005) found that the lack of prior ties induces companies to use of more hierarchical governance modes. Also Ring and Van der Ven (1994) have shown that trust is an essential condition for market transactions. If we extent this view to the broader spectrum of inter-organizational relationships, it can be argued that prior cooperation allows the investing company to use of governance modes that involve a lower level of commitment. Consequently, we propose an alternative hypothesis:

> *Hypothesis 4b. Prior cooperation has a negative effect on the use of more integrated governance modes.*

3.4 Methods

Dependent variable

Because we want to predict the effect of different types of uncertainty on governance mode choice, the dependent variable indicates the type of inter-organizational agreement that was entered to source external technology. The different sourcing modes are non-equity technology alliances, CVC investments, minority holdings, joint ventures and M&As. As argued before, these modes incorporate a full range of options that can be ranked along the continuum between arms-length arrangements and full integration (Williamson, 1985; Powell, 1990; Powell and DiMaggio, 1991). Non-equity technology alliances are defined as 'cooperative efforts in which two or more separate organizations, while maintaining their own corporate identities, join forces to share reciprocal inputs' (Vanhaverbeke et al., 2002). Strategic alliances come closest to market transactions and are hence the most flexible form of cooperation, entailing a relatively low level of control over its partner. CVC investments and minority holdings, in which the investing company takes a minority share in another firm, are also a flexible form of cooperation, though the level of control is greater than in strategic alliances, partly because of the equity participation. CVC investments can be defined as 'equity investments by established corporations in entrepreneurial ventures' (Dushnitksy and Lenox, 2006), whereas minority holdings are regarded as 'partnership in which one of the firms takes a less than 50 percent equity position in the other firm'. Joint ventures represent a higher level of integration, due to the increasing involvement of equity and require the formation of a new organizational entity by the partners. M&As represent the highest level of hierarchy and are defined as 'cumulative ownership of 50 percent or more of a partner firm' (Folta, 1998). The different modes are labeled according to their supposed level of integration, which allows us to perform an ordinal logistic regression. Non-equity technology alliances, being closest to arms-length transactions, are coded 1, followed respectively by CVC investments (2), minority holdings (3), joint ventures (4) and M&As (5), being the mostly integrated governance mode.

Independent variables

An overview of the variables can be found in Appendix III. Following the hypotheses, independent variables include environmental turbulence, technological newness, the technological distance between the investing firm and the partnering or target firm and prior cooperation between them. The independent variables *environmental turbulence*, *technological newness*, and *technological distance*, as well as the control variable *technological capital*, are calculated using patent data as an indicator for technological knowledge. Prior research has pointed towards the fact that technological knowledge depreciates sharply over time (e.g. Grilliches, 1979), losing most of its value within five years. Therefore, a five year moving window is used to calculate most of our variables. Other studies using patent data as an indicator for technological knowledge have for that reason also used five years moving windows (e.g. Katila and Ahuja, 2002; Stuart, 2000).

Environmental turbulence refers to the technological change over time. The measurement is based on patent classes that are relevant for the pharmaceutical companies in our sample. To determine the relevant technological fields, we took the 80% most important patent classes based on the patent applications of the focal firms during the observation period. Because our sample firms are largely diversified, 80% is taken rather than 100% in order to overcome too much noise in the calculation of this variable. Next, for these patent classes, we calculated for each year the number of patent applications worldwide[4]. To determine the similarities of the patent distributions of two subsequent observation years, we calculated the Pearson correlation coefficient ρ. Technological turbulence is then calculated as $1- \rho$, so that higher numbers indicate higher levels of technological turbulence. This variable is lagged one year.

Technological newness is a firm-level variable, which is developed in a two-step process. First, we determine the age of all patent classes. This is calculated as the median of the age[5] of all patents in a patent class in a particular year. To overcome outlier bias, we use

[4] We use all patent applications in a particular year rather than only the patents of the focal firms. Hence, this variable is not dependent on the firm sample.

[5] The age of the patent is the time elapsed between the application year and the year of observation.

the median age rather than the average to calculate the age. Second, to calculate the average technological age per firm, we multiply the share of patent applications by the technology age for each patent class. Technological newness is then calculated as -1 * technology age, such that higher values represent a higher level of technological newness.

Technological distance refers to the (lack of) overlap between the knowledge base of the investing company and the knowledge that is acquired externally. We use the method developed by Jaffe (1986) to calculate the technological proximity between two firms (i and j). Following this method, the technological proximity between two firms is computed as the uncentered correlation between their respective vectors of technological capital (measured as the cumulative patent applications in technology class k over the five years prior to the investment), P_{ik} and P_{jk} respectively:

$$T_{ij} = \frac{\sum_k P_{ik} P_{jk}}{\sqrt{\sum_k P_{ik}^2 \sum_k P_{jk}^2}}$$

The technological proximity (T_{ij}) measure takes a value between 0 and 1 according to their common technological interests. To calculate technological distance, this variable is transformed into a new one, which equals $1 - T_{ij}$.

The variable *prior cooperation* is a count variable, indicating the number of previous cooperation efforts between the focal firm and the partner firm in the five years prior to the observation year (Gulati, 1995).

Control variables

The decision to enter a specific technology sourcing mode can also be affected by factors, other than environmental and relation specific uncertainty. We therefore included a number of control variables to capture firm-specific characteristics.

Prior experience with particular governance modes might lead to the development of certain capabilities that enhance the effectiveness of managing these governance modes (Rothaermel and Deeds, 2006). As a result, prior experience might result in the preference of a particular governance modes over others (e.g. Hagedoorn and Duysters, 2002a; Villalonga and McGahan, 2005). Therefore, we included the control variable *experience*, indicating the firm's experience with respect to particular modes of technology sourcing in the five years prior to the investment under study. Furthermore, we added *technological capital* to measure the firm's technological strength

(Vanhaverbeke et al., 2002). This variable is computed as the cumulative number of patents applied for by the focal firm in the five years prior to the investment under study.

Furthermore, we controlled for *size* (natural logarithm of sales) and *R&D expenditures as a percentage of sales*. Both variables are lagged by one year. Finally, we introduced dummy variables to capture industry and country specific effects. The yearly dummy variables capture eventual changes in preference for particular governance modes. In this way we can control for instance for the booming venture capital markets, the increasing popularity of corporate venture capital or other developments in the environment.

Methods

The dataset used is set up as a cross sectional database where each record represents an inter-organizational relationship of any of the types. In this analysis, it is appropriate to use an ordered logit model to estimate the effect of uncertainty on the choice between less and more integrated governance modes. Ordered logistic regressions control for the ordered nature of the dependent variable. Following the literature (Williamson, 1985; Powell, 1990; Powell and DiMaggio, 1991), we argue that the dependent variable can be ranked along a continuum from less to more integration: non-equity, technology alliances being the most arms-length relationship, moving to CVC investments, which are still highly flexible though more integrated as a result of their equity component, followed respectively by minority holdings, joint ventures and mergers and acquisitions on the other end of the continuum representing the highest level of integration in the company. Although the first results of this estimation procedure seemed to be in line with the hypothesized signs (Appendix IV), it must be noted that in the ordinal logit model the *parallel regression assumption*, which assumes that the relationship between each pair of outcome groups is the same, should hold. The parallel regression assumption was tested using the Wald test by Brant (1990), showing that this assumption was violated for most of the independent variables (Appendix V). As a result, the ordinal logit model was rejected. Although according to Long and Freese (2003) the parallel regression assumption is often violated, the results for our model imply that ranking the different modes for technology sourcing along a continuum from less to more integration, is more complicated than literature suggests.[6]

[6] We will get back to the implications of these results in the discussion section of this chapter.

Since the ordinal logistic regression model, is rejected, we replaced it by a multinomial logit model. This model does not take into account any order in the dependent variable and is therefore an interesting mechanism to test the hypotheses. Since there is no predetermined ordening, the results of the multinomial logit can provide a more detailed insight in when particular governance modes are preferred over other, depending on the circumstances.

Table 1 Descriptive statistics and correlations

	Mean	*Std. Dev.*	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*	*(13)*
(1) alliance experience	8.09	7.55													
(2) CVC experience	1.70	5.27	.18												
(3) minority holding experience	2.01	2.15	.43	.30											
(4) joint venture experience	1.57	2.37	.58	.02	.06										
(5) M&A experience	4.44	3.85	.38	.42	.29	.37									
(6) R&D to sales	0.08	0.09	-.05	-.01	.13	-.22	-.19								
(7) Size	9.45	1.43	.08	.07	.04	.13	.12	-.40							
(8) Dummy Europe	0.39	0.49	.08	-.18	-.09	.13	.15	-.09	.03						
(9) Dummy Japan	0.05	0.22	-.22	-.07	-.18	-.11	-.23	-.06	.55	-.18					
(10) Dummy pharma	0.52	0.50	.02	.12	.21	-.33	-.07	.45	-.01	.07	-.02				
(11) Environmental turbulence	1.60	1.41	-.06	-.12	.03	-.11	-.04	.01	.00	.01	.00	.07			
(12) Technological newness	-10.43	3.29	.00	.15	.18	-.15	-.06	.24	-.08	-.16	-.01	.29	.02		
(13) Technological distance	0.69	0.28	.07	.02	-.10	.18	.13	-.21	.04	.04	-.05	-.22	-.07	-.19	
(14) Prior cooperation	0.20	0.61	.16	.11	.13	.14	.16	-.01	.00	-.01	-.05	.01	.00	.01	-.04

a. Year dummy variables not included in the table; the highest correlation is 0.36 between year 2000 and CVC experience.

3.5 Results

Table 1 presents the descriptive statistics and correlations for all variables.

The results of the multinomial logit estimates are presented in Table 2.[7] Both models show the estimates of the choice of corporate venture capital investments (CVC), minority holdings (MH), joint ventures (JV) and mergers and acquisitions (M&A) over the default category of non-equity alliances. Model 1 includes the results for the control variables only, whereas Model 2 also incorporates the independent variables. Some of the high correlations between some of the independent variables in Table 1 indicate possible multi-collinearity problems. We therefore estimated different models, excluding some of the variables with high correlations from the analyses. The results are very similar to the ones presented in Table 2, indicating that these results are robust.

Table 2 only shows the estimates for each category against the default category (non-equity alliances). To check whether there is still a differential effect of the independent variables on the different governance modes, we can use the odds ratios presented in Table 3. This table decomposes the effect of the independent variables on the governance mode choice into binary choice models. Each binary choice is represented in a different column, where values greater than 1 indicate a significant effect in the hypothesized direction, and a value smaller than 1 indicates a significant effect in the opposite direction. Non-significant results are not included.

The results in Table 2 partially support the hypotheses. Environmental turbulence is expected to have a positive effect on the use of less integrated governance modes (Hypothesis 1). The results in Table 2 indicate that environmental uncertainty has a negative effect on the choice of CVC investments, minority holdings, joint ventures and M&As over non-equity alliances.

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7 An underlying assumption in the multinomial logit model is the independence of irrelevant alternatives (IIA). We used the Hausman and McFadden (1984) test to check if the null hypotheses ((H0: Outcome-J vs Outcome-K) are independent of other alternatives) could be rejected and found that the IIA assumption has not been violated (Appendix VI).

Table 2 Multinomial logit estimates

	Model 1				*Model 2*			
	CVC	MH	JV	M&A	CVC	MH	JV	M&A
Constant	-2.614** (1.292)	-1.805** (0.829)	0.351 (0.974)	2.154*** (0.673)	-3.570** (1.476)	-1.684* (0.928)	-1.492 (1.056)	0.748 (0.736)
Alliance experience	-0.069*** (0.026)	-0.069*** (0.019)	-0.005 (0.017)	-0.062*** (0.012)	-0.077*** (0.027)	-0.070*** (0.019)	-0.012 (0.017)	-0.066*** (0.012)
CVC experience	0.182*** (0.048)	-0.092* (0.053)	-0.096 (0.059)	0.063* (0.036)	0.183*** (0.049)	-0.090* (0.053)	-0.088 (0.058)	0.073* (0.038)
Minority holding experience	0.106 (0.069)	0.037 (0.047)	-0.082 (0.065)	-0.042 (0.036)	0.121 (0.075)	0.012 (0.048)	-0.059 (0.067)	-0.022 (0.036)
Joint venture experience	-0.088 (0.085)	-0.022 (0.058)	-0.027 (0.057)	0.015 (0.039)	-0.089 (0.087)	-0.032 (0.059)	-0.044 (0.057)	0.007 (0.040)
M&A experience	0.026 (0.040)	0.019 (0.031)	0.050 (0.034)	0.069*** (0.021)	0.008 (0.041)	0.013 (0.032)	0.040 (0.034)	0.066*** (0.021)
R&D to Sales	-2.383 (2.346)	1.468* (0.754)	0.701 (2.671)	-3.437 (2.593)	-2.604 (2.896)	1.527* (0.784)	1.458 (1.879)	-2.024 (2.009)
Size	0.271** (0.132)	0.236*** (0.084)	0.031 (0.093)	-0.054 (0.065)	0.365** (0.155)	0.268*** (0.088)	0.029 (0.090)	-0.057 (0.066)
Dummy Europe	-0.521* (0.284)	-0.124 (0.197)	0.504** (0.220)	0.472*** (0.136)	-0.482* (0.287)	-0.124 (0.200)	0.409* (0.228)	0.375*** (0.140)
Dummy Japan	-2.703** (1.138)	-0.843* (0.506)	0.078 (0.657)	0.451 (0.356)	-3.016** (1.220)	-1.020** (0.519)	0.117 (0.646)	0.470 (0.370)
Dummy Pharma	-0.202 (0.316)	-0.671*** (0.191)	-1.316*** (0.316)	-0.668*** (0.209)	-0.154 (0.339)	-0.736*** (0.201)	-1.132*** (0.292)	-0.542*** (0.189)
Environmental turbulence					-0.319*** (0.118)	-0.211** (0.107)	-0.568*** (0.116)	-0.377*** (0.077)
Technological newness					0.101*** (0.037)	-0.017 (0.031)	-0.174*** (0.037)	-0.146*** (0.020)

Technological distance		1.632*** (0.510)	-0.653** (0.293)	0.417 (0.412)	0.110 (0.244)
Prior cooperation		0.133 (0.151)	0.421*** (0.122)	0.397*** (0.143)	0.100 (0.122)
Log Likelihood	*-2120.17*	*-2057.56*			
Prob>Chi2	*0.0000*	*0.0000*			
Pseudo R2	*0.1299*	*0.1556*			

a. Non-equity, technology alliances is the comparison group
b. * significant at 10%; ** significant at 5%; *** significant at 1%
c. Year dummy variables were included in the analyses, but not in the table
d. Robust standard errors in parentheses
e. N = 181

Table 3 Effect of the independent variables on the choice between external governance modes (e^bStdX) (a)

	SD	*CVC over SA*	*MH over SA*	*JV over SA*	*M&A over SA*	*MH over CVC*	*JV over CVC*	*M&A over CVC*	*JV over MH*	*M&A over MH*	**M&A over JV**
Environmental turbulence	*1.41*	0.6378	0.7426	0.4492	0.5882	n.s.	0.7043	n.s.	0.6049	0.7921	1.3095
		$SA > CVC > JV$									
		$SA > MH > M \& A > JV$									
Technological newness	*3.29*	1.3944	n.s.	0.5647	0.6188	0.6776	0.4050	0.4438	0.5976	0.6549	n.s.
		$CVC > SA, MH > JV, M \& A$									
Technological distance	*0.28*	1.5674	0.8354	n.s.	n.s.	0.5330	0.7155	0.6577	1.3426	1.2340	n.s.
		$CVC > SA > MH$									
		$CVC > JV, M \& A > MH$									
Prior cooperation	*0.61*	n.s.	1.2927	1.2733	n.s.	1.1921	n.s.	n.s.	n.s.	0.8221	0.8346
		$MH, JV > SA, M \& A$									
		$MH > CVC$									

a. Table reports change in odds for SD increase of X based on Model 2 in Table 3

b. n.s. = not significant

The odds ratios in Table 3 furthermore show that the environmental turbulence also negatively affects the choice of joint ventures over CVC investments, minority holdings and M&As, and that of M&As over minority holdings. Clearly, under high levels of environmental turbulence, non-equity technology alliances are the most favorable option. CVC investments, minority holdings and M&As are favored over joint ventures, and minority holdings are preferred over M&As, but the data show no significant differential effect of environmental turbulence on the preference for CVC investments over minority holdings or M&As. As a result, the first hypothesis is partly supported by the data, as strategic alliances are the most favorable option, but we did not find a linear ranking from less to more integrated governance modes.

The second hypothesis, predicting that technological newness of the partner's technology has a positive effect on the use of less integrated governance modes, is partially supported by the results. The results presented in Table 2 show that technological newness has indeed a strong, negative effect on the likelihood of using M&As and joint ventures instead of non-equity alliances. However, the results also imply that when the technology is new, CVC investments are preferred over non-equity alliances and minority holdings, which in turn are preferred over joint ventures and M&As. Thus, contrary to our expectations, technological newness leads only to some extent to the use of less integrated governance modes: while M&As and joint ventures become less attractive, there is a clear preference for the companies in this study to choose CVC investments over all other governance modes. This result shows that the uncertainty related to the newness of partners' technology is considered by the focal firms as different from technological turbulence. When technological turbulence is high, alliances are preferred over CVC investments, and the reverse holds in case the partners' technology is new.

Hypothesis 3a predicts that technological distance between partnering firms requires more integrated governance modes. The opposite was proposed by Hypotheses 3b. The results in Table 2 partially corroborate Hypothesis 3a, since a positive, significant effect is found of the likelihood to use CVC investments over non-equity alliances under higher levels of technological distance. However, technological distance between partners does also lead to a preference for non-equity alliances over minority holdings, and no differential effect is found between non-equity alliances and joint ventures and M&As. The odds ratios in Table 3 furthermore show that when technological distance between firms increases, there is an increased tendency to use CVC investments over non-equity alliances and non-equity alliances over minority holdings. CVC investments are also preferred over joint ventures and M&As, which in turn are preferred over minority holdings. Hence, there is no linear relationship between technological distance and the governance modes discussed here, since we find partial evidence for both Hypotheses 3a and 3b. The strong preference for CVCs to source externally developed technology that is distant from the focal firms technology core shows the particular role CVC investments play in external technology sourcing.

Based on the results in Table 2 and Table 3, we find some evidence for Hypothesis 4a as well as for Hypothesis 4b. Hypothesis 4a predicts that prior cooperation has a positive effect on the use of more integrated governance modes, whereas Hypothesis 4b predicts the opposite. Prior cooperation with a partnering firm increases the likelihood of using minority holdings and joint ventures as opposed to non-equity alliances, though the results in Table 3 show no significant result for the choice between joint ventures and minority holdings. Table 3 furthermore shows some preference for minority holdings and joint ventures over strategic alliances and M&As, which points in the direction of both Hypotheses 4a and 4b.

To shed some more light on the propensity of firms to use a particular type of governance under certain levels of uncertainty, we have calculated the predicted probabilities under varying levels of both exogenous and endogenous uncertainty. Recall that exogenous uncertainty incorporates environmental turbulence and technological newness, and that endogenous uncertainty is proxied by technological distance and prior cooperation.

Table 4 Predicted probabilities

	Low Exogenous uncertainty					*High Exogenous uncertainty*				
	SA	CVC	MH	JV	M&A	SA	CVC	MH	JV	M&A
All variables to sample mean	*47*	*4*	*10*	*5*	*34*	*47*	*4*	*10*	*5*	*34*
Low Endogenous uncertainty	29	2	8	9	52	69	3	10	1	17
High Endogenous uncertainty	23	4	8	14	51	62	8	10	2	18

a. Predicted probabilities with all other variables in the sample mean
b. Non-dummy variables are taken as mean plus (high) or minus (low) one standard deviation (Belderbos and Sleuwaegen, 2005)

Table 4 shows that when both exogenous and endogenous uncertainty decreases, the predicted use of more integrated governance modes increases, whereas the likelihood of strategic alliances decreases significantly. Moreover, when both types of uncertainty are high, i.e. when the relationship is subject to maximum uncertainty, less integrated governance modes are preferred over more integrated ones. However, the situations in which only one type of uncertainty is high and the other one is low are interesting.

When looking for instance at the situation in which endogenous uncertainty is low and exogenous uncertainty is high, the likelihood of using non-equity alliances increases from 47 to 69%, showing the importance of flexibility when the source of the uncertainty is beyond control of the firm. However, when exogenous uncertainty is low and endogenous uncertainty is high, the propensity to use M&As increases from 34 to 51%. Thus, explaining how firms source technologies for new business development under varying levels of uncertainty requires the combination of multiple perspectives on uncertainty.

The results for the control variables also deserve some attention. The dummy variables indicate that the pharmaceutical companies are more involved in technology alliances and less in minority holdings, joint ventures and acquisitions. There are also institutional influences: both Asian and European companies prefer alliances over CVC investments. In addition, large firms prefer CVC investments and minority holdings to non-equity alliances. Finally, prior experience with a particular governance mode is not per se related to a preference for that mode over another. As shown in Table 2, alliance experience has a positive effect on the choice of alliances over CVC investments, minority holdings, and M&As, but no effect on the choice of joint ventures. Similarly, CVC experience is related to the choice of CVC investments over strategic alliances, but also to the choice of M&As over alliances, and alliances over minority holdings. Experience with M&As increases the likelihood of choosing M&As over alliances, and interestingly, minority holdings and joint venture experience does not lead to the choice of any of the governance modes over alliances. Although prior studies have argued that firms build governance-form specific capabilities through the experience with different governance modes (e.g. Dyer and Singh, 1998; Rothaermel and Deeds, 2006; Villalonga and McGahan, 2005), our results suggest that this does not necessarily lead to a preference for that particular governance mode over another.

