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Exploration in technological innovations with external partners

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Exploration in technological innovations with external partners

Contents

Chapter 1

Introduction to this study*

1.1 Introduction

The notion of exploration and exploitation has been widely used in studies on organizational learning, strategic renewal and technological innovation. March (1991) introduced the two concepts as follows: "*Exploration* includes things captured by terms such as search, variation, risk taking, experimentation, flexibility, discovery, and innovation. *Exploitation* includes such things as refinement, choice, production, efficiency, selection, implementation, and execution (March, 1991: p. 71)". Exploration is variation-seeking, risk-taking, and experimentation-oriented. Exploitation is variety-reducing and efficiency-oriented (March, 1991). These two concepts require different structures, processes, strategies, capabilities and cultures, and may have different impacts on an organization's performance. Compared to exploitation, returns from exploration are less certain, more remote and more risky. As firms learn from their experiences, the advantages of exploitation cumulate. However, in a Schumpeterian competition context (Schumpeter 1934), particularly for high-tech industries, Schumpeterian rents are likely to be diluted by both imitation and destructive innovations (Nelson and Winter 1982). Therefore, the tendency towards exploitation leads to a sub-optimal equilibrium and the failure to survive in the long run. Consequently, maintaining an appropriate balance between exploitation and exploration is critical in system adaptation and survival (Levinthal and March, 1981; Moch and Morse, 1977; Freeman, 1982; Henderson and Clark, 1990).

Exploration and exploitation have received great attention in the literature on organizational learning and innovation (e.g., Benner and Tushman, 2002; Katila and Ahuja, 2002; Nerkar and Roberts, 2004; Sidhu, Commandeur and Volberda, 2007; Nooteboom, 2000b). For instance, Benner and Tushman (2002) investigated the influence of process management on firms' exploitative and exploratory innovations. Network researchers are interested in the influence of social capital and network structures on exploitation and exploration (Vanhaverbeke *et al.*, 2004). Rosenkopf and Nerkar (2001) looked at the impact of technological exploration, within or cross the organizational or technological boundary, on a firm's subsequent technological evolution. Nerkar (2003) investigated the impact of temporal exploitation and exploration on a firm's later knowledge creation. Ahuja and Lampert (2001) argue that firms under the pressure of avoiding uncertainty and improving efficiency tend to exploit familiar, mature and proximate technologies. In this way, there is an imbalance between exploitation and exploration in favor of the former. In order to escape traps of exploitation and ensure the performance in long-run, firms need to incorporate learning strategies to explore novel, emerging or pioneering technologies. In the studies on strategic alliances, many scholars have distinguished exploitative alliances from exploratory alliances. The criteria for this

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distinction are the motivations of entering an alliances relationship and their main activities. The *exploitative alliances* are usually motivated by leveraging existing competencies across the alliances partners. Therefore, the activities of this kind of alliances typically include manufacturing, marketing or supply agreements. On the contrary, the *explorative alliances* are usually established in order to explore new technological opportunities. Therefore, these alliances inevitably have an R&D component. Many studies have been interested in the relationship between these two alliances and firms' technological or financial performance (Rothaermel and Deeds, 2004; Faems *et al.,* 2004; Schildt *et al.,* 2004; Rothaermel Rothaermel, Hagedoorn and Roijakkers, 2004; Hagedoorn and Duysters, 2002).

Although the existent literature has provided us with great insights on technological exploration and exploitation, there are still underdeveloped areas that deserve further investigations. Since companies are inclined to the refinement and improvement of an existing technology (exploitation) and overlook the opportunities to explore new knowledge that departs in a significant way from the existing practices, *exploration* naturally deserves more attention, in my opinion. The purpose of this thesis, thus, is to extend our knowledge on exploration in technological innovation by taking into account some important endogenous or exogenous factors that might affect a firm's exploration in technological innovation. This purpose can be translated into a general research question that is,

What are the important factors that may have influence on a firm's exploration in technological innovation? And how are these factors related to the exploration of firms?

I confine my attention to one single domain of organizational research—*technological innovation*—because technological innovation is considered as a critical competitive capability for growth and adaptation (Schumpeter, 1934), and it demonstrates a firm's capability of effective organizational learning (Von Hippel, 1994). However, to answer the research questions, there are at least two important issues to be determined. This is because after the seminal work of March in 1991, a great number of researchers studied the notion of exploitation and exploration from different perspectives. These studies displayed to some extent variety in the levels of analysis and inconsistency in the interpretation of exploitation and exploration. Therefore, the starting point of this research project is to review the existent literature on technological innovation that has been published since March's work (1991). Based on the literature review, firstly I try to determine the level of analysis for this study; secondly, to identify the determinant factors in some underdeveloped areas on exploration in technological innovation, upon which I frame three specific sub-research questions of this study[1].