3.6 Discussion

In this chapter we have tested the effect of both exogenous and endogenous uncertainty on the choice between non-equity technology alliances, corporate venture capital investments, minority holdings, joint ventures and mergers and acquisitions. We tested several hypotheses about the impact of exogenous and endogenous uncertainty on this choice. The results provide varying levels of support for these hypotheses.

In the discussion leading to the first hypothesis we have argued that there is a positive relationship between high environmental uncertainty and the use of less integrated governance modes. Although the preference for CVC over minority holdings and M&As

is still unclear, the results show how non-equity alliances are the preferred mechanism to deal with unforeseen contingencies, whereas joint ventures are the least favorable. This is consistent with prior studies on environmental turbulence (e.g. Folta, 1998; Moon, 1998; Santoro and McGill, 2005), indicating that under higher levels of environmental turbulence, companies need to remain flexible, by making small, reversible investments. Contrary to our expectations, M&As are not the least preferred option. Although this seems to be somewhat surprising, it should be noted that in the pharmaceutical sector, the acquisition of small biotech companies is an important mechanism to gain access to new technologies. Even under high levels of environmental turbulence, acquiring a small firm is more attractive than setting up a whole new organizational entity (i.e. joint venture).

The second hypothesis predicted that a higher level of technological newness of the partner firm, will lead to an increased use of less integrated governance modes. We hypothesized that due to the highly uncertain outcomes, flexibility to withdraw from the commitment is an important asset companies need to cope with this uncertainty. The results only partially confirm the hypotheses, suggesting a preference for non-equity alliances and minority holdings over joint ventures and M&As, though showing that CVC investments are clearly preferred to the other governance modes. Prior research also indicated the preference for strategic alliances over M&As in the earlier stages of the technology life cycle (e.g. Lambe and Spekman, 1997), but their discussion is restricted to these two governance modes. On the other hand, researchers studying the use of CVC investments have pointed towards the fact that these investments are particularly oriented towards "having a window on emerging technologies" (Chesbrough, 2002; Dushnitsky and Lenox, 2006; Keil, 2002; Siegel et al., 1988), which might explain why CVC investments are preferred over strategic, non-equity alliances. In addition, although the possible outcomes of emerging technologies are uncertain, the possible return when an emerging technology turns out to be a success is much higher compared to the more incremental innovations based on mature technologies (Ahuja and Lampert, 2001). This might induce companies facing new technologies to opt for equity strategies in order to get some control and as the creation of an option for the future.

The alternative hypotheses 3a and 3b predicted that technological distance between partnering firms induces the firms to use less (more) integrated governance modes. We found mixed results, partially confirming both hypotheses. Although the results show no effect for the use of strategic alliances as opposed to joint ventures and M&As under these circumstances, the outcomes show once more a clear preference among companies to source distant technologies through CVC arrangements. This effect for

CVC investments corresponds with the findings of Dushnitksy (2004). He analyzed the relationship between an investing firm and an entrepreneur and came to the conclusion that this relationship is less likely to materialize when the products of the two are substitutes, i.e. when both parties operate in the same industry. The results also provide some evidence for the largely explorative nature of CVC investments. Interestingly, the results also show a clear differential effect for CVC investments and minority holdings, supporting our arguments that although CVC and minority holdings can both be regarded as minority equity investments, they are clearly used by investing firms as two distinct mechanisms of external technology sourcing.

The last two alternative hypotheses (4a and b) predicted a positive effect of prior cooperation the use of more (less) integrated governance modes. We find that minority holdings and joint ventures are preferred over non-equity alliances, but we also find that these strategies are preferred over M&As. Although this might indicate some support for both hypotheses 4a and 4b, one should be careful when interpreting these results. After a strategic alliance or CVC investment, the investing firm might opt to increase commitment and take a minority participation in its partner or form a joint venture. In line with earlier findings of Hagedoorn and Sadowski (1999), our results also show that prior cooperation does not necessarily lead to an M&A.

Another important finding of this chapter is that we found no empirical support for the proposition that different inter-organizational modes can be ranked along a market-hierarchy continuum as has been argued by many scholars on theoretical grounds (e.g. Gulati and Singh, 1998; Hagedoorn and Sadowski, 1999; Nielsen, 2002; Santoro and McGill, 2005; Villalonga and McGahan, 2005; Williamson, 1985). The results of the Brant test prove that ranking external governance choices (by means of an ordinal logit regression) to reflect the market-hierarchy continuum is not supported by the data. The multinomial logit estimates show that some ranking among the governance modes is possible, but they also suggest that this ranking is not linear as suggested by the previously mentioned continuum. On the contrary, the ranking is sometimes partial and is to some extent different depending on the proxies we have used for both external and relational uncertainty. The benefits of using a particular type of external technology sourcing mode are contingent on the external and relational uncertainty. This implies that each governance mode has its own strengths and weaknesses to cope with environmental turbulence, emerging technologies, technological distance between partners and technology sourcing in the wake of prior cooperation. Hence, the empirical analysis suggests that companies make use of different external technology sourcing modes depending on the type of uncertainty they have to cope with. External technology sourcing is contingent on the type of uncertainty, which, in turn, leads to a more complex understanding of external technology sourcing as suggested by the continuum in terms of more or less integrated modes.

3.7 Implications

Overall we feel that this chapter has contributed to answering the research question in the following ways: First, we have highlighted an important and often understudied topic, i.e. the role of uncertainty in government mode choice. This is particularly important in the context of new business development, because uncertainty about the opportunity ahead is generally high. In addition, when sourcing new technologies externally, the choice between different governance modes determines the ability with which companies are able to adapt to the changing environment. Next, despite the existence of prior research discussing governance mode choice, we increased the theoretical and empirical importance of this chapter by expanding number of mode-types compared to previous studies. This is an important feature because it reflects the current state of external venturing in which firms have a full array of options to fulfill their basic needs for technology development and acquisition. Finally, the empirical results provide evidence that a linear continuum of external technology modes as has been suggested in the literature is too simplistic to understand the technology based cooperation between innovating firms.

The current study clearly has a number of limitations. First, prior cooperation between the two firms in the dyad should be decomposed into the different types of external technology sourcing modes. As suggested in the literature streams on real options, certain types of investment might be considered as the creation of an option, which might be exercised at a later point in time using a more integrated solution (e.g. Bowman and Hurry, 1993; Hagedoorn and Sadowski, 1999; Haspeslagh and Jamison, 1991; Kogut, 1991; Vanhaverbeke et al., 2002). If we want to shed more light on this theory, it is necessary to split up prior cooperation into the specific modes in which prior cooperation existed. Next, prior cooperation should also be differentiated in terms of the partner's characteristics: a minority holding in a small (high-tech) firm will probably have a different effect on follow-up cooperative agreements compared to a minority holding in larger firms.

Furthermore, although we have tested the impact of different types of uncertainty on governance mode choice, future research should also look into the possible moderating effects of uncertainty. For instance, prior cooperation might interact with the effect of different types of uncertainty on governance mode choice. Moreover, the effect of uncertainty on governance mode decisions might differently affect industry leaders and laggards.[8]

An additional limitation of this study stems from the lack of data about partners and the relationship under study. In many cases partners are small firms that are not publicly owned but financed by private equity owners. As a result, it is extremely difficult to obtain financial information about these partners. This limitation excludes the possibility to measure the impact of partner characteristics on the choice of focal firms between external governance modes. Moreover, it might be the case that inter-firm ties differ along various dimensions, other than the ones discussed here. It is very likely that different resources are funneled through different modes. For example, non-equity alliances could serve solely for technological-collaboration whereas CVC is a channel to distribute capital as well. Further research should analyze how different modes channel these different types of resources. In addition, including more information on the inter-firm relationship level enables further insight on the impact of collaboration-specific issues.

Moreover, this is to our knowledge the first empirical study comparing CVC investments with strategic alliances and mergers and acquisitions as alternative modes to source externally developed technology. Hence, additional research in this area might be fruitful. Although CVC investments do impose a condition on the partner firm, i.e. the partner firm should be a start-up, its value as an alternative and complementary means to get access to new technologies is apparent. Further research in this field could go into the direction of not only predicting when CVC should be preferred over other governance modes, but should also focus on the advantages and disadvantages of this mode for technology sourcing as opposed to the other the other modes. As suggested in Chapter 1, a topic which definitely needs more attention is the differential impact of these technology sourcing modes on the innovation performance of focal firms. This issue will be addressed in the next chapter.

[8] We thank one anonymous reviewer for pointing us to this.

Chapter 4

Do Corporate Venture Capital Investments Lead To Better Innovation Performance?[9]

4.1 Introduction

In this chapter, we examine different governance modes to source external technologies and the way in which they affect innovative performance of firms. Prior studies focusing on the effect of externally sourced knowledge on innovative performance has primarily been limited to the effect of one or two governance modes in particular (an exception is Nicholls-Nixon and Woo, 2003). A large body of research has studied the positive effects of strategic alliances on subsequently patenting rates (e.g. Stuart, 2000), as well as a number of scholars who studied the relationship between M&As and performance (e.g. Ahuja and Katila, 2001; Hagedoorn and Duysters, 2002b). Recently, a study by Dushnitsky and Lenox (2005a) examined the positive relationship between corporate venture capital (CVC), a fairly new organization structure to get access to external technologies, and the patenting rates of investing firms. In addition to that, Laursen and Salter (2006) have studied the relationship between firm's external search strategies and innovation performance, focusing on the types of partners involved rather than on the types of relationships used.

However, as argued in Chapter 1, despite the evident positive effects shown by most of these studies, their explanation is limited to a certain extent. After all, most large diversified companies do not limit their sourcing strategies to one or two governance modes. They rather set up a portfolio of innovation projects ranging all the way from more incremental to high-risk, radical innovations. To cover this broad range of innovation projects, firms use a variety of distinct sourcing modes, each with their own characteristics, advantages and management challenges. Thus, in order to fully explain the effect of different governance modes for external technology sourcing on

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[9] This chapter is based on: Van de Vrande, V., Vanhaverbeke, W., Duysters, G. and Roijakkers, N. (2007) "Open Innovation: Do CVC Investments Lead to Better Innovative Performance?", paper presented at the Academy of Management Meetings, Philadelphia, PA.

innovative performance, it is important to include a broader variety of governance modes that are used by these firms.

In this chapter, we will therefore examine the effect of using multiple sourcing strategies on a company's subsequent innovative performance. In spite of our focus on this broad array of external technology acquisition modes we will pay particular attention to the added value of corporate venture capital investments. Corporate venture capital investments are minority equity investments in young, start-up firms and during recent years, these types of investments have received increased attention recently both in academia as well as in business. We argue that CVC investments are complementary rather than substitutes to other external sourcing modes, because they provide access to new technologies in their earliest stages of development. We furthermore argue that using CVC investments in combination with other modes of technology sourcing (e.g non-equity alliances, equity alliances and M&As) increases the overall innovative performance of investing firms.

The chapter intends to contribute to the main research question by discussing and empirically testing the differential effect of different external technology sourcing modes on the innovative performance of firms. By including non-equity alliances, equity alliances, M&As and CVC investments in one single model, we offer a more detailed insight in the actual value of external technology sourcing. In addition to that, since CVC investments have become a very popular way to access external knowledge, our analysis shows whether and to what extent this type of investment adds value to other external sourcing strategies for improving firms' innovative performance.

The remainder of this chapter is organized as follows: first we will discuss the reasons for companies to be engaged in external technology sourcing and how external technology sourcing affects innovative performance. We will then discuss the benefits of using CVC investments next to more traditional ways of bringing external technology to the firm. We hypothesize that CVC investments positively affect innovative performance of investing firms, especially when this type of investment is combined with strategic alliances and M&As. The next section describes the data and methods used to estimate the results, which are discussed thereafter. The chapter will conclude with a discussion of the results and with some implications and directions for further research.

4.2 Theoretical Background

Internal and external sources of innovation

In the past, companies tended to rely almost exclusively on internal R&D as a way to conduct research and development of new technologies within a company. The main reason for companies to invest in internal R&D is the so-called "first-mover advantage", which enables them to create barriers of entry for new firms (Rosenberg, 1990). Others argue that investments in internal R&D enhance the diversification of firms (MacDonald, 1985; Penrose, 1959), which in turn spurs growth. In addition to that, internal R&D not only improves the firm's technological competence, but it also increases its absorptive capacity, i.e. the ability to identify, assimilate and exploit externally available information (Cohen and Levinthal, 1989, 1990). This absorptive capacity can be regarded as a stock of knowledge that is to a large extent built up trough prior engagement in internal R&D (Cohen and Levinthal, 1990). The ability to efficiently tap into externally created knowledge is however an important condition for successful internalizing of external knowledge (e.g. Henderson and Cockburn, 1996; Rosenberg, 1990; Veugelers, 1997).

Although strategic alliances have always received a fair amount of attention, the search for a broader variety of external sources of innovation has received a growing amount of attention both in academics as well as in practice ever since the term Open Innovation was coined by Chesbrough (2003). Although staying connected to the outside world has always been an important aspect of innovation, the use of external sources has recently become a much more crucial aspect of companies' innovation strategies. There are many reasons for firms to engage in external technology sourcing. If we look at firms as a bundle of resources (Penrose, 1959; Wernerfelt, 1984), the firm's future competitive position is largely determined by the resources at hand, more specifically by resources that are distinctive or superior relative to those of competitors (Andrews, 1971). Sustained competitive advantage in that respect is mainly achieved though the availability of superior resources (Peteraf, 1993). As noted by Dyer and Singh (1998), these superior resources may span firm boundaries. External acquisition of supplementary or even complementary resources (Wernerfelt, 1984) might result in an advantage over firms that are not able or willing to do so (Dyer and Singh, 1998). In addition, companies need to combine and cooperate in order to remain globally competitive (Harrison et al., 2001) and to exploit future opportunities (Kogut and Zander, 1992). In today's turbulent business environment no single firm can afford to go it alone. The increasing complexity of technologies and products, as well as the rising costs of R&D combined with ever shortening product and technology life cycles has forced firms to acquire technology externally. Thus, the external sourcing of knowledge can be regarded as an important way to sustain a companies' competitive advantage.

Not only does external technology sourcing allow a firm to acquire supplementary or complementary resources that broaden the investing firm's knowledge base (Vermeulen and Barkema, 2001), it also enables companies to share the costs and risks associated with R&D and to speed up the time-to-market. Governance forms such as joint ventures and strategic alliances make it possible for companies to get access to a set of complementary resources, without internalizing them immediately. This is especially valuable in the earlier stages of new business development, where internalization of technologies is risky because of their uncertain future potential. Moreover, getting access to external technologies in an early stage of development might be much more effective than when a company has to develop the technology itself. Furthermore, investing in inter-firm relationships allows firms to simultaneously continue their own R&D while scanning the environment for promising ideas and technologies.

A previous study by Rosenkopf and Nerkar (2001), has also stressed the importance for firms to be engaged not only in different types of innovation projects, but also in search activities that span organizational boundaries, for instance through the use of inter-firm relationships. Hence, the growth of firms is not only determined by their internal R&D performance, but also by their ability to be engaged in inter-firm relationships that enhance their innovative performance through external knowledge acquisition.

External technology sourcing through M&As and strategic alliances

Companies that have decided to source knowledge from outside the firm, have a broad choice of governance modes they can employ for that purpose. Traditionally, mergers and acquisitions have been regarded as the primary way for companies to grow and to obtain additional resources. When sourcing external ideas through a merger or acquisition, the acquired resources are likely to be internalized in the investing firm. Thus, the resources obtained are accumulated to or integrated in the resources that were already present. The general assumption is that through economies of scope and scale, this enlarged bundle or resources make more efficient production possible and should thus have a positive impact on firm performance (Lubatkin, 1983). Additionally, from an innovation point of view, M&As are likely to increase innovativeness since technological knowledge is often tacit and M&As raise the overall R&D budget (De Man and Duysters, 2005). Moreover, technology buying might speed up the capability process because you buy technology instead of having to develop it yourself from scratch. Despite these apparent advantages, prior research has shown mixed results for the overall effect of M&As on the investing company's innovative performance (e.g. Hitt et al. (2001) found a negative relationship between R&D related acquisitions and patent intensity). One of the reasons for these mixed effects might be the short-term focus on results, or the type of acquisition under study. Ahuja and Katila (2001) point towards the fact that non-technological acquisitions are likely not to provide technological inputs and hence cannot be expected to increase the innovative output. In a similar vein, Vermeulen and Barkema (2001) indicate that firms learn from related acquisitions and not from unrelated ones. Hagedoorn and Duysters (2002b) found a positive effect between related M&As and technological performance based on patent intensity. The latter also show that the R&D intensity of the partner and the similarity of size affect innovativeness in a positive way. Koenig and Mezick (2004) furthermore demonstrate a positive relationship between mergers and R&D productivity using a sample from the pharmaceutical industry.

Although M&As are still a popular way for firms to achieve growth, more intermediate forms of governance have also gained ground. Strategic alliances, such as non-equity R&D agreements and joint ventures, have become more important vehicles for knowledge acquisition since the latest decades. Strategic alliances can be described as ‘cooperative efforts in which two or more separate organizations, while maintaining their own corporate identities, join forces to share reciprocal inputs’ (Vanhaverbeke et al., 2002) and can be roughly divided into equity and non-equity alliances (Inkpen, 1998; Zollo et al., 2002). Equity alliances involve the transfer of equity, for instance through the creation of a new organizational entity (joint venture), whereas non-equity alliances do not require the use of equity investments. Despite the possible risks that are associated with strategic alliances, such as free-riding and opportunistic behavior (Gulati, 1998), the main advantage of strategic alliances and joint ventures as opposed to M&As is the sharing of costs and risks, which makes them particularly attractive in turbulent environments. Sharing the costs and risks connected to R&D with a partner can be regarded to as an effective way to manage the uncertainty surrounding this process (Hagedoorn, 1993). Besides, strategic alliances allow the partners to access only part of each others resources, which is especially valuable when not all the resources possessed by the partner are sought after by the investing firm (Das and Teng, 2000). Additionally, strategic alliances are also more flexible than M&As. Withdrawing from a strategic alliance or joint venture is not as complicated and costly as it might be to divest a prior acquisition. This makes strategic alliances a more viable alternative to M&As in order to cope with the uncertainty of R&D in earlier stages of the new business development process, when the technology and its potential rewards are not yet fully known.

Especially the ability to share costs and risks, integrate complementary knowledge, the radar function, and the aim at specific pieces of knowledge are reasons why strategic alliances spur innovation (De Man and Duysters, 2005). A literature review by the same authors shows a strong, positive effect for strategic alliances on innovative performance (De Man and Duysters, 2005). Moreover, Dyer and Singh (1998) argue that interorganizational competitive advantage not only comes from complementary resources and capabilities, but is also grounded in more relationship-specific attributes such as relation-specific assets, knowledge-sharing routines and effective governance. Stuart (2000) finds a positive effect between strategic alliances with large and innovative partners and innovation improvement and growth rates, and Baum et al. (2000) finds that the number of alliances positively affects the success of biotech start-ups.

Corporate venture capital investments

The strategies described above have often been discussed in prior studies on inter-firm ties and innovation (e.g. Vanhaverbeke et al., 2002). In addition to these technology sourcing modes, a strategy that has received growing attention more recently among researchers and practitioners alike is the use of corporate venture capital. Corporate venture capital (CVC) emerged in the 1960s and can be defined as "equity investments by established corporations in entrepreneurial ventures" (Dushnitsky and Lenox, 2006: 754). Prior research has indicated that the motives for companies to invest in entrepreneurial start-ups range from purely financial objectives (i.e. return on investment) to more strategic motivations, such as identifying possible acquisition targets and for obtaining a window on new technologies (Ernst et al., 2005; Keil, 2003; Siegel et al., 1988; Sykes, 1990). As shown in a study by Kortum and Lerner (2000), venture capital activity has significant, positive impacts on the patenting rates of industries, stressing the role of venture capital to spur innovation. From a companies' perspective, CVC investments are particularly interesting to contribute to the firm's innovation output, because they enable companies to get access to technologies in an early stage of development.

Because CVC investments are specifically targeted at young, privately held companies (Gompers and Lerner, 1998), they provide the investing firm with access to a source of knowledge that might be difficult to target through M&As or strategic alliances. Moreover, these new ventures are an important source of innovative ideas that still need to be further developed or commercialized. Therefore, getting access to these ideas and technologies in this stage provides the investing firm with a possible vital source of competitive advantage. After all, breakthrough inventions often come from new, pioneering technologies (Ahuja and Lampert, 2001). Additionally it should be noted that CVC investments are a flexible way to invest in new technologies with unknown future potential. This allows companies to invest simultaneously in different, even competing technologies, thereby creating a portfolio of options that might be exercised in a later stage when the importance of these technologies becomes clearer.

A number of prior studies have examined the effect of corporate venture capital investments on the performance of the investing company. Dushnitsky and Lenox (2005) found a positive relationship between CVC investments and future patent citation levels. Siegel et al. (1988) report that most CVCs judge the performance to be satisfactory, though it should be taken into account that they have used a self-reporting measure, leading to a potential bias of the results. Gompers (2002) finds that the success rate of CVCs within the same industry is larger than the success rate of non-related CVCs, which is partially supported by the findings of Keil et al. (2004). They have studied the effect of intra-industry, related and unrelated CVCs, and found only a significant effect for the hypothesized positive direction in the case of related CVCs. In addition, a recent study by Dushnitsky and Lenox (2006) has indicated that CVC investments that focus specifically on strategic outcomes provide greater firm value than financially focused CVC investments.

To summarize, CVC investments are targeted at young, entrepreneurial ventures that are generally regarded as an important source of innovative ideas. Getting access to these emerging technologies provides the investing firm with a viable source of competitive advantage, which eventually will result in an increased firm performance. We thus hypothesize:

> *Hypothesis 5a. The number of CVC investments is positively related to innovative performance.*

However, notwithstanding the potential positive effect of CVCs on innovative performance, previous studies have indicated that there is natural limit to the amount of attention a company can allocate to the management of external relationships (Gomes-Casseres, 1996; Ocasio, 1997; Laursen and Salter, 2006). As Koput (1997) argues, there may be too many ideas to manage and to choose from, which makes it difficult to allocate the right amount of attention to the right idea. Furthermore, over-exploration of new ideas is likely not to be beneficial to the firm (Levinthal and March, 1993). Thus, it can be argued that although CVC investments positively affect innovation performance of investing firms in general, this effect only partially holds and is likely to diminish after a certain amount of CVC investments. To explore this potential curvilinear effect of CVC investments on innovation performance, we hypothesize:

> *Hypothesis 5b. The number of CVC investments is curvilinearly (inverted U-shaped) related to innovative performance.*

Complementarity of CVC investments

Because of their specific nature, CVC investments should be regarded as a complementary way of technology sourcing, next to the more traditional modes such as M&As and strategic alliances. CVC investments, strategic alliances and M&As serve the same purpose: getting access to external knowledge. However, despite this commonality, they all have different characteristics and can hence be used to target different pieces of knowledge. For instance, due to the irreversible nature of M&As, they are less attractive when, in the early phases of development, the potential value of the technology is highly uncertain. Strategic alliances are more flexible, and they are also valuable for sharing of costs and risks, which makes them more suitable for co-developing new technologies. In this sense, strategic alliances and M&As can serve as complementary ways to source new technologies throughout the dynamic process of new business development (Van de Vrande et al., 2006). In turn, CVC investments are especially valuable to target knowledge that is in an early stage of development and which is often privately held. Because these kinds of technologies might be more difficult to target through an M&A or through the use of strategic alliances, CVC investments can play an important role here. Even when a strategic alliance or M&A is a possibility, these strategies might be less interesting because they do not have the desired level of flexibility. When technologies are embryonic, it is important for the investing firm to make small investments that involve a relatively low level of commitment (Van de Vrande et al., 2006) in order to minimize the risks associated with R&D. Thus, throughout the innovation funnel different governance modes play a role to source technologies externally, depending on the stage of development of the technology and the corresponding level of uncertainty. This is illustrated in Figure 2.

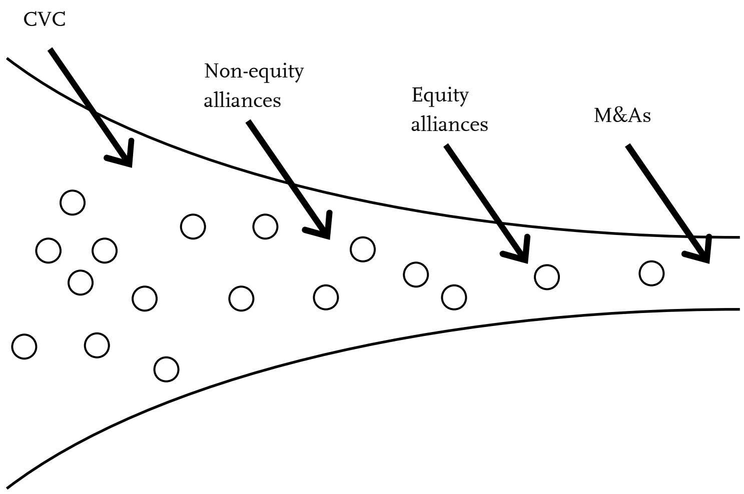

Figure 2 Technology sourcing throughout the innovation funnel

As a result, being involved in different types of technology sourcing modes is an important way for innovating companies to get access to different types of knowledge in different stages of development. Prior studies have shown that the diversity of ties enhances innovative outcomes (Powell et al. 1999; Baum et al. 2000). Organizations involved in multiple types of ties such as licensing agreements, joint research, and commercialization are more innovative than organizations that engage in fewer types of ties, since different types of ties are conducive to the transfer of different types of knowledge. Prior research comparing strategic alliances and acquisitions as two competitive modes for technology acquisition, has also stressed the importance of using alliances not as a substitute for acquisitions, but as a complementary mode (Garette and Dussauge, 2000; Veugelers and Cassiman, 1999). In similar vein real options theory suggests that companies should simultaneously invest in multiple options on new technologies. Besides, alliance experience as well as prior alliances between partners can help to overcome post-merger integration problems and thereby enhance the performance of M&As (Garette and Dussauge, 2000; Porrini, 2004a; 2004b), an argument that also holds for CVC investments. This implies that companies are using different modes for technology sourcing at the same time.

Thus, investing in new technologies that are in different phases of development creates a portfolio of options for the investing company. Different stages of development inherently involve different levels of uncertainty (e.g. future potential), but also involve different levels of the need for more control as technologies might turn out to become more valuable for the investing firm. CVC investments, strategic alliances (equity and non-equity) and M&As are all useful ways to bring external technologies inside the company, but they differ in respect to their flexibility to cope with technological uncertainty and the amount of control that is involved. Being exposed to a broad range of ideas and governance modes thus helps the company to get acquainted with different types of new knowledge. Therefore, using these strategies as complements rather than substitutes enables the investing firm to source each new technology in the most effective and efficient way. In the long run, being involved in different strategies that cover the different stages in the technology development funnel enhances the variety of technologies that is invested in, thereby increasing the innovative performance of the firm (Powell et al. 1999; Baum et al. 2000).

To conclude, investing in different types of inter-organizational relationships targeted at a variety of knowledge enhances the innovative output of firms. Since CVC investments are clearly a distinctive mechanism for external technology sourcing, aiming at new technologies in early stages of development, we expect CVC investments to be complementary to other, more traditional modes of knowledge acquisition, such as strategic alliances and M&As. Therefore, we hypothesize:

> *Hypothesis 6. CVC investments are complementary to other modes of external technology sourcing.*

Figure 2 shows that each governance mode plays a different role in the new business development process and can be regarded as complements. However, the distinctive characteristics of the different governance modes are fluid and the preference for one governance mode over the other is contingent on many different aspects. Thus, as projects move through the funnel, the distinction between governance modes that are presented in Figure 2 as being subsequent may not be as univocally as is suggested here. For example, non-equity alliances (as opposed to equity alliances) are also an effective way to enhance discovery of new knowledge (Hagedoorn and Narula, 1996; Osborn and Hagedoorn, 1997). Thus, both CVC investments and non-equity alliances are flexible modes for technology sourcing that are likely to be used in the early phases of the innovation process, when the uncertain future potential of the technology under development increases the need for flexibility. As a result, CVC investments and non-equity alliances can also be regarded as exchangeable strategies for external technology sourcing in the earlier stages of the technology life cycle.

Equity alliances and M&As on the other hand are strategies that are much more focused towards the later stages of the technology development process (see also

Figure 2). Contrasting non-equity alliances, equity alliances involve ownership and enhanced control. Equity alliances emphasize target setting, measurement of progress and taking corrective action, implying that the direction of the development process is clear (Osborn and Hagedoorn, 1997). Moreover, equity alliances and M&As require the investing firm to make (additional) equity investments in its partner, thereby forcing the firm to make a long-term commitment.

Thus, although the different governance modes are complementary from a longitudinal perspective, they can also serve as substitutes. We argue that some of the governance modes presented here are closely related in terms of commitment and flexibility, and hence with respect to the type of knowledge they aim at. As shown in Figure 2, non-equity alliances are closer to CVC investments than equity alliances and M&As respectively. While non-equity alliances can help to further develop projects in the earlier stages of development, equity alliances and M&As are more powerful mechanisms to move projects through the innovation funnel. Because of their inflexible nature and their attention on the development rather than the discovery of new ideas and technologies, they serve as a valuable complement (or even follow-on investment) to the more flexible and exploration-oriented CVC investments.

As a result, we expect that the greater the overlap between two different governance modes, the smaller the complementarity between them, because they can be substitutes as well. The smaller the overlap, on the other hand, and the more distinct the governance modes and the type of knowledge acquired, the greater the synergistic effects between them. More specifically, we hypothesize that:

> *Hypothesis 7. The complementarity of CVC investments on other modes for external technology sourcing increases when the overlap between the modes decreases.*

4.3 Data and Methods

Sample

To test our hypotheses, we use a sample consisting of all corporate venture capital investments, non-equity technology alliances, equity alliances, and mergers and acquisitions that have been completed between 1985 and 1996[10] by the largest companies in the pharmaceutical industry during our observation period.

Dependent variable

Our *dependent variable*, innovative performance, measures the innovation output of the focal firms. Innovation output can be measured using different indicators, such as patent counts, patent citations and new product announcements (Hagedoorn and Cloodt, 2003). Each of these indicators has been used frequently in previous studies on innovation performance, and every indicator is subject to debate regarding its biases and shortcomings. *Raw patent counts* is a count variable that simply counts the number of granted patent applications in the observation year. The main shortcoming of using patent counts as an indicator for innovative performance lies in the fact that patent counts give an identical weight to each patent application, and hence does not capture the importance of the innovation (Hagedoorn and Cloodt, 2003; Trajtenberg, 1990). Despite this critique, patent counts are a well accepted measure of innovative output, used in many studies on innovation performance (e.g. Ahuja and Katila, 2001; Hagedoorn and Duysters, 2002b; Powell et al., 1999).

In order to capture the value of innovation, one might be better off using patent citations, or weighted patent counts (Trajtenberg, 1990). *Weighted patent counts* (WPC) is also a count variable, but each patent i is now weighed according to the subsequent citations C_i it receives, assuming that more important patents receive more citations and vice versa. Weighted patent counts for n patents applied for in year t can be calculated following the formula below (Trajtenberg, 1990):

$$WPC_t = \sum_{i=1}^{n_t} (1 + C_i)$$

Patent citations were collected until 2003 and in order to avoid right-censoring problems, we take 1997 as the last observation year. Because our time horizon is limited and we are hence not able to observe all possible patent citations for each patent, we use the simulated cumulative distribution lags by Hall et al. (2001) to estimate the total number of citations each patent is likely to receive.

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[10] Longer time lags are used because of the use of patent citations (a patent can only be cited after it has been issued which takes on average 3 years for the firms in our sample. In order to avoid right-censoring of the data, we take 1997 as the last observation year.

Both raw patent counts and weighted patent counts are generally accepted measures in economics literature, and Hagedoorn and Cloodt (2003) find a high correlation between these indicators in all high-tech sectors, suggesting that these indicators are equally good predictors of innovative output. However, their results also show that the correlations between the different indicators are lower than average in the pharmaceutical industry as compared to other industries. For that reason, we have computed both raw patent counts and weighted patent counts as an indicator for innovative performance and found that the two variables are highly correlated ($r = .91$). We decided to use weighted patent counts as our dependent variable in order to account for both the number of patent applications and their value as estimated by the subsequent citations these patents receive. As a robustness check we have also estimated the models presented in this chapter using raw patent counts as the dependent variable showing that, as expected, the results were similar to the ones presented here.

Independent variables

Our first hypothesis predicts a direct relationship between *CVC investments* and innovative output. Therefore, for every observation year *t* we counted the number of CVC investments in the five years prior to the observation year (*t-1* to *t-5*). Prior research has pointed towards the fact that technological knowledge depreciates sharply over time (e.g. Griliches, 1979), losing most of its value within five years. Therefore, a five year moving window is used to calculate this variable. Other studies using patent data as an indicator for technological knowledge have for that reason also used five years moving windows (e.g. Katila and Ahuja, 2002; Stuart, 2000).

Additionally, we are interested in the substitutability or complementarity of CVC investments with other modes of technology sourcing. Consequently, we include the corresponding interaction terms between these sourcing modes as additional independent variables. Interaction terms allow us to estimate the possible synergistic effects that occur when two modes are used together. In case the modes are complementary, we expect positive and significant coefficients for these interaction terms; in the case of substitutes, negative coefficients are expected. We first computed the independent variables that are used to calculate the cross terms: non-equity alliances, equity alliances, and M&As. Equity alliances are strategic technology partnerships that involve the use of equity investments, such as joint ventures and minority holdings. For every observation year *t* we counted the number of times each governance mode was used in the five years prior to the observation year (*t-1* to *t-5*). To calculate the different interaction terms, we standardize the independent variables prior to computing their cross terms in order to enhance their interpretability and to eliminate nonessential multicollinearity (Aiken and West, 1991; Cohen et al., 2003; Rothaermel and Deeds, 2004). To test the complementarity of CVC investments with other modes for external technology sourcing, we computed the cross-term: non-equity alliances, equity alliances, and M&As x CVC investments. In similar vein, we computed the cross terms *non-equity alliances x CVC investments*, *equity alliances x CVC investments* and *M&As x CVC investments* to test the interaction between respectively non-equity alliances and CVC investments, equity alliances and CVC investments, and M&As and CVC investments.

As a robustness check, we also computed the independent variables using a 4-year window. The 4-years and 5-years lagged variables were highly correlated ($r > .95$ in all cases) and the estimation results using the 4-years lagged variables were very similar to the results presented in this chapter, showing that these variables are robust.

Control variables

Prior studies have already indicated that there exists a direct impact of *strategic alliances* and *M&As* on a firm's subsequent innovation output (e.g. Ahuja and Katila, 2001; Stuart, 2000; Vanhaverbeke et al., 2002). Firms do have the choice among different governance modes to get access to external technology and most diversified companies use different governance modes at the same time to acquire externally developed technology. As a result, including only one or two governance modes in the analyses might lead to a potential omitted variable bias. We therefore include the number of prior non-equity alliances, equity alliances and M&As as a control variable. Evidently, we have also employed a five year moving window for the calculation of these control variables.

Furthermore, we added *technological capital* as a measure of a firm's technological strength (Vanhaverbeke et al., 2002). This variable is computed as the cumulative number of patents applied for by the focal firm in the five years prior to the observation year *t*, based on the argumentation presented earlier.

Because prior research has indicated a strong relationship between R&D inputs and innovation, and has also viewed R&D expenditure as a means to generate absorptive capacity necessary to benefit from external technology sourcing (Cohen and Levinthal, 1990), we include *R&D intensity* (R&D expenditures as a percentage of sales) as a control variable. In addition to that, we controlled for *size* (natural logarithm of sales) and we introduced yearly dummy variables to capture eventual changes in patent application levels. The control variables *size* and *R&D intensity* are lagged by one year.

Method

Our dependent variable, weighted patent counts, is a count variable. Although Poisson models are often used to estimate count outcomes, the model in practice rarely fits due to overdispersion (Long and Freese, 2003). Because our data shows significant evidence of overdispersion (i.e. the variance exceeds the mean), a negative binomial regression model seems to be more appropriate (Cameron and Trivedi, 1998). Prior studies that used patent counts as a dependent variable have for that reason also used a negative binomial model (e.g. Hausman et al., 1984; Stuart, 2000). The negative binomial model for panel data is estimated using the XTNBREG command in STATA.

We furthermore employed a Hausman specification test (1978) on the baseline model to determine the choice between a random- and a fixed-effects model. The Hausman test was strongly significant, indicating that a fixed-effects model is the appropriate model for this analysis. A fixed-effects model furthermore allows us to control for omitted variables that differ between cases but are constant over time. Because fixed effects models do not allow the inclusion of time-invariant variables, we cannot include industry and region dummies.

4.4 Results

Table 5 shows the descriptive statistics and correlations between the independent variables. Although the largest firms in the industry were selected for our sample, Table 5 shows that these firms are highly heterogeneous in terms of size, R&D expenditures and technological capital. In addition to that, Table 5 shows also high correlations among the control variables representing the various forms of external technology sourcing (non-equity alliances, equity alliances, and M&As). Although these high correlations stress our belief that most diversified firms are involved in a large number of external technology sourcing agreements at the same time, they also indicate possible multicollinearity problems.

Table 6 presents the results of the negative binomial regressions, using weighted patent counts as a dependent variable. Model 1 presents the baseline model, including only the control variables *size*, *R&D intensity* and *technological capital*. Model 2 presents the effect of CVC investments on innovation performance, without controlling for other modes of external technology sourcing.

Table 5 Descriptive statistics and correlations

		Mean	*S.D.*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*
(1)	Weighted patent counts	1666	2491							
(2)	Size	9.61	2.19							
(3)	R&D intensity	0.10	0.24	-.43						
(4)	Technological capital	0.61	0.82	.16	-.12					
(5)	Non-equity alliances, equity alliances and M&As	0.00	1.00	.01	-.11	.59				
(6)	Non-equity alliances	0.00	1.00	.00	-.07	.57	.93			
(7)	Equity alliances	0.00	1.00	.02	-.09	.46	.86	.74		
(8)	M&As	0.00	1.00	.00	-.14	.45	.74	.50	.54	
(9)	CVC investments	0.00	1.00	-.06	.00	.13	.28	.29	.26	.13

Table 6 Fixed effects panel estimation results for innovative performance

	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*
Constant	0.918***	0.634***	0.867***	0.862***	0.866***	0.777***	0.764***	0.745***
	(0.243)	(0.241)	(0.245)	(0.245)	(0.244)	(0.243)	(0.242)	(0.242)
Size	0.094***	0.116***	0.097***	0.098***	0.097***	0.103***	0.104***	0.109***
	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)
R&D intensity	0.074	0.161	0.099	0.103	0.083	0.093	0.110	0.128
	(0.270)	(0.267)	(0.270)	(0.270)	(0.270)	(0.270)	(0.269)	(0.268)
Technological capital (x1000 patents)	0.281***	0.388***	0.300***	0.306***	0.319***	0.349***	0.366***	0.374***
	(0.043)	(0.038)	(0.044)	(0.044)	(0.045)	(0.041)	(0.041)	(0.042)
Non-equity alliances, equity alliances and M&As	0.159***		0.146***	0.143***	0.127***			
	(0.023)		(0.024)	(0.024)	(0.028)			
Non-equity alliances						0.096***		
						(0.025)		
Equity alliances							0.068***	
							(0.023)	
M&As								0.045**
								(0.023)
CVC investments		0.062***	0.034*	0.054	0.019	0.026	0.021	0.050**
		(0.018)	(0.019)	(0.034)	(0.023)	(0.023)	(0.023)	(0.020)
(CVC investments)^2				-0.004				
				(0.005)				
Non-equity alliances, equity alliances and M&As x CVC investments					0.010			
					(0.008)			
Non-equity alliances x CVC investments						0.008		
						(0.007)		
Equity alliances x CVC investments							0.017*	
							(0.009)	
M&As x CVC investments								0.035***
								(0.011)
Wald Chi2	362.79***	311.35***	376.00***	379.49***	393.31***	379.10***	363.97***	353.70***
Log Likelihood	-4683.67	-4699.10	-4682.23	-4681.98	-4681.38	-4685.14	-4688.65	-4691.29

a. Standard errors in parentheses

b. * significant at 10%; ** significant at 5%; *** significant at 1%

c. Number of observations = 792; Number of firms = 109

d. Year dummy variables were included but are not shown

In Model 3, the control variable *non equity alliances, equity alliances and M&As* is included in the analysis. Models 3 and 4 investigate the effect of the number of CVC investments and its squared term, in order to check for possible linear and curvilinear relationships between CVC investments and innovation output. In Models 5 to 8 we included the different interaction terms of CVC investments and other modes of external technology sourcing, with the aim to test the added value of CVC investments next to the more traditional ways of external technology sourcing.

Hypothesis 5a predicted a positive relationship between CVC investments and subsequent innovation output. Models 2 and 3 in Table 6 show that CVC investments have a positive effect on weighted patent counts, even when controlling for other modes of external technology sourcing. Following Hypothesis 5b, we also tested for a possible curvilinear effect of CVC investments and innovative performance (Model 4), but as shown in Table 6, the squared term was not significant, indicating that CVC investments experience a linear, rather than a curvilinear, effect on the weighted patent counts of the investing firm. Thus, support is found for Hypotheses 5a, but not for Hypothesis 5b.

Hypothesis 6 stated that CVC investments are complementary to other modes of external technology sourcing. In other words, Hypothesis 6 predicted that CVC investments increase the effect of other governance modes on innovation performance. Models 5 to 8 in Table 6 provide only partial support for this hypothesis. The interaction term *Non-equity alliances, equity alliances and M&As x CVC investments* (Model 5) is not significant and also the interaction term *CVC investments x non-equity alliances* shows a non-significant, non-negative effect on weighted patent counts (Model 6). However, the interaction terms with equity alliances (Model 7) and M&As (Model 8) are positive and significant, indicating that CVC investments combined with equity alliances or with M&As positively affect weighted patent counts, thereby supporting the hypothesis.