[1] For detailed information on the research approach and selected literature, see Appendix I

1.2 Level of analysis

Scholars interpret the notion of exploration and exploitation differently because they conducted their research at different levels. The different levels of analysis constrain the focus of researchers and yield great variety in interpretation of constructs. For instance, at the *individual level*, exploration and exploitation are considered as two different types of creative idea generation (Audia and Goncalo, 2007). At the *project level*, exploration manifests itself in the newness of a project (McGrath 2001) or the composition of project development teams indicates the degree of exploration (Perretti and Negro, 2007). At the *firm level*, some scholars interpret exploration as distant knowledge search and exploitation as proximate knowledge search (Benner and Tushman, 2002; Katila and Ahuja, 2002; Nerkar and Roberts, 2004; Sidhu, Commandeur and Volberda, 2007). At the *corporate group level*, exploration and exploitation are usually considered in terms of corporate strategy for venturing (Vanhaverbeke and Peeters, 2005; Cantwell and Mudambi, 2005). At the *alliances level*, exploration and exploitation are usually seen as different motivations to enter inter-firm collaboration (Hagedoorn and Duysters, 2002; Rothaermel and Deeds, 2004; Rothaermel, Hagedoorn and Roijakkers, 2004). At the *industry level*, exploitation and exploration build upon each other and form a dynamic “cycle of discovery” (Gilsing and Nooteboom, 2006). Comparison between studies at different levels of analysis is sometimes not easy and straightforward. To have a unique and consistent research, one needs to determine the level of analysis for his study. For this thesis, I’ve conducted three empirical studies at the *firm level* of analysis for two reasons. Firstly, the majority of the selected articles under review are at the firm level (see table 2 in Appendix I). This manifests that the scholars’ research interests are mostly in the firm level issues. Second, the original discussion on exploration and exploitation by March (1991) is a rigorous investigation on a managerial dilemma with respect to firms’ performance. By sticking to the firm level of analysis, I believe this thesis could make strong and relevant contributions to the extent literature.

1.3 Knowledge domain along value chain and distance in knowledge search: The competence perspective

Exploration and exploitation are different types of learning. Many researchers have linked these two different types of learning activities with unique functions of the value chain of a firm, where learning takes place. To simplify the issue, we focus on three main functions along the value chain: *science* (fundamental research), *technology* (product development) and *product-market* (manufacturing and marketing). In the existent literature, there is no consensus on which function of the value chain is associated with exploration or exploitation. For instance, some researchers distinguish exploration from exploitation by highlighting the distinction between science and technology. *Science* refers to knowledge concerning general theories about the relationships associated with natural and social phenomena, and *technology* refers to theoretical and practical knowledge, skills and experiences that are of use to develop products or services (Geiger and Makri, 2006). Science search, thus, is related to *fundamental* research, which is *exploratory* and often driven by the researcher’s curiosity, interest, or intuition. It is conducted without any practical end in mind, although it may have unexpected results pointing to practical applications. Technology search is related to *applied* research, which is *exploitative* and often driven by the motivation of solving a particular practical problem. Science can provide a guide for new technology search (Fleming and Sorenson, 2004). Due to their very different nature, the uncertain science search is argued as exploration and technology search is argued as exploitation (Ahuja and Katila, 2004; Geiger and Makri, 2006). Some examples manifest this interpretation of exploration and exploitation based on the distinction between science and technology. For instance, with respect to R&D projects, some researchers define research projects as exploration and development projects as exploitation (Garcia *et al.*, 2003). In a recent study on the biotechnology industry, Gilsing and Nooteboom (2006) describe that for the firms in the biotechnology industry, the collaboration between a biotechnology firm and academic institutes aiming for scientific research, is exploration for the biotechnology firm.