Hypothesis 7 predicted that when the overlap between the governance modes decreases, the complementarity of CVC investments on other modes for external technology sourcing increases. Models 6 to 8 provide full support for this hypothesis. Although the interaction term *CVC investments x non-equity alliances* is not significant, we see a steady increase of the magnitude of the correlation coefficient (0.022 for *CVC investments x non-equity alliances*; 0.037 for *CVC investments x equity alliances*; and 0.049 for *CVC investments x M&As*).

The control variables also deserve some attention. Table 6 shows that size and technological capital have a strong effect on innovation output. Prior non-equity alliances, equity alliances and M&As also have a positive, direct effect on subsequent patent citation levels in all cases, as expected. Interestingly, the effect of CVC investments on innovative performance is indeed affected by the other governance modes used. As shown in Table 6, the effect of CVC investments on innovation output is much stronger when the control variable for other external technology sourcing modes is not included (Model 1), indicating a potential omitted variable bias.

4.5 Discussion

In this chapter, we examined how different modes for external technology sourcing affect innovative performance of the investing firm. Focusing on CVC investments, which are a relatively new vehicle for technology sourcing, we have estimated the direct effect of CVC investments on innovation output followed by an investigation of the effects when CVC investments are combined with the more traditional ways of technology sourcing, such as non-equity alliances, equity alliances and M&As.

The results indicate that there exists a positive effect between CVC investments and subsequent innovative performance and does hence support Hypothesis 5a. A curvilinear effect was tested as well, but turned out to be non-significant thereby rejecting Hypothesis 5b. The results presented in this chapter are in line with earlier studies on CVC investments and innovative performance. For instance, Dushnitsky and Lenox (2005) found a direct, positive effect of CVC investments on innovative output, although their research did not include the other modes for external technology sourcing as was done in this study. Including other strategies for technological search provides a richer explanation of the role of different modes for external technology sourcing. The results presented in Model 1 and 2 in Table 6 indicate the existence of a potential omitted variable bias and thereby stress our belief that one must control for the whole portfolio of governance modes that a company has at its disposal. Wadhwa and Kotha (2006), in their study on CVC investments in the telecommunications equipment manufacturing industry found a curvilinear effect of CVC investments on successful patent applications, while controlling for other modes of technology sourcing. It could be that the different setting of their study (telecommunication equipment manufacturing versus pharmaceuticals) or the different dependent variable used (successful patent application counts versus weighted patent counts) explains the difference between their findings and the ones presented in this chapter.

This chapter presents a clear indication of the added value of CVC investments when used jointly with other governance modes for knowledge acquisition. Although Hypothesis 6 is not fully borne out, the results show that combining CVC investments with equity alliances or M&As does indeed positively affect the innovation rates of the investing firm. As shown in Figure 2, CVC investments on the one hand and equity alliances and M&As on the other hand aim at different types of knowledge, in different stages of development. Using CVC investments and equity alliances or M&As simultaneously enables the investing firm to track projects as they move through the funnel. Moreover, the use of different strategies, allows the firm to spread its investments over different projects. Dividing its resources among the generation of new knowledge (exploration) and the exploitation of knowledge the firm is already familiar with, enhances the continuous character of innovation processes within the firm and facilitates the firm to produce a constant stream of new knowledge, thereby enhancing its innovative performance.

In line with Hypothesis 7 the results show that the synergistic effect of CVC investments is greatest when CVC investments are combined with M&As. In other words, combining CVC investments with non-equity alliances does not necessarily lead to an increase of their effect on innovative performance, probably because these investments are closely related in terms of the targeted knowledge and the flexible characteristics. But when the development stages of the targeted knowledge become more distinct, the added value of CVC investments to spur innovation becomes more apparent. In other words: the greater the gap between the different modes and the stage in which the projects occur, the more synergistic the effect of CVC investments on innovation output. This is particularly relevant, because these results suggest that it is not only essential for firms to spread their investments over a number of projects using a number of governance modes, but it also stresses the importance of being engaged in particular in different projects in different stages of the new business development funnel.

4.6 Implications

This study contributes to answering the initial research question in a number of ways. First, we have estimated the differential impact of different external technology sourcing modes in one model. Since most large firms are engaged in different technology partnerships at the same time, including a broad range of technology sourcing strategies in one model provides a richer description of the dynamics that are surrounding the more open way of innovation that is pursued by an increasing number of firms. Additionally, we have shed more light on the role of CVC investments, a technology sourcing strategy that has only recently become more popular as a way to gain access to external knowledge. We have shown how CVC investments can increase innovation performance when used in combination with the other modes of technology partnering, especially when used simultaneously with governance modes that target a more mature type of technology as opposed to the relatively new technologies that are aimed at through the use of CVC investments. These findings have important implications for firms starting up and investing in corporate venture capital programs. Although firms do consider CVC investments as an increasingly important way to get access to new sources of knowledge, the positive effects are always clear and the costs might exceed the perceived benefits of such investments. These results stress once more the enhanced innovative performance of firms investing CVC in start-up firms, but they also show that these positive effects are most likely to occur when CVC investments are used in combination with other governance modes. This implies that getting access to new technologies as such is not sufficient; companies need to further develop these technologies by using other types of governance modes that are more oriented towards the later stages of development of the technology.

Of course this study is subject to a number of limitations. The first limitation regards the use of weighted patent counts to measure innovation output. Although patent indicators are widely used as a proxy for technological knowledge (e.g. Hagedoorn and Cloodt, 2003; Jaffe and Trajtenberg, 2002), it should be noted that there is also a significant share of knowledge that is created within the firm which cannot be captured in patent information. Furthermore, improvements in technology do not necessarily lead to a better financial performance of a company. Technological knowledge is not the same as successful new product introductions that lead to increased sales.

Furthermore, in this chapter we have constrained our attention to the outside-in movement of technologies, i.e. the external acquisition of new technology. Corporate venture capital investments, however, are also widely used as a means to accelerate the growth of internally created businesses. After the technology has become more mature, it can than be reintegrated in the existing technology portfolio. Further research should be conducted to obtain a better picture of this specific use of CVC investments and its impact on innovative performance.

In addition to that, we have studied the impact of CVC investments on innovative performance and the extent to which these types of investments are complementary to other modes of external technology sourcing. However, we do not take a truly dynamic perspective on external technology acquisition: CVC investments are often regarded as a first stage investment that might evolve in another type of mode when the technology further matures. CVC investments, strategic alliances and M&As are all part of a broader spectrum of technology in-sourcing that can be used sequentially when a technology becomes more mature. Future research into the dynamics of CVC investments as a first stage investment should be conducted in order to get the full picture of how CVC investments can add value for firms. A dynamic view on technology in-sourcing would also give us a better understanding how one technology mode in one phase of the innovation process can be transformed in another one in the next phase depending on the specific needs of the venture in each phase.

Finally, as noted in a number of prior studies, innovation performance consists of two distinct aspects, each affecting the performance of firms in its own way: exploitation and exploration. Improvement of existing routines, practices, or technologies ensures the company's immediate survival. However, in the long run, better opportunities might be provided by new, yet to be explored technologies (March, 1991; Levinthal and March, 1993). Especially the role of new, pioneering technologies has been stressed in the literature as a determinant for firm performance (e.g. Kleinschmidt and Cooper, 1991). The next chapter focuses on the use of different governance mode to create pioneering technologies.

Chapter 5

The Creation of Pioneering Technologies [11]

5.1 Introduction

As noted by March (1991), companies must not only focus on incremental innovations in existing markets or products, but also on the creation of new businesses and the generation of pioneering technologies. Although the exploration of pioneering technologies entails a high level of technological and commercial uncertainty, prior studies have acknowledged the role of pioneering technologies in overall firm success (Kim and Mauborgne, 2004; Kleinschmidt and Cooper, 1991), the creation of breakthrough inventions (Ahuja and Lampert, 2001) and the generation of economic returns (Achilladelis et al., 1990). Exploration of pioneering technologies is thus an important way for companies to determine their future competitive advantage. In Chapter 1, we have already stressed the importance of external technologies to generate pioneering technologies. In this chapter, we will explore how the creation of pioneering technologies is enhanced by different governance modes for external technology sourcing.

Despite the vital role of pioneering technologies to improve firm performance, prior studies discussing how breakthrough technologies are discovered is relatively scarce. O'Connor and Rice (2001) stress the role of opportunity recognition for breakthrough innovation. According to these authors, the recognition of breakthrough opportunities is key to the development of radical innovations. In addition, Mascitelli (2000) argues that harnessing tacit knowledge is a crucial aspect in achieving breakthrough innovations. Moreover, prior studies have stressed the importance of new combinations (Fleming, 2001; Schumpeter, 1934) and the fundamental role of moving beyond local search (Rosenkopf and Nerkar, 2001). As noted by Rosenkopf and Nerkar (2001), moving beyond local search consists of two main elements: moving beyond current organizational boundaries, and moving beyond current technological boundaries. A combination of both organizational and technological boundary-spanning will naturally lead to the exploration of radical or pioneering innovation.

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[11] This chapter is based on: Van de Vrande, V., Vanhaverbeke, W., and Duysters, G. (2007) "Technology In-Sourcing and the Generation of Pioneering Technologies", working paper.

When considering the creation of pioneering technologies it is thus important to look at both organizational and technological boundary-spanning. Although Rosenkopf and Nerkar (2001) have indicated the importance of looking beyond organizational boundaries, they have not included the particular role of different inter-organizational relationships in this respect. Organizational boundary-spanning can take the form of engaging in inter-organizational relationships, for instance through strategic alliances, corporate venture capital investments and mergers and acquisitions. Because different external technology sourcing modes enable access to different types of technologies, it is important to disentangle them in order to estimate their individual impact. Although many prior studies have investigated the impact of different external technology sourcing modes on overall innovative performance (e.g Ahuja and Katila, 2001; Dusnitsky and Lenox, 2005; Stuart, 2000), the way in which these strategies affect explorative innovation performance has not yet been studied in a full-fledged manner.

In addition, Rosenkopf and Nerkar (2001) stress the role of technological boundary-spanning when creating pioneering technologies. Technological boundary-spanning can be achieved through the investment in distantly related technological knowledge, or by investing in recently developed technologies. Prior studies have also indicated the importance of technological newness (Katila, 2002; Nerkar, 2003) and technological distance (Nooteboom, 2000) in the creation of knowledge. However, the way in which these types of technological boundary-spanning affect the relationship between external technology sourcing and the creation of pioneering technologies is still unclear.

In this chapter we intend to fill this gap by empirically analyzing the effect of different external technology sourcing modes on the generation of pioneering technologies. Because different governance modes facilitate access to different types of knowledge in different stages of development, we argue that they affect exploration outcomes differently as well. Strategic alliances and corporate venture capital investments, for instance, are loosely integrated governance modes that allow the focal firm to remain flexible when investing in external knowledge. Mergers and acquisitions, on the other hand, are more integrated and therefore embody a lower level of flexibility. Additionally, we link these governance modes to the newness of the technology a firm invests in and the technological distance between the investor and its partner. Both technological newness and technological distance affect the extent to which the knowledge acquired matches the absorptive capacity embedded in the organization and hence the effectiveness with which the external knowledge can be internalized.

The contribution of this chapter to the literature is threefold. First, we incorporate a broad range of external technology sourcing modes that firms have at their disposal when looking for new technologies. Second, we specifically focus on the generation of pioneering technologies. Our analyses show how different governance modes lead to the generation of new technologies, thereby shedding more light on the specific use and characteristics of different strategies for explorative technology sourcing. Third, we incorporate the role of technological newness and technological distance when analyzing the effect of different governance modes on explorative innovation performance.

The remainder of this chapter is organized as follows. Making a distinction between organizational and technological boundary-spanning, we start with the development of hypotheses that predict the effect of different inter-organizational relationships on the generation of pioneering technologies. Next, we add the role of technological boundary-spanning by developing hypotheses about the interaction effects of technological distance and technological newness. These hypotheses are then tested on a longitudinal dataset comprising data on inter-organizational relationships of the largest companies in the pharmaceutical industry. This section contains a description of the data, the variables included in the study and the methods used. Next, we present and discuss the results, followed by the conclusions and some suggestions for further research.

5.2 Theoretical Background

Exploration across firm boundaries

Prior studies have described innovation as a process of recombinant search (Fleming, 2001), thereby stressing the importance of new combinations for explorative innovation (Schumpeter, 1934). Recombination can be realized by combining different technologies and the innovation efforts of different firms (Rosenkopf and Nerkar, 2001). These authors argue that exploration consists of looking beyond both technological and organizational boundaries. They furthermore note that organizational boundary spanning naturally leads to the spanning of technological boundaries. Thus, engagement in inter-firm relationships is an important determinant for the explorative performance of firms because it allows them to look beyond their organizational and technological domains. As a consequence, open innovation practices are more important for exploration as for exploitation. In addition, external technology sourcing enables firms to create a higher level of internal variety, which is crucial in order to effectively adapt new technologies (McGrath, 2001). Moreover, external technology sourcing is an important vehicle to acquire new technologies, to get access to superior resources (Dyer and Singh, 1998) and to ensure corporate renewal (Vanhaverbeke and Peeters, 2005).

There are different ways in which firms can engage in external technology sourcing. Mergers and acquisitions and strategic alliances, such as R&D agreements and joint ventures, have for years been popular ways to tap into other firms' knowledge. Increasingly important are university cooperation and the use of corporate venture capital investments, in which the focal firm takes a minority equity stake in a young, start-up company, often accompanied by board membership in the start-up. Evidently, since different governance modes have different characteristics, they are also likely to be employed to source different types of knowledge. Depending on whether the new venture involves explorative or exploitative innovation, companies will use different strategies for technology sourcing (Schildt et al., 2005). Exploration, involving a higher level of uncertainty, usually involves less integrated governance modes, while exploitative innovations might be better conducted through more integrated strategies (Schildt et al., 2005). As a result, it can be argued that the way they affect the generation of pioneering technologies also differs between different external technology sourcing modes. The generation of pioneering technologies is by definition a high risky venture with uncertain outcomes. One of the ways to effectively manage high risks and the high costs often associated with this is by using technology transfer modes that are reversible and offer a high level of flexibility. Reversibility and flexibility are necessary to withdraw from the commitment as soon as the new technology turns out not to be promising (Van de Vrande et al., 2006).

Strategic alliances

Investing in strategic alliances is one way in which companies can enhance the flexibility of external technology sourcing. Strategic alliances have the advantage that they enable the sharing of costs and risks and provide access to complementary knowledge developed by the partners. Furthermore, alliances allow firms to co-develop new technologies or knowledge with a partner, which is an important asset in the development of complex or pioneering technologies (Eisenhardt and Schoonhoven, 1996; Hagedoorn and Duysters, 2002a). The cooperative nature of strategic alliances furthermore facilitates the creation of rich information channels which enhance learning (Keil, 2002).

Strategic alliances can be divided in equity and non-equity alliances (Inkpen, 1998; Zollo et al., 2002). Non-equity alliances evidently do not involve an equity investment in the partner firm, and can hence be regarded as a flexible means to invest in new technologies. Equity alliances, on the other hand, require the co-investment of financial resources, thereby posing an increased level of commitment on the focal organization. Although both equity and non-equity alliances are characterized by flexible contractual agreements (Hagedoorn and Hesen, 2007), the lack of equity investment in non-equity alliances, make them more suitable to be used in earlier stages of the highly risky new business development process. Equity alliances, on the other hand, may be playing an increasingly important role once the future potential of the technology is becoming more apparent or the technology is expected to be crucial for the focal firm.

A number of prior studies have examined the positive effects of strategic alliances on subsequent innovation performance (e.g. Stuart, 2000) and the use of strategic alliances as a means to conduct explorative innovation (see for instance Koza and Lewin (1998) and Rothaermel and Deeds (2004) and their notion of explorative alliances). Moreover, as argued by Tushman and Anderson (1986), radical new technologies are often generated by young, start-up firms, which often face resource constraints. This forces them to rely on strategic alliances with other start-ups or incumbent firms (Rothaermel, 2001). As a result, engaging in a strategic alliance with such a start-up firm might provide the focal firm with access to knowledge that leads to the development of radical innovations.

To sum up, strategic alliances are suitable mechanisms to use in the earlier stages of the technology development process, in which technological uncertainty is still very high. They enable the focal firm to make small, reversible investments to manage the uncertainty surrounding the development of pioneering technologies. Moreover, cooperation with another firm is an attractive way to share the costs and risks involved with the innovation process, or to tap into the knowledge embedded in the partner firm. Although equity alliances pose a higher level of involvement on the focal firm, it should be noted that equity alliances also increase the level of control. When the outcomes of the R&D process are highly uncertain, companies might either want to maintain their flexibility through non-equity arrangements, or secure their future involvement through an equity investment. Hence we hypothesize that non-equity and equity alliances both have a positive effect on the subsequent generation of pioneering technologies.

Hypothesis 8. Strategic alliances (both equity and non-equity) have a positive effect on the generation of pioneering technologies.

Corporate venture capital investments

The same reasoning can be applied to the use of corporate venture capital investments. Corporate venture capital (CVC) investments are flexible and reversible investments in start-up companies. CVC investments are widely known as a means to have a 'window on new technologies' (Ernst et al., 2005; Keil, 2002; Siegel et al., 1988; Sykes, 1990) and to 'explore the external environment' (Wadhwa and Kotha, 2006). Moreover, a CVC investment often comes with board membership of the focal firm in the start-up and close cooperation to further mature the technology. In addition, as argued before, new entrants are often associated with the generation of radical innovation. Due to their flexible and explorative nature, CVC investments are an interesting mechanism to get access to new knowledge in the earlier stages of technology development. Combining this knowledge with the knowledge already embedded within the focal firm might lead to the generation of pioneering technologies.

Thus, CVC investments are also an appropriate strategy to use in the earlier stages of the technology development process. They enable the focal firm to make small, reversible investments to manage the uncertainty surrounding the development of pioneering technologies. Moreover, cooperation with the start-up firm is an important aspect in many CVC investments and thereby serves as an attractive way to share the costs and risks involved with the innovation process. Hence we hypothesize that CVC investments also have a positive effect on the subsequent generation of pioneering technologies.

Hypothesis 9. Corporate venture capital investments have a positive effect on the generation of pioneering technologies.

Mergers and acquisitions

Mergers and acquisitions, on the other hand, are a somewhat different story. An acquisition can be defined as 'one firm buying another for the intent of gaining access to the acquired firm's technology' (Schilling and Steensma, 2002) and is often used when the need for strategic flexibility is low or when the firm intends to utilize sustaining economies of scale and scope efficiently (Garette and Dussauge, 2000; Hoffmann and Schaper-Rinkel, 2001). Previous studies have shown mixed results for the effect of M&As on overall innovation outputs (for an overview see De Man and Duysters, 2005), indicating both positive as well as negative effects. Although it can be argued that acquisitions broaden a firm's knowledge base (Vermeulen and Barkema, 2001), it should be noted that M&As pose a high level of financial and organizational commitment on the focal firm. As a result, M&As are likely to be used in later stages of the new business development process, when the uncertainty about the opportunity has decreased (Van de Vrande et al., 2006) or when the partner's technology has proven to be important to the focal firm's core business (Hagedoorn and Duysters, 2002a).

When developing pioneering technologies, uncertainty about the opportunity is generally high and companies need to remain flexible in order to be able to withdraw from the commitment if necessary. Prior research has indicated that exploration of new technologies is enhanced by loosely coupled governance modes (Schildt et al., 2005), suggesting that a higher level of integration has a higher impact on exploitation of existing knowledge. As a result, it can be argued that, as opposed to loosely coupled linkages such as strategic alliances and CVC investments, M&As will have a negative effect on the creation of breakthrough technologies.

> *Hypothesis 10. Mergers and acquisitions have a negative effect on the generation of pioneering technologies.*

Exploration across technological boundaries

As argued in the introduction, radical or pioneering innovation results from both organizational and technological boundary-spanning (Rosenkopf and Nerkar, 2001). Organizational boundary-spanning can take the form of investing in interfirm relationships, such as strategic alliances, corporate venture capital and mergers and acquisitions. Technological boundary-spanning, on the other hand, can take the form of investing in technologies that are distantly related, in other words on a large technological distance between the focal firm and its partner. Moreover, investing in new or recent technologies also affects technological boundary-spanning of focal firms by being at the forefront of technological innovation. Because technological and organizational boundary-spanning are found to interact (Rosenkopf and Nerkar, 2001), the attention will be on how the spanning of technological boundaries affects the relationship between external technology sourcing and the creation of pioneering technologies.

Technological distance

Inter-organizational learning is affected by the extent to which the information acquired is 'new' to the recipient. The degree to which certain knowledge is new depends on the technological distance between the parties involved. Technological distance refers to the relative overlap between the technological knowledge bases of the firms involved. If this overlap is small, the focal firm and its partner have little past knowledge in common. As a result, the way in which they 'perceive, interpret and evaluate' the information that they are exposed to is different (Nooteboom, 2000), and only through interaction are they able to learn from each other. Although some overlap is always necessary in order to recognize and assimilate new knowledge (Cohen and Levinthal, 1990; Lane and Lubatkin, 1998), large technological distance embodies the opportunity to learn distantly related skills and to be exposed to distant knowledge which is relatively new to the focal firm.

Due to their flexible nature and small commitments, CVC investments and strategic alliances are particularly interesting mechanisms to target distant knowledge. As argued by Nooteboom (2004), exploration requires a loosening of linkages with large cognitive distance. Exploration thus benefits from external technology sourcing on a higher technological distance (Rosenkopf and Nerkar, 2001). The higher the technological distance, the smaller the overlap of knowledge, and hence the newer the knowledge is, relative to the focal firm (Schildt et al., 2005). Moreover, access to knowledge from unrelated contexts stimulates the creation of new combinations, thereby enhancing the creation of pioneering technologies. As a result, we expect a positive effect between the technological distance between the partnering firms and the creation of pioneering technologies. Moreover, when combined with the different governance modes to course external technologies, we expect an additional effect: the technological distance between the focal firm and its partner strengthens the relationship between external technology sourcing and the subsequent creation of pioneering technologies. Hence, we hypothesize:

> *Hypothesis 11. The technological distance between the focal firm and its partner strengthens the effect of external technology sourcing on the generation of pioneering technologies.*

Technological newness

In addition to technological distance, technological newness also plays an important role in the spanning of technological boundaries. Creating pioneering technologies requires the focal firm to constantly invest in cutting-edge technologies that are on the verge of breaking through. Past studies have argued why recent knowledge enhances innovation processes. Investing in recent knowledge enables a firm to maintain the constant fit between the firm and its environment, which is likely to lead to better solutions (Katila, 2002). Moreover, by building on recent technologies, firms build upon routines and capabilities already embedded in the organization which provide them with a better view on future developments (Katila, 2002; Nerkar, 2003). In addition, investing in recent technologies prevents the firm from ending up in a maturity trap, in which the focal firm sticks to the exploration of mature technologies (Ahuja and Lampert, 2001). Thus, investing in recent, or newer, technologies enhances the explorative outcomes of the innovation process.

In the previous section, we have argued that external technology sourcing through flexible, reversible governance modes such as strategic alliances and CVC investments has a positive effect on the generation of pioneering technologies. Building upon the arguments presented earlier, we expect technological newness to positively affect this relationship. After all, sourcing newer knowledge evidently requires more flexible and hence more reversible modes of governance to manage the risks associated with this type of learning. Therefore, we argue that using flexible forms of governance to source more recent technologies enhances the positive exploration outcomes. Hence we hypothesize:

> *Hypothesis 12. The newness of the technology a focal firm invests in strengthens the effect of external technology sourcing on the generation of pioneering technologies.*

5.3 Methods

Dependent variable

The *dependent variable*, pioneering technologies, measures the extent to which the focal firms generate pioneering technologies. *Pioneering technologies* are technologies that are new to the world and hence do not build on any prior knowledge. To calculate this variable we follow the method by Ahuja and Lampert (2001), and count all patent applications in year *t* that do not cite any other patents. In total, the focal firms included in the ample have applied for 10,021 patents that do not cite prior art. On average, the focal firms apply for 7.4 pioneering patents per year ($\sigma = 13.5$). Since all patents are required to disclose prior art information, a lack of citations to prior patents indicates that there are no visible technological antecedents. The patent can therefore be regarded as being new to the world. Pioneering technologies is thus a count variable, indicating the number of patent applications in year *t* that have no citations.

Independent variables

The hypotheses predict a direct relationship between *CVC investments, non-equity alliances, equity alliances, M&As* and explorative performance. Therefore, for every observation year t we counted the number of CVC investments, non-equity alliances, equity alliances and M&As respectively in the five years prior to the observation year (*t-1* to *t-5*). As mentioned earlier, a five year moving window is appropriate, since technological knowledge loses most of its value within the first five years.

In addition, hypothesis 11 and 12 predict a moderating relationship between technological distance and technological newness on the one hand and the different modes of external technology sourcing on the other hand. *Technological distance* refers to the (lack of) overlap between the knowledge base of the investing company and the knowledge that is acquired externally. We use the method developed by Jaffe (1986) to calculate the technological proximity between two firms (i and j). Following this method, the technological proximity between two firms is computed as the uncentered correlation between their respective vectors of technological capital (measured as the cumulative patent applications in technology class k over the five years prior to the investment), Pik and Pjk respectively:

$$T_{ij} = \frac{\sum_k P_{ik} P_{jk}}{\sqrt{\sum_k P_{ik}^2 \sum_k P_{jk}^2}}$$

The technological proximity (Tij) measure takes a value between 0 and 1 according to their common technological interests. To calculate technological distance, this variable is transformed into a new one, which equals $1 - T_{ij}$.

Technological newness is a firm-level variable, which is developed in a two-step process. First, we determine the age of all patent classes. This is calculated as the median of the age[12] of all patents in a patent class in a particular year. To overcome outlier bias, we use the median age rather than the average to calculate the age. Second, to calculate the average technological age per firm, we multiply the share of patent applications by the technology age for each patent class. Technological newness is

[12] The age of the patent is the time elapsed between the application year and the year of observation.

then calculated as -1 * technology age, such that higher values represent a higher level of technological newness.

To test the moderating effects, we include the corresponding interaction terms between the relevant independent variables. To calculate the different interaction terms, we standardize the independent variables prior to computing their cross terms in order to enhance their interpretability and to eliminate nonessential multicollinearity (Aiken and West, 1991; Cohen et al., 2003; Rothaermel and Deeds, 2004). To test the interaction between technological distance and different modes for external technology sourcing, we computed the cross-terms *technological distance x CVC investments*, *technological distance x non-equity alliances,* and *technological distance x equity alliances*. In similar vein, we computed the cross-terms *technological newness x CVC investments*, *technological newness x non-equity alliances,* and *technological newness x equity alliances* to test the interaction between technological newness and the different modes for external technology sourcing.

Control variables

Because we expect the generation of pioneering technologies to be dependent on a firm's history in creating such technologies, we included the lagged dependent variable as a control variable to control for unobserved heterogeneity (Blundell et al., 1995). Since technological knowledge depreciates over time, we calculated the lagged dependent variable, using the following formula:

$$Patents_{it} = \sum_{s=1}^{5} (Patents_{it-s})(1-\delta)^{s} \text{, where } \delta = 0.15$$

Consistent with prior studies that have incorporated patent data as independent variables, we use a depreciation rate of 15%, and a 5 year depreciation schedule (e.g. Crepon and Duguet, 1997; Hall et al., 2005). As a robustness check, we have also calculated the lagged dependent variable using a 30% depreciation rate (e.g. Blundell et al., 1995; Dushnitsky and Lenox, 2005) which led to similar results as presented in this chapter, indicating this variable is robust.

Because prior research has indicates a strong relationship between R&D inputs and innovation , but also as a means to generate absorptive capacity necessary to benefit from external technology sourcing (Cohen and Levinthal, 1990), we include *R&D expenditures as a percentage of sales* as a control variable. In addition to that, we controlled for *size* (natural logarithm of sales) and we introduced yearly dummy variables to capture eventual changes in patent application levels. The control variables *size* and *R&D intensity* are lagged by one year. Additionally, we included industry and region dummies to control for unobserved effects that industry- or region-specific.

Method

The dependent variable *pioneering technologies* is a count variable. Although Poisson models are often used to estimate count outcomes, the model in practice rarely fits due to overdispersion (Long and Freese, 2003). Because our data shows significant evidence of overdispersion (i.e. the variance exceeds the mean), a negative binomial regression model is more appropriate (Cameron and Trivedi, 1998). Prior studies that used patent counts as a dependent variable have for that reason also used a negative binomial model (e.g. Hausman et al., 1984; Stuart, 2000). The negative binomial model for panel data is estimated using the XTNBREG command in STATA.

We furthermore employed a Hausman specification test (1978) on the baseline model to determine the choice between a random- and a fixed-effects model. The Hausman test was not significant, indicating that it is safe to use a random-effects model. Because random-effects model do not control for time-invariant variables (i.e. variables that differ between cases but are constant over time), we manually control for unobserved effects that are industry and region specific this by including industry and region dummies. Moreover, as mentioned earlier, we included the lagged dependent variable as a control variable to control for unobserved heterogeneity (Blundell et al., 1995).

5.4 Results

Table 7 shows the descriptive statistics and correlations for all variables.

Table 7 Descriptive statistics and correlations

	Mean	*S.D.*	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*
(1) Pioneering technologies	7.78	12.61												
(2) Size	9.66	2.14	.08											
(3) R&D intensity	0.09	0.17	.03	-.34										
(4) Dummy Europe	0.32	0.47	.26	-.17	.01									
(5) Dummy Japan	0.20	0.40	-.12	.76	-.04	-.33								
(6) Dummy Pharma	0.49	0.50	.18	.01	.30	.12	.16							
(7) Pioneering technologies $_{t-1\ to\ t-5}$	22.11	30.94	.84	.11	.01	.29	-.13	.20						
(8) CVC investments	0.00	1.00	.06	-.05	.01	-.04	-.13	-.02	.06					
(9) Non-equity alliances	0.00	1.00	.40	-.07	-.02	.14	-.29	-.03	.45	.24				
(10) Equity alliances	0.00	1.00	.34	-.03	-.06	.12	-.25	-.16	.35	.70	.22			
(11) M&As	0.00	1.00	.18	-.04	-.14	.26	-.35	-.21	.24	.42	.22	.46		
(12) Technological distance	0.00	1.00	-.01	-.10	-.10	.06	-.18	-.21	.01	.08	.07	.10	.17	
(13) Technological age	0.00	1.00	-.11	.02	-.25	.17	-.16	-.42	-.09	-.01	-.11	.06	.21	.21

Table 8 shows the results for the negative binomial regression using pioneering technologies as a dependent variable. Model 1 in Table 8 shows the baseline model with only the control variables included. Models 2 to 4 show the effects of CVC investments, non-equity alliances, equity alliances and M&As on the generation of novel technologies respectively, whereas Models 5 and 6 represent the effects of the different governance modes on the generation of pioneering technologies combined in a single model. Note that the high correlation between non-equity and equity alliances point to potential multicollinearity problems, which might lead to very large standard errors for the coefficient estimates leading them to show up as non-significant or which might cause a flip in signs even after minor changes in the specification or sample (Greene, 1997). After estimating the effects of the different governance modes on the generation of pioneering technologies, we include the variables technological age (Model 7) and technological distance (Model 11). Model 8-10 and Models 12-14 show the respective interaction terms to test for possible reinforcing relationships between technological distance and technological age on the one hand and the different external technology sourcing modes on the other hand.

Hypothesis 8 predicts a positive effect of strategic alliances on the generation of pioneering technologies. Models 3 and 4 in Table 8 show positive, significant coefficients for both non-equity and equity alliances, thereby supporting the hypothesis. Moreover, these positive effects are consistent throughout other models that include these variables as well, showing that these effects are robust when other variables are included in the analysis. Thus, both non-equity and equity alliances have a positive effect on the generation of pioneering technologies.

Hypothesis 9 predicts a positive effect of CVC investments on the creation of pioneering technologies. The positive and significant coefficient in Model 2 in Table 8 confirms that CVC investments positively affect the generation of subsequent pioneering technologies. In addition, we also find that the coefficient remains positive and significant throughout all models, supporting the robustness of this result. Hence, Hypothesis 9, CVC investments positively affect the creation of pioneering technologies, is also confirmed by the analysis. However, when compared with Models 3 and 4, it can be concluded that the effect of CVC investments is much smaller than the effects of non-equity and equity alliances.

Table 8 Random effects panel estimation results for pioneering technologies

	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*
Constant	-0.756	-0.700	-0.326	-0.606	-0.903*	-0.469	-0.758
	(0.538)	(0.537)	(0.544)	(0.535)	(0.542)	(0.545)	(0.538)
Size	0.188***	0.180***	0.133**	0.167***	0.204***	0.145**	0.182***
	(0.058)	(0.058)	(0.059)	(0.058)	(0.059)	(0.059)	(0.058)
R&D intensity	0.636*	0.630*	0.517	0.607*	0.667**	0.550	0.646*
	(0.335)	(0.336)	(0.337)	(0.334)	(0.335)	(0.338)	(0.334)
Dummy Europe	0.621***	0.656***	0.686***	0.674***	0.665***	0.756***	0.735***
	(0.171)	(0.172)	(0.171)	(0.173)	(0.172)	(0.172)	(0.173)
Dummy Japan	-0.244	-0.185	0.052	-0.154	-0.322	-0.001	-0.214
	(0.320)	(0.321)	(0.329)	(0.318)	(0.321)	(0.329)	(0.319)
Dummy Pharma	0.485***	0.476***	0.486***	0.533***	0.424***	0.402**	0.446***
	(0.154)	(0.154)	(0.154)	(0.154)	(0.156)	(0.156)	(0.156)
Pioneering technologies $_{t-1\ to\ t-5}$	0.009***	0.009***	0.008***	0.007***	0.010***	0.009***	0.009***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
CVC investments		0.048**				0.046**	0.045**
		(0.021)				(0.023)	(0.023)
Non-equity alliances			0.109***			0.111***	
			(0.028)			(0.028)	
Equity alliances				0.101***			0.104***
				(0.029)			(0.029)
M&As					-0.070**	-0.089***	-0.092***
					(0.030)	(0.030)	(0.030)
Wald Chi2	180.18***	185.82***	197.68***	192.81***	184.39***	207.48***	205.25***
Log Likelihood	-2174.15	-2171.87	-2167.02	-2168.47	-2171.47	-2161.32	-2162.59

a. Standard errors in parentheses
b. *significant at 10%; ** significant at 5%; *** significant at 1%
c. Number of observations = 863; Number of firms = 105
d. Year dummy variables were included but are not shown

Table 8 Random effects panel estimation results for pioneering technologies (cont.)

	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Constant	-0.728	-0.668	-0.338	-0.551	-0.747	-0.631	-0.353	-0.612
	(0.540)	(0.539)	(0.544)	(0.534)	(0.531)	(0.531)	(0.538)	(0.530)
Size	0.188***	0.180***	0.131**	0.160***	0.186***	0.171***	0.136**	0.167***
	(0.058)	(0.058)	(0.059)	(0.058)	(0.058)	(0.058)	(0.058)	(0.057)
R&D intensity	0.645*	0.641*	0.473	0.586*	0.597*	0.568*	0.461	0.576*
	(0.335)	(0.337)	(0.334)	(0.335)	(0.333)	(0.334)	(0.333)	(0.333)
Dummy Europe	0.633***	0.668***	0.632***	0.666***	0.669***	0.719***	0.678***	0.710***
	(0.171)	(0.172)	(0.172)	(0.172)	(0.171)	(0.171)	(0.173)	(0.173)
Dummy Japan	-0.253	-0.195	0.024	-0.149	-0.273	-0.176	-0.022	-0.185
	(0.321)	(0.322)	(0.329)	(0.317)	(0.316)	(0.317)	(0.327)	(0.315)
Dummy Pharma	0.461***	0.450***	0.504***	0.517***	0.412***	0.414***	0.477***	0.473***
	(0.156)	(0.156)	(0.155)	(0.156)	(0.157)	(0.156)	(0.160)	(0.158)
Pioneering technologies $_{t-1 \text{ to } t-5}$	0.009***	0.009***	0.009***	0.008***	0.009***	0.009***	0.008***	0.007***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
CVC investments		0.050**				0.119***		
		(0.022)				(0.046)		
Non-equity alliances			0.090***				0.118***	
			(0.029)				(0.029)	
Equity alliances				0.094***				0.097***
				(0.030)				(0.029)
M&As								
Technological distance	-0.034	-0.038	-0.008	-0.020				
	(0.036)	(0.038)	(0.037)	(0.038)				
Technological distance x CVC investments		-0.003						
		(0.054)						
Technological distance x non-equity alliances			0.065**					
			(0.029)					
Technological distance x equity alliances				0.040				
				(0.035)				

Technological age					-0.085*	-0.050	-0.028	-0.072
					(0.045)	(0.048)	(0.050)	(0.048)
Technological age x CVC investments						0.128*		
						(0.073)		
Technological age x non-equity alliances							0.093*	
							(0.049)	
Technological age x equity alliances								0.000
								(0.042)
Wald Chi2	181.23***	187.12***	203.31***	193.26***	185.67***	192.63***	207.91***	197.13***
Log Likelihood	-2173.70	-2171.34	-2164.24	-2167.46	-2172.34	-2168.85	-2164.24	-2167.19

a. Standard errors in parentheses
b. *significant at 10%; ** significant at 5%; *** significant at 1%
c. Number of observations = 863; Number of firms = 105
d. Year dummy variables were included but are not shown

Hypothesis 10, on the other hand, indicates a negative effect of M&As on pioneering technologies. Consistent with the expectation, Model 5 in Table 8 shows a negative, significant coefficient for M&As on the creation of pioneering technologies. Moreover, as shown in Model 6 and 7, this negative effect is robust when other technology sourcing modes are also included in the analysis. Thus, we find support for the third hypothesis. Firms investing in M&As do not focus on pioneering technologies, rather they pursue other advantages related to M&As, such as improving their market position, market power, or economies of scale and scope in production or distribution.

We argued that technological boundary-spanning positively influences the effect of external knowledge sourcing on the creation of pioneering technologies. The results in Table 8 indicate that technological distance has no direct effect on the generation of pioneering technologies, whereas technological newness has a positive, but weakly significant impact on pioneering technology creation (Models 8 and 12). On top of the direct effect, the variables also have a strengthening effect on the relationship between external technology sourcing modes and the emergence of pioneering technologies. Hypothesis 11 predicts that the effect of external technology sourcing on pioneering technologies is amplified with increasing technological distances between the focal firm and its partners. The results in Table 8 Models 9 to 11 show mixed results. Technological distance does not play a role in the relation between CVC investments and equity alliance on the creation of pioneering technologies. The interaction term *technological distance x non-equity alliances*, on the other hand, is positive and significant, indicating that the efficiency to create pioneering technologies with non-equity alliances increase with larger technological distances. This corroborates Hypothesis 11 only for non-equity alliances. When searching for distantly related knowledge, the flexibility provided by the flexible nature of non-equity alliances proves to be a vital aspect of the inter-organizational relationship.

Hypothesis 12 proposes that technological newness also enhances the effect of external technology sourcing on pioneering technologies. The results in Table 8 show again mixed evidence. In line with our expectation, Model 12 shows a negative, significant sign for the direct effect of technological age on the creation of pioneering technologies. Older technologies appear to have a negative impact on pioneering technologies. The results for the interaction terms, however, are interesting. While one interaction term (*technological age x equity alliances*) does not reach significance, the other two interaction terms (*technological age x CVC investments* and *technological age x non-equity alliances*) are positive and significant. Contrary to our expectations, technological age (and not technological newness as hypothesized) enhances the effects of CVC investments and non-equity alliances on the generation of pioneering technologies. Consequently, the fifth hypothesis is not confirmed. Possible explanations for this will be considered in the discussion section.

As for the control variables, it is interesting to note that firm size has a consistently, positive effect on the generation of pioneering technologies. Although some research believe otherwise, larger firm seem to be more successful in the creation of breakthrough technologies. R&D intensity, on the other hand, also has a positive effect on pioneering technologies, but in some models the coefficient is non-significant. In addition, it appears that European firms and pharmaceutical firms are positively associated with the generation of breakthrough technologies. Interestingly, pharmaceutical firms in this sample are more successful in creating breakthrough technologies than their chemical counterparts.

5.5 Discussion

In this study we have examined the effect of different inter-organizational relationships on the subsequent generation of pioneering technologies. Pioneering technologies take an important role in determining the firm's future competitive advantage, as they provide access to knowledge that is superior to that of its competitors. In addition to studying the direct effects of external technology sourcing on the creation of breakthrough technologies, we have studied how these relationships are affected by increasing technological distance and technological newness. The results indicate that loosely coupled linkages such as strategic alliances (non-equity as well as equity) and corporate venture capital investment have a positive effect on the creation of breakthrough innovations, thereby supporting Hypotheses 1 and 2. Furthermore, the results presented in this chapter indicate that M&As, representing a higher level of commitment and integration have a negative impact on the generation of pioneering technologies (as suggested by Hypothesis 3). In line with Rosenkopf and Nerkar (2001) these results indicate the importance for firms to be involved in search activities that span organizational boundaries. Moreover, these results stress the particular role of flexibility and reversibility when developing radical or pioneering technologies with highly uncertain technological and commercial value.

Interestingly, the results also suggest that non-equity and equity alliances are more important for the creation of pioneering technologies than CVC investments. Apparently, investing in revolutionary technologies is something that is best done through a long-term relationship that focuses on the joint development of new knowledge. Through a strategic alliance, two or more firms combine their efforts to create something new. Although CVC investments are stressed in the literature as a "window on new technological developments" (Dushnitksy and Lenox, 2006), they appear to be less important for the creation of pioneering technologies. Instead CVC investments can be seen as a way for companies to catch up with the latest technological developments, rather than to develop something new from scratch.

In addition, we studied how technological distance and technological newness affect the impact of different external technology sourcing modes on pioneering technologies. The fourth hypothesis, arguing that technological distance increases the effect of external technology sourcing on pioneering technologies is only partially confirmed. The interaction term representing the enhancing effect of technological distance between the focal firm and its partner is found to be positive and significant only for non-equity alliances. In line with our expectations, a larger technological distance between the two partnering firms increases the effect this organizational mode has on the creation of pioneering technologies. In other words, non-equity alliances are more effective in generating pioneering technologies from distantly related knowledge. Interestingly, this effect does not hold for CVC investments and equity alliances as these two interaction terms are statistically not significant. A possible explanation for the lack of impact of technological distance on the relationship between CVC and pioneering technologies might be the highly explorative nature of CVC investments. Especially in the pharmaceutical industry, CVC investments are often cross-industrial investment in young, start-up biotech firms. As a result, these investments already involve a large deal of uncertainty. Increasing this uncertainty by investing in more distantly related ventures might result in difficulties for the focal firm to recognize and assimilate the technology at stake. In other words, it could be the case that the absorptive capacity of the focal firm falls short when investing in start-up ventures on a high technological distance.

The fifth hypothesis proposes that technological newness of the partner firm also increases the effect of external technology sourcing on pioneering technologies. Although the expectation holds for the direct, linear effect of technological newness (the effect of technological age on the emergence of pioneering technologies is negative and significant), the opposite appears to be true for the interaction terms. Technological age enhances the positive effect of CVC investments and non-equity alliances on the creation of pioneering technologies. In other words, the effect of CVC investments and non-equity alliances on the generation of pioneering innovations increases when the partner firm works with relatively older technologies. A possible explanation for this effect could be found in the proven reliability of older knowledge (Katila, 2002). External sourcing of technologies in itself already poses a large amount of risk and uncertainty on the focal organization. Making this type of investments in more recent technologies even increases the amount of uncertainty involved and as a result the investing firm might be more comfortable by investing in external technologies that have been in existence for some time already.

To conclude, this study shows how different modes for organizational boundary spanning add to the creation of pioneering technologies and how this is affected by technological distance and technological age. Small investments with a high level of flexibility appear to be the most appropriate ways to invest in breakthrough technologies. As suggested by real options theory, highly uncertain investments are best tackled in a multiple step process: by making small, initial investments, firms can defer commitment until uncertainty about the opportunity has decreased to a manageable level (Adner and Levinthal, 2004; Folta, 1998). The generation of pioneering or breakthrough technologies is a highly uncertain process since the promise of a particular technology is not always clear in the beginning of the development process. Small, flexible arrangements such as strategic alliances and CVC investments enable the focal firm to withdraw from the commitment as soon as it turns out not to be promising. Moreover, since investing in technology in an early stage of development already poses a high level of uncertainty on the focal firm, an increase of this uncertainty by investing in distant or emerging technologies is proved not to be favorable. In other words, there seems to be a maximum of the amount of uncertainty a firm is willing to tackle. When investing in the development of radically new technologies, stacking of different types of uncertainty makes this process too difficult to manage.

5.6 Implications

Overall, this study contributes to the initial research question in a number of ways. By focusing specifically on the creation of pioneering technologies, we shed light on the specific use and characteristics of each of the different governance modes when exploring into breakthrough innovation. Moreover, we have included the roles of technological distance and technological newness, showing how crossing technological boundaries affects the relationship of external technology sourcing on the creation of pioneering technologies.

Of course this study is not without limitations, which in turn provide some interesting avenues for future research. First, exploration of technological frontiers entails more than just the creation of pioneering technologies. As suggested by Ahuja and Lampert (2001), novel (technologies that are already in existence but new to the firm) and emerging technologies also play an important role in this process. Clearly, novel and emerging technologies take a less radical approach to technological innovation, but they are nonetheless important aspects of explorative search. Moreover, our analysis does not take into account the role of exploitation, which is recognized as being an important aspect for the immediate survival of the ambidextrous firm (O'Reilly and Tushman, 2004; Tushman and O'Reilly, 1996). Exploitation of existing knowledge and technologies is not only needed to sustain competitive advantage, it also ensures the resources that are crucial to invest in the generation of pioneering technologies. Future research could thus benefit from including exploitation and other types of exploration, such as novel and emerging technologies, as well. In this study we have shown how different governance modes affect the generation of pioneering technologies differently and it might very well be the case that other governance modes play a dominant role in other types of innovation output. Including a larger range of innovation output measures will help both researchers and managers alike to get a better grip on the complex nature of external technology sourcing and innovation.

Another limitation of this study is that we limit our attention to the use of inter-organizational relationships. As argued by Lam (2007), universities partners provide companies with access to the latest scientific developments. Hence, universities, but also research labs may also play an important role in the creation of radical or breakthrough technological innovation. In addition, this study takes a rather static view of the innovation funnel. Future research in the field should benefit from including the dynamic nature of the innovation process. This allows us to gain more insight in the sequential aspects of investments and in the importance of building capabilities to use external sources of technology for new business creation (Keil, 2004). Heimeriks and Duysters (2007), for instance, showed that experience and capabilities are positively associated with alliance performance. The extent to which companies are able to build capabilities with different external technology sourcing modes might thus affect the amount of pioneering technologies a firm can create. In addition, if projects move from an explorative state to a more exploitative state of development, it is likely that the employment of inter-organizational relationships also changes (Van de Vrande et al., 2006). Further research in this area is needed to advance our understanding of this phenomenon.

Finally, the analysis indicates that prior engagement in pioneering technologies has a positive, significant effect on the creation of subsequent pioneering technologies. This raises the question as to what extent are firms able to build competences around the creation of breakthrough technologies? And if so, does that also lead other firms to leave the creation of pioneering technologies to their competitors and become good "fast followers"? Bogner and Bansal (2007) found that the extent to which firms build on their prior knowledge positively impacts their performance. Especially in today's open innovation paradigm (Chesbrough, 2003), where the creation of new technologies is scattered and benefiting from new technology has become more a question of finding the right business model (Chesbrough, 2006) than of being the owner of the technology, these questions are becoming more and more important.

Chapter 6

Discussion

6.1 Discussion

In today's dynamic competitive landscape, new business development can no longer be achieved by internal technology development only. As a result, external sourcing of new knowledge and technologies has become a more vital part of companies' corporate strategy. External technology sourcing among firms can take a number of forms, such as strategic alliances, joint ventures, mergers and acquisitions, or corporate venture capital investments. The effectiveness with which companies adapt to changes in the competitive environment is largely determined by the choice companies have among this broad range of governance modes. Nevertheless, the role of different governance modes in the new business development process has not yet been analyzed in a full-fledged manner. Therefore, in this study an attempt has been made to answer the following research question:

How do firms choose between the different modes for external technology sourcing and how do these modes affect the performance of innovating firms?

In order to tackle this research question, it was split into three sub questions, each of which has been dealt with in a separate chapter.

When looking at the role of different governance modes, the first question that comes to mind is: how do companies choose between different governance modes? In Chapter 3, it is argued that uncertainty is a determining factor in explaining governance mode choice. Uncertainty can be divided into two groups: environmental uncertainty and relationship-specific uncertainty. Environmental uncertainty includes environmental turbulence and technological newness, whereas relationship-specific uncertainty is concerned with technological distance between the focal firm and its partner and (the lack of) prior cooperation. The results in Chapter 3 suggest that environmental uncertainty is a much more powerful driver behind governance mode decisions than relationship-specific uncertainty (Table 4). A high level of environmental uncertainty leads firms to choose less integrated governance modes, such as non-equity alliances and CVC investments, over their more integrated counterparts. As suggested by real options reasoning (Kogut, 1991; Folta and Leiblein, 1994; Folta, 1998), uncertainty about the future drives firms to make small, reversible investments. Real options enable companies first to learn about business opportunities through small, learning investments and to put off stronger financial commitment until uncertainty about the opportunity has decreased (Adner and Levinthal, 2004). The flexibility generated by real options allows firms to cope with unforeseen contingencies (De Meyer et al, 2002).

It is also worth noting that the existence of a continuum from less to more integrated governance modes is not confirmed. Based on the literature, we propose a ranking from less to more integrated governance modes, ranging from non-equity alliances, corporate venture capital investments, minority holdings, joint ventures and M&As. However, the results from the ordinal and multinomial logit analyses show no support for an ordinal ranking of the different external sourcing modes as has been suggested in prior studies (Gulati and Singh, 1998; Hagedoorn and Sadowski, 1999; Nielsen, 2002; Santoro and McGill, 2005; Villalonga and McGahan, 2005; Williamson, 1985).

Although the focus of Chapter 3 is on the choice companies have between different modes for external sourcing, we acknowledge the fact that different governance modes may be used to target different types of technology in different stages of development. This suggests that instead of being substitutes, the different external sourcing modes are actually complements, used next to each other or even sequentially when sourcing technology throughout the new business development funnel. The results in Chapter 4 show that all governance modes under study are positively related to the subsequent innovative performance of the focal firms (Table 6). In addition, the results support our suggestion that different governance modes are complementary. According to the results in Chapter 4, the external governance modes appear to reinforce rather than substitute each other. This is in line with prior studies, arguing that strategic alliances should be used complementary to M&As (Garette and Dussauge, 2000; Veugelers and Cassiman, 1999). Moreover, we see a steady increase in the coefficient of the respective interaction terms with non-equity alliances, equity alliances, and M&As, indicating that the complementarity of external technology sourcing increases when the different sourcing modes become more distinct. In other words, governance modes that are alike in terms of flexibility and the targeted knowledge can also serve as substitutes. For instance, corporate venture capital investments and non-equity alliances are both loosely-coupled governance modes that involve a high level of flexibility. The preference for one the two modes when sourcing early stage technologies might then be contingent upon other factors, making non-equity alliances and corporate venture capital investments substitutes rather than complements. Equity alliances and M&As, on the other hand, are much more distinct from corporate venture capital investments, making substitutability less likely.

Another interesting finding from this study is found when we compare the results from Chapter 3 with those from Chapter 5. Although corporate venture capital investments are clearly the most favorable option when investing in new technologies, the result in Chapter 5 show that the largest impact on the creation of pioneering technologies does not come from investing in CVC investments (Table 8). Rather, pioneering technologies stem from collaboration through a non-equity or equity alliance. Moreover, even though CVC investments are most likely to be used for recent technologies or technologies that are on a larger technological distance, the interaction terms in Chapter 5 show that the effect of CVC investments on the generation of pioneering technologies is not enhanced by technological distance, nor by technological newness. This is in line with studies by Gompers (2002) and Keil et al. (2004) who have shown that the success rate of CVC investments is higher for intra-industry or related CVC investments. In fact, CVC investments as well as non-equity alliances benefit more from investing in older technologies (Table 8 cont.), indicating that recent knowledge is not necessarily related to the creation of radical technologies. It should be noted though that in the setting of this study, CVC investments by large, pharmaceutical firms are often cross-industry ties with small, biotech firms. Our dependent variable, pioneering technologies, is defined as patent applications with no citations to prior patents. It might thus be the case that new patent applications are indeed new for the pharmaceutical industry, but refer to biotech patents that have been around for some time already.

Although the results from this study point towards the benefits of external technology sourcing, we should not neglect the importance of internal R&D and the creation of an internal knowledge base. The importance of internal technology development has been stressed in organizational literature on absorptive capacity. The absorptive capacity of a firm is defined as "the ability of a firm to recognise the value of new, external information, assimilate it, and apply it to commercial ends" (Cohen and Levinthal, 1990). Cohen and Levinthal (1990) argue that a firm's absorptive capacity is critical to its innovative capabilities and that absorptive capacity is a function of the firm's level of prior knowledge. In other words, internal technology development enhances the firm's technological competence and increases its ability to recognize and adapt externally acquired technologies (Arora and Gambardella, 1994; Rosenberg, 1994; Veugelers, 1997; Veugelers and Cassiman, 1999). The results from this study confirm the importance of internal R&D and the current knowledge base. The results in Chapter 4 show that the technological capital of a firm is positively related to the innovative performance of firms, whereas the results in Chapter 5 confirm the importance of R&D intensity for the creation of pioneering technologies. Moreover, the results in Chapter 5 show that prior experience with pioneering technologies also positively affects the subsequent creation of pioneering technologies. This does not only stress the importance of having a strong internal knowledge base, but it also suggests that firms are path dependent.

To conclude, the results of the three empirical chapters of this thesis provide a number of interesting viewpoints on answering the initial research question. We have shed light on the choice companies have between different governance modes and how this choice is affected by different types of uncertainty surrounding the investment decision. In addition, we have shown how these governance modes affect the innovative performance of firms and how they interact with each other. Moreover, we have illustrated how the creation of pioneering technologies benefits from external technology sourcing under circumstances of technological distance and technological newness. However, the role of different external technology sourcing modes in the new business development process appears to a very complex process. Although different governance modes all serve the same purpose (i.e. getting access to externally developed technologies), they differ greatly in their characteristics. Moreover, getting access to external ideas and technologies is not limited to the use of inter-organizational agreements. Other sources of knowledge, such as universities, research labs, users and online communities are becoming more important. As a result, the employment of a particular source of knowledge or governance mode is subject a number of decision-factors, some of which objectively measurable, but some of which also may depend upon personal characteristics or preferences. Nevertheless, this study has a number of interesting findings and conclusions, some of which also affecting managers' decisions. These management implications will be discussed in the next section.

6.2 Managerial implications

Managers of large, multinational companies are typically confronted with growing maturity of their existing businesses and insufficient internal R&D capabilities. One way to cope with the increasing complexity of products and to ensure corporate renewal is by investing in external sourcing of new knowledge and technologies (Chesbrough, 2003, 2006; Kim and Mauborgne, 2004). This study focuses on the use of different inter-organizational relationships to rejuvenate the existing business, in an attempt to provide more insight in the question as to *how* to get access to external technologies. A number of criteria that can be used as a guideline when confronted with this decision have emerged from this study.

First of all managers need to take into account the level of environmental uncertainty. What is the level of technological turbulence in the industry, and, perhaps more important, how far is the external technology from the market? Turbulent environments call for loosely-coupled arrangements that allow the focal firm to withdraw from the commitment as soon as it seems not to be promising. A non-equity alliance or a CVC investment can provide a flexible environment to learn about the new technology while waiting for the uncertainty to decrease. After uncertainty has decreased, the focal firm can then decide to move to a relationship that entails a higher level of commitment.

Another aspect to consider is the relationship-specific uncertainty. Relationship-specific issues are associated with the organization of the relationships themselves. Tight or frequent cooperation with a partner, for instance, often leads to mutual trust and hence reduces the need for the focal firm to make large investments to protect itself against opportunistic behavior of its partner. Relationship-specific uncertainty can thus be reduced by the focal firm. This is particularly important since the way in these relationships are managed has an impact on its performance!

Third, managers need to think about the type of knowledge they are targeting. For instance, exploration into new technological domains might induce the need to source distantly related knowledge. According to the technological distance between the focal firm and its partner, loosely-coupled governance modes, such as corporate venture capital investments or non-equity alliances prevail over other because they allow for flexibility and enhance learning opportunities. Manager confronted with a sourcing decision on distantly related areas should be aware of the fact that the level of knowledge relatedness affects the choice of governance, which in turn has an impact on the innovative performance of firms.

Another issue that needs to be considered is the type of innovation the firm is aiming for. Sustaining competitive advantage comes from both investing in exploitation of the existing knowledge base as well as from the creation of new knowledge. Evidently, the use of external sources for the strengthening of the current technological capabilities is organized differently from the use of external knowledge sources to create new or pioneering technologies. Pioneering technologies are technologies that do not build on prior patents, and are hence of a largely explorative nature. The results in this study have shown that the generation of pioneering technologies is a path-dependent process that is most likely to benefit from loosely-coupled relationships. In fact, strategic alliances appear to play a crucial role in the creation of pioneering knowledge. Since the potential outcomes of this type of innovation process are very uncertain while the costs and risks associated with it are generally high, collaborating with a partner might be a viable alternative to internal development or acquisition of knowledge. Strategic alliances seem to be more important for pioneering technologies than CVC investments: strategic alliances are long-term relationships in which partners focus on the collaboration to develop new technologies. CVC investments, on the other hand, focus on investing in new technologies, though this new technology may already exist in the start-up firm.

To conclude, we might say that the external sourcing of knowledge is becoming more and more important in the development of new businesses. Companies therefore need to develop a set of methods or guidelines in order to efficiently in-source external technologies. The choice between different modes of governance plays an important role in this process. As shown in this study, external sourcing modes differ in their characteristics and the role they play in the innovation process. In addition, the results show that the mix of different governance modes is an important driver behind innovative performance. Each of the governance modes has advantages and disadvantages, depending on the motives that drive the external sourcing decision. Matching these motives with the appropriate governance choice is a major challenge for firms. Therefore, it is crucial for companies to have a clear view on their innovation strategy. Moreover, it is important for firms to focus on developing capabilities for the in-sourcing of external technologies, since this is a process that requires sufficient management attention!

6.3 Limitations and future research

Evidently, this study is not without limitations, which in turn provide interesting avenues for future research. One of the limitations of this study is perhaps the use of secondary data to compile the dataset. As mentioned already in Chapter 2, secondary data has the advantage of providing researchers with a large amount of information in a relatively short time. However, as this data is originally collected for different purposes, there is the possibility of noise in the data which might affect the outcomes of the analyses. Although we have used different techniques throughout this study to ensure robustness of the variables as well as of the results, we should be aware of this. Future research in order to gain more insight in the actual processes that underlie particular investment decisions might thus benefit from a richer set of data that could be obtained through the use of survey research or case studies. Especially case studies and interviews in large, diversified companies might help us to obtain a more detailed insight in the way in which companies choose between different governance modes and how they asses their contribution to innovation.

In addition, the dataset used in this study contains a large set of data on the focal firms, which are large pharmaceutical companies. We should be aware that the analyses concern a single industry study and that generalization across industries might not always be possible. Although we believe that the development of high-level technologies can be generalized in terms of uncertainty and risk, the choice companies have and the challenges they face when sourcing new technologies externally might differ between industries. For instance, the competitive landscape of the pharmaceutical industry is to a large extent affected by the rise of biotechnology. The growth of biotech companies has to a large extent changed the way pharmaceutical companies innovate and collaborate. On the other hand, other industries might also be subject to different IP mechanisms. For instance, in the software industry, the challenges faced by firms to secure their IP are much different due to a weaker IP regime. This might also affect external technology sourcing strategies. As a result, repeating this study in a different industry might very well lead to different findings. Moreover, since our dataset is focused on large, pharmaceutical firms, we have little data on the characteristics of the partner firms, which are often small, biotech companies. Data such as sales and R&D intensity are particularly difficult to obtain for small companies in the data sources used in this project, because they are often not publicly owned. This limitation reduces the possibility to measure the impact of partner characteristics on the choice of focal firms between external governance modes.

Additionally, from the results in chapter three and four, the need to investigate the role of prior cooperation when studying external technology sourcing becomes apparent. As argued by Van de Vrande et al. (2006), external technology sourcing is affected by real options reasoning. In other words, in the early stages of technology development, where uncertainty is high and the future potential of the technology is still unknown, firms might opt to make small, initial learning investments to reduced the technical or market uncertainty. Previous studies have already indicated the existence of a real options motivation behind external technology sourcing (Duysters and De Man, 2003; Garette and Dussauge, 2000; Kogut, 1991; Porrini, 2004). Thus, prior cooperation and the transitions from one mode to another mode while the technology further matures are important aspects in explaining firm performance. Further research could go in the direction of investigating the added value of prior cooperation when determining innovative performance, or investigating the possible transitions between the modes under different circumstances.

Another stream for future research can be sought in the current debate on the ambidextrous organization (Lee et al., 2003; O'Reilly and Tushman, 2004; Tushman and O'Reilly, 1996). Previous research has stressed the importance for firms to be balance their efforts between exploration and exploitation. Improvement of existing routines, practices, or technologies ensures the company's immediate survival. However, in the long run, better opportunities might be provided by new, yet to be explored technologies (March, 1991; Levinthal and March, 1993). However, most prior studies have focused on the internal organization of ambidexterity. As suggested in the current study, exploration of new technologies, as well as exploitation of existing technologies can be enhanced by different types of inter-organizational relationships. Chapter 5 has already indicated that corporate venture capital investments and strategic alliances increase the number of subsequent pioneering technologies that are developed by the focal firm. However, the creation of pioneering technologies is only one part of the puzzle. Exploration of new technological opportunities is not limited to the creation of breakthrough technologies. As suggested in the discussion section of Chapter five, access to knowledge that is already in existence but which is still new to the firm can also be a source of competitive advantage for the focal firm. Vanhaverbeke and Peeters (2005) have also stressed the importance of external technology sourcing for new business development, and its interplay with the building of new competences. Future research could thus benefit from a more thorough discussion of the concepts of exploration and exploitation and how they are affected by external technology sourcing. Moreover, in combination with the role of prior cooperation, it would be interesting to see if the transition from one mode to another is also related to a shift from explorative to exploitative technology sourcing.

Furthermore, as noted by Chesbrough (2003), open innovation includes the simultaneous pursuit of two different processes: outside-in and inside-out. In this thesis, we have limited our attention to bringing externally developed knowledge into the firm. However, equally important is to put internally developed innovations outside the firm. Bringing internally developed technologies outside the firm can help nascent technologies to further mature without the limitations of being embedded in a large organization (for instance through an incubator). Moreover, internally developed technology that does not match the firms strategy or is just not used, can deliver extra value for the focal firm as well as for the customers if it developed by another party, for instance through a license. Making maximum use of your own and other's IP is a crucial element to be successful in the world of open innovation. As a result, future research should take into account the inside-out processes of firms, next to the outside-in movements. A full picture of how companies innovate in today's competitive landscape can only be obtained if we consider the different options of firms in parallel. Future research could for instance focus on the determinants of inside-out processes, the governance modes preferred by companies to do so and how this affects the technological and financial performance of firms.

Finally, although a number of prior studies have focused on many aspects of strategic alliance formation (e.g. Gulati, 1998; Gulati and Singh, 1998; Hagedoorn, 1993; Rothaermel and Deeds, 2004; Santoro and McGill, 2005), there is still a lot of white space in the context of corporate venture capital investments and their role within corporate strategy. As mentioned earlier, one way in which firms can use corporate venture capital is to stimulate the development of internally developed technologies. In this study, we have not considered this use of CVC investments because getting access to this type of data is very difficult. Nevertheless, when we consider the inside-out movements in parallel with the outside-in movements, it would be interesting to focus the research on exactly the innovation projects that are backed by corporate venture capital and are put outside the parent organization in order to stimulate its development. Internal ventures that are developed independently are seldom abandoned, and a strategic alliances or a full acquisition to reintegrate the venture in the business unit is likely to occur in the future.

To conclude, the question of how companies use different modes for external technology sourcing is far from answered yet. However, this thesis has contributed to the next step in solving the external technology sourcing-puzzle. The main contribution of the study is the inclusion of corporate venture capital investments as a distinct strategy for external technology sourcing, thereby expanding the range of governance modes under study. The avenues for future research, as presented earlier, are only the next steps that can be undertaken to get a complete understanding of the external technology sourcing phenomenon. And, as we have learned by now, the answers will raise more questions in turn.

Appendix I

List of focal firms

NAME	*Total*	*Strategic Alliances*	*CVC*	*Minority holdings*	*Joint ventures*	*M&As*
3M	46	20	2	3	9	12
ABBOTT LABORATORIES	38	19	5	9	0	5
AJINOMOTO COMPANY INCORPORATED	5	1	0	2	0	2
AKZO NV	69	33	0	1	10	25
ALLERGAN, INC.	11	4	0	2	2	3
ALLIED-SIGNAL INC.	121	59	5	6	18	33
ALZA CORPORATION	8	3	0	2	0	3
AMERICAN CYANAMID COMPANY	25	11	4	0	4	6
AMERICAN HOME PRODUCTS CORPORATION	53	31	0	8	0	14
AMGEN, INC.	11	7	0	3	0	1
AMOCO CORPORATION	53	34	1	3	7	8
ASAHI KASEI KOGYO KABUSHIKI KAISHA	14	6	3	0	5	0
ASTRA AB	14	13	0	0	0	1
BASF AG	84	48	0	5	13	18
BAXTER INTERNATIONAL INC.	45	10	11	5	0	19
BAYER AG	54	35	0	3	1	15
BECTON, DICKINSON AND COMPANY	31	7	9	4	2	9
BEECHAM GROUP P.L.C.	2	0	0	0	0	2
BETZ LABORATORIES INC.	1	0	0	0	0	1
BOEHRINGER INGELHEIM, GMBH	18	9	0	8	0	1
BOEHRINGER MANNHEIM G.M.B.H.	13	9	1	0	1	2
BRISTOL-MYERS SQUIBB COMPANY	49	32	3	5	2	7
BRITISH TECHNOLOGY GROUP LIMITED	1	0	0	1	0	0
CETUS CORPORATION	8	3	3	1	1	0
CHEVRON CORP	31	14	0	5	4	8
CHINOIN GYOGYSZER	0	0	0	0	0	0
CHIRON CORPORATION	28	18	0	5	0	5
CHUGAI SEIYAKU KABUSHIKI KAISHA	5	4	0	1	0	0
CIBA-GEIGY AG	55	30	1	7	3	14
COLGATE-PALMOLIVE COMPANY	12	0	0	0	1	11
COOPER DEVELOPMENT	5	4	1	0	0	0
CORNING INCORPORATED	61	23	11	1	5	21
CPC INTERNATIONAL INC.	3	0	0	0	0	3
DAIICHI SEIYAKU COMPANY, LTD.	6	5	0	0	1	0
DAINIPPON PHARMACEUTICAL CO. LTD.	3	2	0	1	0	0
DEGUSSA AKTIENGESELLSCHAFT	9	6	0	0	3	0
DELALANDE S.A.	0	0	0	0	0	0

NAME	*Total*	*Strategic Alliances*	*CVC*	*Minority holdings*	*Joint ventures*	*M&As*
DOW CHEMICAL COMPANY	110	60	10	11	15	14
E. I. DU PONT DE NEMOURS AND COMPANY	138	72	8	9	19	30
EASTMAN KODAK COMPANY	91	52	7	8	7	17
EISAI CO., LTD.	4	3	0	0	1	0
ELI LILLY AND COMPANY	72	47	3	13	1	8
ETHYL CORPORATION	4	2	0	1	0	1
EXXON CORP	17	0	1	7	0	9
FISONS LIMITED	3	1	0	0	0	2
FMC CORPORATION	13	2	1	0	1	9
FUJI PHOTO FILM CO., LTD	18	2	0	1	4	11
FUJISAWA PHARMACEUTICAL CO., LTD.	7	3	0	1	0	3
GAF CORPORATION	9	0	0	2	0	7
GENENCOR INTERNATIONAL, INC.	4	3	0	1	0	0
GENENTECH, INC.	18	7	3	8	0	0
GENETICS INSTITUTE, INC.	9	7	0	1	0	1
GEN-PROBE INCORPORATED	0	0	0	0	0	0
GIST-BROCADES N.V.	14	6	0	2	2	4
GLAXO GROUP LIMITED	19	11	0	4	2	2
GLAXO WELLCOME INC.	20	13	0	5	0	2
GREEN CROSS CORP.	8	4	0	1	3	0
HAYASHIBARA BIOCHEMICAL LABORATORIES	0	0	0	0	0	0
HENKEL KGAA	25	1	0	4	4	16
HERCULES INCORPORATED	23	14	0	0	4	5
HOECHST AKTIENGESELLSCHAFT	112	59	3	7	14	29
HOFFMANN-LA ROCHE INC.	65	40	7	10	2	6
HUMAN GENOME SCIENCES, INC.	1	1	0	0	0	0
IMMUNEX CORPORATION	0	0	0	0	0	0
IMPERIAL CHEMICAL INDUSTRIES PLC	71	34	0	1	11	25
INSTITUT PASTEUR	2	2	0	0	0	0
INTERNATIONAL FLAVORS + FRAGRANCES INC	1	0	0	0	0	1
INTERNATIONAL MINERALS AND CHEMICAL CORP	22	4	0	7	2	9
ISIS PHARMACEUTICALS, INC.	2	1	0	0	1	0
JOHNSON + JOHNSON	120	20	67	8	1	24
KANEGAFUCHI CHEMICAL INDUSTRY CO., LTD.	0	0	0	0	0	0
KAO KABUSHIKI KAISHA (KAO CORPORATION)	5	0	0	0	0	5
KARL THOMAE GMBH	0	0	0	0	0	0
KOWA COMPANY LTD.	0	0	0	0	0	0
KUREHA CHEMICAL INDUSTRY CO., LTD.	0	0	0	0	0	0
KYOWA HAKKO KOGYO CO., LTD	18	6	0	2	10	0
LION CORPORATION	1	0	0	0	0	1
L'OREAL S.A.	8	1	1	2	0	4
LUBRIZOL CORP	20	3	7	3	2	5
MEIJI SEIKA KAISHA LTD.	3	3	0	0	0	0
MERCK + CO., INC.	30	23	1	1	2	3
MERCK KGAA	14	4	0	1	1	8
MITSUBISHI CHEMICAL INDUSTRIES LTD.	9	1	0	0	1	7
MITSUI TOATSU CHEMICALS INC.	0	0	0	0	0	0

NAME	*Total*	*Strategic Alliances*	*CVC*	*Minority holdings*	*Joint ventures*	*M&As*
MOBIL CORP.	21	7	0	3	5	6
MONSANTO COMPANY, INC.	75	38	7	6	9	15
MONTEDISON S.P.A.	35	20	0	1	7	7
NESTLE	18	2	0	1	2	13
NEXSTAR PHARMACEUTICALS, INC.	0	0	0	0	0	0
NIPPON KAYAKU KABUSHIKI KAISHA	8	3	0	0	3	2
NIPPON SHINYAKU CO., LTD.	0	0	0	0	0	0
NISSHIN SEIFUN GROUP INC.	0	0	0	0	0	0
NOVARTIS AG (FORMERLY SANDOZ LTD.)	28	12	6	2	1	7
NOVO NORDISK A/S	22	14	1	3	2	2
OLIN CORPORATION	10	3	0	0	1	6
ONO PHARMACEUTICAL COMPANY, LIMITED	5	5	0	0	0	0
OTSUKA PHARMACEUTICAL CO., LTD.	4	0	4	0	0	0
PENNWALT CORPORATION	1	0	0	0	0	1
PFIZER INC.	68	40	6	7	1	14
PHARMACIA & UPJOHN COMPANY	11	8	0	0	0	3
PHARMACIA AKTIEBOLAG	13	5	0	3	2	3
PHILLIPS PETROLEUM COMPANY	24	14	0	1	3	6
PIONEER HI-BRED INTERNATIONAL, INC.	7	4	0	1	0	2
PROCTER + GAMBLE COMPANY	22	6	4	3	0	9
REVLON, INC.	4	1	0	2	0	1
RHONE POULENC INDUSTRIES	90	35	1	14	17	23
RHONE-POULENC RORER, S.A.	0	0	0	0	0	0
RICHTER GEDEON VEGYESZETI GYAR RT	0	0	0	0	0	0
ROHM AND HAAS COMPANY	26	11	0	2	7	6
RORER PHARMACEUTICAL CORPORATION	2	1	0	1	0	0
ROYA; DUTCH PETROLEUM CO	84	34	0	6	12	32
SANDOZ LTD.	25	10	0	2	1	12
SANKYO COMPANY LIMITED	11	7	0	2	0	2
ELF AQUITAINE	49	15	18	3	6	7
SCHERING AKTIENGESELLSCHAFT	26	14	0	3	0	9
SCHERING CORP.	33	25	3	2	0	3
SERVIER	4	2	0	1	0	1
SHIONOGI + CO. LTD.	2	2	0	0	0	0
SHISEIDO CO., LTD.	3	1	0	0	0	2
SIGMA-TAU S.P.A.	1	1	0	0	0	0
SMITHKLINE BECKMAN CORPORATION	1	0	0	1	0	0
SMITHKLINE BEECHAM CORPORATION	90	38	35	10	5	2
SOLVAY	28	10	0	6	4	8
NABISCO	6	0	0	1	0	5
SUMITOMO CHEMICAL COMPANY, LIMITED	8	0	0	3	0	5
SUNTORY LTD.	7	1	0	2	3	1
SYNTEX CORPORATION	8	5	0	2	1	0
TAKEDA CHEMICAL INDUSTRIES LTD.	13	6	0	2	4	1
TANABE SEIYAKU CO. LTD.	3	2	0	0	0	1
TEIJIN LIMITED	7	3	0	1	0	3
TEXACO INC.	31	17	0	4	5	5

NAME	***Total***	***Strategic Alliances***	***CVC***	***Minority holdings***	***Joint ventures***	***M&As***
TOYO JOZO COMPANY, LTD.	0	0	0	0	0	0
UNILEVER	45	6	0	4	4	31
UNION CARBIDE CORPORATION	38	27	0	1	4	6
UNIROYAL, INC.	4	3	0	0	1	0
UPJOHN COMPANY	9	5	0	0	0	4
W. R. GRACE & CO.-CONN.	37	11	2	3	3	18
WARNER-LAMBERT COMPANY	20	11	0	4	0	5
WELLCOME PLC	9	9	0	0	0	0
WESTVACO CORPORATION	6	0	0	0	2	4
YAMANOUCHI PHARMACEUTICAL CO., LTD.	5	5	0	0	0	0
YEDA RESEARCH AND DEVELOPMENT CO., LTD.	1	1	0	0	0	0
YOSHITOMI PHARMACEUTICAL INDUSTRIES LTD.	1	0	0	0	1	0
ZAIDAN HOJIN BISEIBUTSU KAGAKU KENYKU KAI	0	0	0	0	0	0
ZENECA LIMITED	11	6	0	1	0	4
TATE & LYLE PUBLIC LIMITED COMPANY	8	0	0	1	1	6
ASTRAZENECA	0	0	0	0	0	0
EXXON-MOBIL	0	0	0	0	0	0
AVENTIS	3	3	0	0	0	0
Total	*3253*	*1521*	*266*	*327*	*319*	*820*
Min	*0*	*0*	*0*	*0*	*0*	*0*
Max	*138*	*72*	*67*	*14*	*19*	*33*
Median	*9*	*4*	*0*	*1*	*0*	*2*
Mean	*21.8*	*10.2*	*1.8*	*2.2*	*2.1*	*5.5*
S.D.	*28.8*	*14.7*	*6.6*	*3*	*3.8*	*7.5*

Appendix II

Distribution of firms among combinations of organizational modes

Combination of governance modes	*# of firms*	*Average yearly sales (USD)*	*Average yearly R&D intensity*	*Average number of patent applications*
No activity	19	115,001	18.5	203
Only non-equity alliances	10	151,656	10.6	241
Only CVC investments	1	unknown	unknown	360
Only equity alliances	3	50,339	10.8	315
Only M&As	7	147,081	3.7	413
Non-equity alliances and CVCs	1	unknown	unknown	69
Non-equity and equity alliances	12	116,794	29.3	384
Non-equity alliances and M&As	6	149,653	11.7	340
CVC investments and equity alliances	0	n.a.	n.a.	
CVC investments and M&As	0	n.a.	n.a.	
Equity alliances and M&As	6	185,712	1.9	865
Non-equity alliances , CVCs and equity alliances	3	574,097	24.9	369
Non-equity alliances, CVCs and M&As	0	n.a.	n.a.	
Non-equity alliances, equity alliances, and M&As	48	137,107	8.1	1647
CVC investments, equity alliances, and M&As	1	unknown	unknown	3413
Non-equity alliances , CVCs, equity alliances, and M&As	32	13,010	7.6	3129

Appendix III

Definition of variables

Variable	*Description*	*Ch.3*	*Ch.4*	*Ch.5*
Type of investment	Categorical variable indicating the type of inter-organizational relationship under study. Set to 1 for non-equity technology alliances, 2 for CVC investments, 3 for minority holdings, 4 for joint ventures, and 5 for mergers and acquisitions.	✓		
Innovative performance	Count variable indicating the number of successful patent applications, weighed by the number of citations they receive		✓	
Pioneering technologies	Count variable indicating the number of successful patent applications representing pioneering technologies (i.e. no citations to prior art).			✓
CVC investments (experience)	Number of CVC investments by firm i prior to the investment under study (t-1 to t-5)	✓	✓	✓
Strategic alliances (experience)	Number of strategic alliances (equity and non-equity) by firm i prior to the investment under study (t-1 to t-5)	✓		✓
Non-equity alliances (experience)	Number of non-equity technology alliances by firm i prior to the investment under study (t-1 to t-5)	✓	✓	✓
Equity alliances (experience)	Number of equity alliances (joint ventures and minority holdings) by firm i prior to the investment under study (t-1 to t-5)	✓	✓	✓
Minority holdings (experience)	Number of minority holdings by firm i prior to the investment under study (t-1 to t-5)	✓		
Joint ventures (experience)	Number of joint ventures by firm i prior to the investment under study (t-1 to t-5)	✓		
M&As (experience)	Number of mergers and acquisitions by firm i prior to the investment under study (t-1 to t-5)	✓	✓	✓
Environmental turbulence	Changes in patent applications in the industry prior to the investment under study (t-1)	✓		
Technological newness	Weighted average technological age of classes in which the patent applications of the dyad partner took place (t-1 to t-5)	✓		✓
Technological distance	Technological distance between the focal firm and its dyad partner, based on their respective patent portfolios prior to the investment (t-1 to t-5)	✓		✓
Prior cooperation	Number of prior cooperation efforts with the partner firm prior to the investment under study (t-1 to t-5)	✓		

Lagged pioneering technologies	Lagged dependent variable, calculated using a a depreciation rate of 15%, and a 5 year depreciation schedule			✓
R&D intensity	Research and development expenses divided by sales for firm i in year t-1	✓	✓	✓
Size	Natural logarithm of sales by firm i in year t-1	✓	✓	✓
Year	Dummy variables indicating a particular year (1991-2000, default is 1990)	✓	✓	✓
Dummy pharma	Dummy variable set to one if the firm is a pharmaceutical company (default is non-pharma firms)	✓		✓
Dummy Europe	Dummy variable set to one if the firm is headquartered in Europe (default is US)	✓		✓
Dummy Japan	Dummy variable set to one if the firm is headquartered in Japan (default is US)	✓		✓

Appendix IV

Ordinal logit estimates

	Model 1	*Model 2*
	Type	Type
Intercept 1	-2.193	-1.163
	(0.538)	(0.570)
Intercept 2	-1.873	-0.834
	(0.537)	(0.570)
Intercept 3	-1.350	-0.291
	(0.535)	(0.568)
Intercept 4	-1.010	0.061
	(0.535)	(0.569)
Alliance experience	-0.045***	-0.046***
	(0.009)	(0.010)
CVC experience	0.005	0.012
	(0.008)	(0.008)
Minority holding experience	-0.037	-0.021
	(0.027)	(0.027)
Joint venture experience	0.015	0.008
	(0.033)	(0.033)
M&A experience	0.058***	0.051***
	(0.016)	(0.017)
R&D to sales	-1.604	-0.992
	(1.312)	(1.043)
Size	-0.046	-0.057
	(0.056)	(0.056)
Dummy Europe	0.361***	0.304***
	(0.105)	(0.107)
Dummy Japan	0.405	0.442
	(0.299)	(0.304)
Dummy pharma	-0.658***	-0.530***
	(0.140)	(0.133)
Environmental turbulence		-0.268***
		(0.050)
Technological newness		-0.114***
		(0.015)
Technological distance		0.103
		(0.183)
Prior cooperation		0.058
		(0.072)

a. Year dummy variables were included in the analyses, but not in the table
b. Observations: 1810; Robust standard errors in parentheses
c. * significant at 10%; ** significant at 5%; *** significant at 1%

Appendix V

Brant Test of Parallel Regression Assumption

Variable	*chi2*	*p>chi2*	*df*
All	307.05	0.000	69
alliance experience	15.81	0.001	3
CVC experience	12.41	0.006	3
minority holding experience	4.10	0.251	3
joint venture experience	4.26	0.235	3
M&A experience	2.20	0.531	3
R&S to sales	-2.92	-999.000	3
Size	16.98	0.001	3
Dummy Europe	2.42	0.490	3
Dummy Japan	9.72	0.021	3
Dummy pharma	9.76	0.021	3
Environmental turbulence	9.91	0.019	3
Technological newness	25.01	0.000	3
Technological distance	23.92	0.000	3
Prior cooperation	8.89	0.031	3

a. Year dummy variables were included in the analysis but are not included in the table

A significant test statistic provides evidence that the parallel regression assumption has been violated.

Appendix VI

Hausman tests of IIA assumption

Ho: Odds(Outcome-J vs Outcome-K) are independent of other alternatives.

Omitted	*chi2*	*df*	*P>chi2*	**evidence**
1	-20.737	70	1.000	for Ho
2	-1.916	71	1.000	for Ho
3	5.470	71	1.000	for Ho
4	3.817	71	1.000	for Ho
5	18.099	70	1.000	for Ho

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Samenvatting

Toegang tot externe ideeën en technologieën om de ontwikkeling van nieuwe business te bevorderen neemt een steeds grotere rol in binnen het innovatieproces van bedrijven. Externe technologie acquisitie wordt daarmee een vereiste om concurrentievoordeel te creëren en te behouden, maar ook om te kunnen inspelen op veranderende condities in de markt en nieuwe technologische mogelijkheden.

Bedrijven die externe kennis willen aanboren hebben hiervoor verschillende mogelijkheden. Van oudsher worden vooral strategische allianties, joint ventures, licenties en fusies en overnames benadrukt als verschillende manieren om toegang te krijgen tot externe kennis. Meer recentelijk is er bij bedrijven ook aandacht ontstaan voor andere strategieën zoals corporate venture capital investeringen en samenwerking met onderzoekslaboratoria, universiteiten, en starters. De keuze die bedrijven hebben tussen deze verschillende strategieën stelt hen in staat om op een flexibele manier om te gaan met nieuwe technologische ontwikkelingen en veranderende markt condities.

In dit proefschrift richt ik me op het gebruik van verschillende strategieën om externe kennis te verwerven, zoals technologie allianties, corporate venture capital investeringen, minderheidsbelangen, joint ventures en fusies en overnames. De onderzoeksvraag die ten grondslag ligt aan dit proefschrift kan omschreven worden als: Hoe gebruiken bedrijven de verschillende externe technologie acquisitievormen? Deze onderzoeksvraag kan onderverdeeld worden in 3 subvragen, die elk in een apart hoofdstuk van de thesis uitgewerkt zijn.

Het eerste deel van het proefschrift gaat in op het effect van onzekerheid op de keuze die bedrijven hebben tussen de afzonderlijke strategieën voor het werven van externe technologie. Onzekerheid kan worden onderverdeeld in twee groepen, namelijk exogene onzekerheid, die niet beïnvloed kan worden door de investerende partij, en endogene onzekerheid, die geborgen is in de relatie tussen de samenwerkende partijen en door deze partijen beïnvloed kan worden. Exogene onzekerheid omvat enerzijds onzekerheid in de omgeving en anderzijds de nieuwheid van de technologie waarin geïnvesteerd wordt. Waneer de omgeving waarin de transactie plaatsvindt gekenmerkt wordt door een hoge mate van turbulentie hechten bedrijven meer waarde aan flexibiliteit en omkeerbaarheid van hun investeringsbeslissingen. Dit is ook het geval waneer bedrijven investeren in nieuwe technologieën: de onzekerheid met betrekking tot de toekomstige waarde van de nieuwe technologie is immers zeer groot. In dergelijke gevallen zullen bedrijven bij voorkeur kleine, flexibele (leer)investeringen maken die een hoge mate van flexibiliteit waarborgen in combinatie met een lage financiële participatie.

Onzekerheid kan ook bestaan in de betreffende relatie. Wanneer er bijvoorbeeld sprake is van ene grote technologische afstand tussen twee partijen kan het lastig zijn voor de investerende partij om de technologische capaciteiten van de partners te herkennen en te absorberen. Aan de ene kant leidt dit tot het gebruik van meer geïntegreerde governance mechanismen om zodoende de transfer van kennis te bevorderen. Aan de andere kant kan een grote technologisch afstand tussen partners ook leiden tot het gebruik van minder geïntegreerde en dus meer flexibele investeringen om op die manier eerst van de partner te leren alvorens het besluit te nemen om een langdurige relatie aan te gaan met een groteren financiële inbreng. Een andere indicator voor relationele onzekerheid is (het gebrek aan) eerdere samenwerking. Eerdere samenwerking tussen twee partijen kan bijvoorbeeld een middel zijn om onzekerheid tussen de partners te verlagen. Wanneer de onzekerheid gedaald is kan er gekozen worden om een meer geïntegreerde vorm van samenwerking op te zetten. De verwachting is hier dus dat het bestaan van een eerdere samenwerking leidt tot de keuze voor een meer geïntegreerde vorm. Aan de andere kant zou ook gesteld kunnen worden dat herhaalde samenwerking tussen partners tot vertrouwen leidt, waardoor er een minder gestructureerde vorm van samenwerking nodig is en minder geïntegreerde samenwerkingsverbanden verkozen worden.

De resultaten laten zien dat afhankelijk van het type van onzekerheid waarmee ze te maken hebben, bedrijven een sterke voorkeur voor bepaalde strategieëen hebben. In turbulente omgevingen worden bijvoorbeeld vooral strategische allianties gebruikt. Bij jongen of embryonale technologieën wordt aanzienlijk minder gebruik gemaakt van fusies en overnames en joint ventures, terwijl corporate venture capital investeringen juist een toename kennen in deze omstandigheid. De technologische afstand tussen bedrijven leidt ook tot een voorkeur voor corporate venture capital investeringen ten opzichte van strategische allianties. De sterke voorkeur voor het gebruik van corporate venture capital investeringen om toegang te krijgen tot technologieën die ver van het investerende bedrijf afstaan, laat zien dat dit type van investeringen een speciale rol spelen in het proces van externe technologie acquisitie. Tenslotte wijzen de resultaten erop dat eerdere samenwerking tussen partners wel leidt tot een voorkeur van minderheidsbelangen en joint ventures ten opzicht van strategische allianties, maar we vinden geen differentieel effect tussen strategische allianties en fusies en overnames. De resultaten suggereren dat exogene onzekerheid een veel grotere invloed heeft op de keuze tussen verschillende governance modes dan relationele onzekerheid. Onzekerheid in de omgeving waarin transacties plaatsvinden, leidt tot het gebruik van meer flexibele sourcing strategieën zoals strategische allianties en corporate venture capital investeringen. Wanneer de omgeving gekenmerkt wordt door een hoge mate van onzekerheid zijn bedrijven meer geneigd tot het maken van kleine leerinvesteringen om zodoende meer te leren over de mogelijkheden in de markt. Op deze manier wordt een grotere investering uitgesteld tot de onzekerheid over de grootte van de opportuniteit gedaald is.

In de literatuur wordt er ook van uitgegaan dat er een ranking van minder tot meer geïntegreerde vormen van samenwerking mogelijk is. Dat wordt niet bevestigd wordt door de data. Op basis van de literatuur wordt een rangorde voorgesteld lopend van strategische allianties, corporate venture capital investeringen, minderheidsbelangen en joint ventures tot fusies en overnames. Echter, dit continuüm wordt niet bevestigd door de resultaten van de analyses. Deze bevinding houdt in dat iedere vorm van externe technologieverwerving een aparte rol vervult en onder bepaalde omstandigheden verkozen zal worden boven de andere vormen.

In het tweede deel van dit proefschrift wordt de toegevoegde waarde van corporate venture capital investeringen en de relatie tot de technologische innovativiteit onder de loep genomen. Corporate venture capital investeringen zijn minderheidsbelangen in jonge start-ups. Recentelijk is er zowel bij bedrijven als bij onderzoekers meer aandacht gekomen voor dit type van investeringen. Ik veronderstel dat corporate venture capital investeringen een positief effect hebben op de innovativiteit van de investerende bedrijven, zelfs als rekening gehouden wordt met de andere strategieën die zij gebruiken om toegang te krijgen tot externe kennis. Daarnaast veronderstel ik dat corporate venture capital complementair is aan andere strategieën voor externe technologie acquisitie, omdat zij toegang kunnen verschaffen tot nieuwe technologie in een vroeg stadium van ontwikkeling, terwijl andere strategieën meer toepasbaar zijn op het binnenhalen van kennis in latere fasen van het technologie ontwikkeltraject. Het gebruik van corporate venture capital investeringen in combinatie met de meer traditionele vormen van technologie acquisitie zal daardoor een positief effect hebben op de innovativiteit van bedrijven.

De empirische resultaten bevestigen dat corporate venture capital investeringen een positief effect hebben op de innovativiteit van bedrijven, zelfs wanneer de andere strategieën voor externe kennis acquisitie in acht worden genomen. Daarnaast bevestigen de resultaten de veronderstelling dat corporate venture capital investeringen complementair zijn aan andere governance modes. De grootte van de coëfficiënten van de interactietermen suggereren daarnaast dat de complementariteit toeneemt wanneer governance modes meer verschillen van elkaar. Met andere woorden: strategieën die gelijkwaardig zijn qua flexibiliteit en gericht zijn op het binnenhalen van dezelfde type van kennis kunnen ook substituten van elkaar zijn. Bijvoorbeeld corporate venture capital investeringen en strategische allianties zijn beiden redelijk flexibele mechanismen om nieuwe kennis aan te boren. Hierdoor is de voorkeur voor de één of de andere strategie afhankelijk van een heel aantal factoren. Joint ventures en fusies en overnames, aan de andere kant, verschillen in grote mate van corporate venture capital investeringen in termen van flexibiliteit en reversibiliteit, waardoor de kans op substitueerbaarheid zo goed als niet bestaat.

Het laatste deel van dit proefschrift heeft betrekking op de exploratieve natuur van externe technologie acquisitie. In het betreffende hoofdstuk ga ik in op het effect van corporate venture capital investeringen, strategische allianties, joint ventures en fusies en overnames op de creatie van zgn. 'pioneering technologies'. Dit zijn nieuwe technologieën met een hoge mate van exploratie, waarbij geen referenties naar eerdere patenten zijn opgenomen. Wanneer we kijken naar exploratie dient zowel buiten de grenzen van het eigen bedrijf als buiten de grenzen van de eigen technologie gekeken te worden. Buiten de grenzen van het eigen bedrijf kijken doet men bijvoorbeeld door middel van de verschillende vormen van externe technologie acquisitie, zoals hierboven beschreven. De grenzen van de huidige technologie overschrijden kan men doen door te investeren in samenwerking met bedrijven die op een grote technologische afstand staan of die werken rond zeer jonge technologieën. Omdat verschillende governance modes gericht zijn op bepaalde typen van technologie in verschillende fasen van ontwikkeling, verwacht ik dat ze ook een verschillende impact hebben op de mate van exploratie die daarvan het gevolg is. Strategische allianties en corporate venture capital investeringen zijn bijvoorbeeld los geïntegreerde governance modes die een bedrijf in staat stellen om op een flexibele manier te investeren in externe technologie. Fusies en overnames, aan de andere kant, zijn veel meer geïntegreerd en veel minder flexibel. Daarnaast bekijk ik de relatie tussen het effect van de verschillende governance modes op exploratie enerzijds en de invloed van technologische nieuwheid en technologische afstand tussen de partners anderzijds. Zowel technologische nieuwheid als wel technologische afstand tussen de partners zijn van invloed op de mate waarin de te acquireren kennis past bij de absorptive capacity van bedrijven. Dit beïnvloedt de effectiviteit waarmee nieuwe technologie in huis gehaald wordt.

De resultaten tonen aan dat zowel strategische allianties en joint ventures als corporate venture capital investeringen een positief effect hebben op de creatie van 'pioneering technologies'. Daarnaast vind ik dat een grotere technologische afstand tussen partners deze relatie op een positieve manier beïnvloedt. Voor technologische nieuwheid geldt het tegenovergestelde: de positieve relatie tussen strategische allianties en corporate venture capital investeringen wordt zwakker naarmate de te absorberen kennis nieuwer is. Dit is vooral interessant omdat corporate venture capital investeringen met name gericht zijn op het investeren in nieuwe technologie, terwijl de resultaten laten zien dat de grootste impact op exploratieve technologie juist komt van strategische allianties en joint ventures en niet van corporate venture capital investeringen. Sterker nog, ondanks de eerdere bevinding dat corporate venture capital investeringen vaak gebruikt worden om een grote technologische afstand te overbruggen of om te investeren in nieuwe technologieën, laten de resultaten van deze studie zien dat het effect op exploratie eerder zwakker wordt naarmate dit type van investeringen gecombineerd worden met grote afstand of hoge mate van nieuwheid. In feite profiteert geen van de governance modes van technologische nieuwheid waaruit kan worden opgemaakt dat nieuwheid niet per definitie gerelateerd is aan de creatie van radicale technologie.

Concluderend kunnen we stellen dat het aanboren van externe technologische kennis steeds belangrijker wordt voor bedrijven. Dit houdt in dat bedrijven methoden en technieken zullen moeten ontwikkelen om dit op een effectieve en efficiënte manier te organiseren. De keuze die bedrijven hebben tussen verschillende governance modes speelt hierin een belangrijke rol. Zoals deze studie laat zien spelen verschillende governance modes elk een unieke rol in het innovatieproces. Daarnaast tonen de resultaten aan dat elke governance mode een verschillende impact heeft op de innovatitiveit van bedrijven. Elke vorm van externe technologie acquisitie heeft voor- en nadelen, afhankelijk van de achterliggende redenen voor technologie acquisitie. Het in overeenstemming brengen van deze verschillende motieven met de best passende strategie is een enorme uitdaging voor bedrijven. Het is daarom cruciaal om een duidelijk beeld van de innovatie strategie te hebben om zodoende de kansen op succes te vergroten.

Summary

Not Invented here: Managing Corporate Innovation in a New Era

External technology sourcing as a means to develop new businesses is taking a more central role in established companies. Acquiring new technologies from outside the firm which speeds up the innovation process and complements internal R&D is an important aspect of new business development within the paradigm of open innovation. It is becoming a requirement to create and sustain competitive advantage in different product markets, and to respond quickly to changing market needs and new technological opportunities.

Companies that co-develop technology or in-source external technology to set up new business can choose from a myriad of different sourcing modes. Traditionally, entrepreneurial firms have emphasized strategic alliances, joint ventures, license agreements and mergers and acquisitions as means to source knowledge they do not have in-house. More recently, firms have also become aware of other options such as corporate venture capital investments and technology exploration in cooperation with research labs, universities, high-tech start-ups or other large companies. Innovating companies can choose between these external technology sourcing modes in order to react in a flexible way to new technological developments and changing market conditions.

In this thesis I analyze the use of different governance modes for external technology sourcing, incorporating a broad range of governance modes, such as technology alliances, corporate venture capital investments, minority holdings, joint ventures, and mergers and acquisitions. The main research question that serves as a basis for the project is: How do companies use different governance modes for external technology sourcing? The thesis can be split up in three sub-questions, each of which is tackled in a different chapter.

The first part of the thesis focuses on the effect of uncertainty on the governance choice for inter-organizational technology sourcing. I argue that uncertainty can be roughly divided into two groups: exogenous uncertainty, which is unaffected by firm's actions, and endogenous uncertainty, which is embedded in the relationship and can be reduced by actions of the firm. Exogenous uncertainty includes environmental turbulence and technological newness. When the environment is turbulent,

innovating firms attach more value in keeping their options open. In addition, when an innovating firm intends to source nascent technologies, uncertainty about the future business potential of the technology is very high. Hence, under conditions of exogenous uncertainty, firms will prefer to maximize flexibility and prefer to make small (learning) investments, which facilitate reversibility of actions in combination with low degrees of financial commitments.

Uncertainty may also exist within a technology sourcing relationship. For instance, when two partners have a relatively small technological overlap (i.e. when the technological distance is high) it might be difficult for the investing firm to recognize and absorb its partner's technological capabilities. On the one hand, this might lead to a preference for more integrated modes which require a higher level of integration in order to increase the efficiency of the transfer and accumulation of knowledge. On the other hand, the greater the dissimilarities in the knowledge bases, the longer it will take before uncertainty about the opportunity has resolved, making a higher level of commitment less attractive. Another indicator for endogenous uncertainty is the existence of prior cooperation between the partners. Prior cooperation can be used to overcome information asymmetry among partners, which occurs when they do not have access to all the relevant information to make an investment decision. Therefore, we expect that prior cooperation enhances the willingness of companies to enter into a relationship that involves a higher level of commitment. However, one might also argue that prior cooperation enhances the building of trust between partners, thus making a more integrated solution less favorable.

The results show a clear preference for particular governance modes, depending on the type of uncertainty. Under high levels of environmental turbulence, non-equity technology alliances are clearly the most favorable option. Technological newness has a strong, negative effect on the likelihood of using M&As and joint ventures instead of non-equity alliances. However, the results also show a clear preference for the use of CVC over non-equity alliances. A larger technological distance between two firms also increases the chance to use CVC investments over non-equity alliances, whereas minority holdings are the least favored option. The strong preference for CVCs to source externally developed technology that is distant from the focal firms technology core shows the particular role CVCs play in external technology sourcing. Finally, when prior cooperation between firms exists, we find that minority holdings and joint ventures are preferred over non-equity alliances, but we find no differential effect between the use of non-equity alliances and M&As. The results furthermore suggest that exogenous uncertainty is a much more powerful driver behind governance mode decisions than relationship-specific uncertainty. A high level of environmental uncertainty leads firms to choose less integrated governance modes, such as non-equity alliances and CVC investments, over their more integrated counterparts. Uncertainty about the future thus drives firms to make small, reversible investments. This enables firms to learn about business opportunities through small, learning investments and to put off stronger financial commitment until uncertainty about the opportunity has decreased.

It is also worth noting that the existence of a continuum from less to more integrated governance modes is not confirmed. Based on the literature, I proposed a ranking from less to more integrated governance modes, ranging from non-equity alliances, corporate venture capital investments, minority holdings, joint ventures and M&As. However, the results from the ordinal and multinomial logit analyses show no support for an ordinal ranking of the different external sourcing modes as has been suggested in prior studies.

In the second part of this thesis, I discuss the added value of corporate venture capital investments as a means to source new technologies and the effect on a company's subsequent innovative performance. Corporate venture capital investments are minority equity investments in young, start-up firms and during recent years, these types of investments have received increased attention both in academia as well as in business. I argue that corporate venture capital investments positively affect the innovation performance of firms, even when controlling for other modes of external knowledge sourcing. In addition, it is argued that corporate venture capital investments are complements rather than substitutes to other external sourcing modes, because they enable access to new technologies in the earliest stages of technology development, while other modes are more appropriate for later stages or less explorative technology acquisition. Using corporate venture capital investments in combination with the more traditional modes of technology sourcing will therefore positively affect the innovative performance of investing firms.

The main empirical results indicate that corporate venture capital investments have a direct, positive effect on innovative output of investing firms, even when controlling for other modes of external technology sourcing. Moreover, the results support our suggestion that different governance modes are complementary. External governance modes appear to reinforce rather than substitute each other. Moreover, we see a steady increase in the coefficient of the respective interaction terms with non-equity alliances, equity alliances, and M&As, indicating that the complementarity of external technology sourcing increases when the different sourcing modes become more distinct. In other words, governance modes that are alike in terms of flexibility and the targeted knowledge can also serve as substitutes. For instance, corporate venture capital investments and non-equity alliances are both loosely-coupled governance modes that involve a high level of flexibility. The preference for one of the two modes when sourcing early stage technologies might then be contingent upon other factors, making non-equity alliances and corporate venture capital investments substitutes rather than complements. Equity alliances and M&As, on the other hand, are much more distinct from corporate venture capital investments, making substitutability less likely.

The last part of the thesis is oriented towards the explorative nature of external technology sourcing. In this chapter, I analyze the effect of corporate venture capital investments, non-equity alliances, equity alliances and M&As on the generation of pioneering technologies. Pioneering technologies are technologies that are new to the world and do not refer to prior patents. When considering the creation of pioneering technologies it is thus important to look at both organizational and technological boundary-spanning. Organizational boundary-spanning can take the form of engaging in inter-organizational relationships, for instance through strategic alliances, corporate venture capital investments and mergers and acquisitions. Because different external technology sourcing modes enable access to different types of technologies, it is important to disentangle them in order to estimate their individual impact. Technological boundary-spanning, on the other hand, can be achieved through the investment in distantly related technological knowledge, or by investing in recently developed technologies. In this chapter I analyze the effect of different external technology sourcing modes on the generation of pioneering technologies. Because different governance modes facilitate access to different types of knowledge in different stages of development, I argue that they affect exploration outcomes differently as well. Strategic alliances and corporate venture capital investments, for instance, are loosely integrated governance modes that allow the focal firm to remain flexible when investing in external knowledge. Mergers and acquisitions, on the other hand, are more integrated and therefore embody a lower level of flexibility. Additionally, I link these governance modes to the newness of the technology a firm invests in and the technological distance between the investor and its partner. Both technological newness and technological distance affect the extent to which the knowledge acquired matches the absorptive capacity embedded in the organization and hence the effectiveness with which the external knowledge can be internalized.

The results indicate that loosely coupled linkages such as strategic alliances (non-equity as well as equity) and corporate venture capital investment have a positive effect on the creation of breakthrough innovations. Moreover, I find that a larger technological distance between the two partnering firms increases the effect this organizational mode has on the creation of pioneering technologies, while technological newness decreases the positive effect of CVC investments and non-equity alliances on the creation of pioneering technologies. Interestingly, although corporate venture capital investments are clearly the most favorable option when investing in new technologies, the results show that the largest impact on the creation of pioneering technologies does not come from investing in CVC investments. Rather, pioneering technologies stem from collaboration through a non-equity or equity alliance. Moreover, even though CVC investments are most likely to be used for recent technologies or technologies that are on a larger technological distance, the results suggest that the effect of CVC investments on the generation of pioneering technologies is not enhanced by technological distance, nor by technological newness. In fact, CVC investments as well as non-equity alliances benefit more from investing in older technologies, indicating that recent knowledge is not necessarily related to the creation of radical technologies.

To conclude, we might say that the external sourcing of knowledge is becoming more and more important in the development of new businesses. Companies therefore need to develop a set of methods or guidelines in order to efficiently in-source external technologies. The choice between different modes of governance plays an important role in this process. As shown in this study, external sourcing modes differ in their characteristics and the role they play in the innovation process. In addition, the results show that the mix of different governance modes is an important driver behind innovative performance. Each of the governance modes has advantages and disadvantages, depending on the motives that drive the external sourcing decision. Matching these motives with the appropriate governance choice is a major challenge for firms. Therefore, it is crucial for companies to have a clear view on their innovation strategy.

About the author

Vareska van de Vrande was born on January 14, 1977 in Eindhoven, the Netherlands. She attended the Eckart College in Eindhoven, where she graduated in 1997. In the same year, she started her studies Industrial Engineering and Management Science at the Eindhoven University of Technology, Faculty of Technology Management. During her study, she attended an International Business and Management of Technology semester at the Lappeenranta University of Technology in Finland. During the last part of her study, she specialized in Organization Science and wrote her Master's Thesis on the topic of internationalization and governance mode choice. She graduated in 2002, after which she did various projects before starting her PhD research in 2003.

Currently, Vareska works as an Assistant Professor at the RSM Erasmus University, at the department of Strategic Management and Business Environment. Her research interests include technology management and innovation, corporate entrepreneurship and corporate venturing, open innovation and external technology sourcing, (corporate) venture capital, strategic alliances, and mergers and acquisitions.

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