Nevertheless, the search for science and technology is not sufficient to achieve successful innovations. A successful innovation also requires searching for *product-market knowledge* gained from customers, suppliers and even competitors as a complementary source to scientific and technological knowledge (Von Hippel, 1988; Chesbrough and Rosenbloom, 2002). A commonly accepted product innovation typology defines exploration and exploitation according to the interplay between technology search and product-market knowledge search (Danneels, 2002; Nerkar and Roberts, 2004). Sidhu *et al.* (2004, 2007) argue that the notion of exploration and exploitation should be understood as external information acquisition. They use the term “supply-side” to label the search for technology and the term “demand-side” to label the search for product-market knowledge. Several studies at the alliance level also consider technology and product-market knowledge in defining exploratory or exploitative alliances (Rothaermel, 2001; Rothaermel and Deeds, 2004; Rothaermel *et al*., 2004; Lavie and Rosenkopf, 2006; Hagedoorn and Duysters, 2002). Whether an alliance is exploratory or exploitative depends on their main activities and the motivation to enter an alliance. On the one hand, exploratory alliances are usually established in order to explore new technological opportunities (technology search). Therefore, these alliances inevitably have an R&D component (Rothaermel and Deeds, 2004). On the other hand, exploitative alliances are those that leverage complementary competencies across the alliances partners. Exploitative alliances enable firms to commercialize the technology gained through exploration. Therefore, the activities of this type of alliances include manufacturing, marketing or supply agreements, which are typical product-market knowledge (Rothaermel, 2001).

The interpretation of exploration and exploitation based on the functions of the value chain has also been recognized by Lavie and Rosenkopf (2006). They argued that the “function domain” as one way to define exploration and exploitation. The rationale here is that the nature of a specific function on the value chain determines *ex facto* whether the learning is exploratory or exploitative within the function. For each pair of the functions, i.e. *science vs. technology* and *technology vs. product-market knowledge*, the former function is exploration, based on which further exploitation takes places in the latter function. While this is one way to interpret exploration and exploitation in terms of the type of learning, another track of studies does so based on the distance in knowledge search.

While March (1991, pp71) simply associates “search” with exploration, many researchers later extended the idea of knowledge search in explaining exploration and exploitation. Most studies employed the idea of *local or distant* knowledge search to interpret exploration and exploitation. They interpreted exploitation as activities that search for familiar, mature, current, or proximate knowledge; and exploration as consisting of activities that search for unfamiliar, distant, and remote knowledge (Benner and Tushman, 2002; Rosenkopf and Nerkar ,2001; Ahuja and Lampert, 2001; Nerkar, 2003; Katila and Ahuja, 2002). Particularly in technological innovation, exploitation involves local search that builds on a firm’s existing technological capabilities, while exploration involves more distant search for new capabilities. Local search provides a firm with advantages in making incremental innovations, while distant search might give opportunities to a firm to achieve radical innovations (Nerkar and Roberts, 2004). “Innovation is increasingly exploratory the more it departs from knowledge used in prior innovation efforts and, conversely, increasingly exploitative the more deeply anchored it is in existing firm knowledge” (Benner and Tushman, 2002, pp679).

In the existent literature on technological innovation, distant or local knowledge search has been studied in different dimensions. I summarize three independent dimensions that construct the knowledge space. I label the first dimension as the *cognitive dimension*. It measures the degree of familiarity between the newly searched knowledge and a firm’s existing knowledge-base in term of the cognition distance. For instance, it is exploration for a firm that is specialized in electronic technology to get access to technology from pharmaceutical industry, and it is exploitation for the firm to search for new technology within the electronic industry. In the literature of technological innovation, a large number of studies have defined exploration and exploitation from such a perspective (Dowell and Swaminathan, 2006; Argyres, 1996; Ahuja and Lampert, 2001; Rosenkopf and Nerkar, 2001; Nerkar, 2003; Katila and Ahuja, 2002; Benner and Tushman, 2002). Most of the studies usually measure how local or distant the knowledge search is along the cognitive dimension by means of patent classification. The patent classes represent the differences between two patents with respect to their cognitive distance.

The second dimension is the *temporal dimensions*, which is independent from the cognitive dimension. The temporal dimension of knowledge search examines the role of time and the tension between exploitation and exploration (Nerkar, 2003; Katila, 2002). *Temporal exploitation* is the creation of new knowledge through searching for recent knowledge (recency) and *temporal exploration* is the creation of new knowledge through searching for knowledge remote in time (time spread) (Nerkar, 2003). The old knowledge is valuable for exploration for at least two reasons. First, individuals and firms tend to choose the path close to the neighborhood of their current expertise along the knowledge development path. As a result, some valuable choices might be missed in this process. Second, some of those missed opportunities were not useful because complementary knowledge was not available in the company at a particular point in time. Knowledge that was useless in the past may nevertheless have a high potential in the future because the necessary complementary knowledge and institutions become available. The time lags between the emerging technological opportunities and complementary markets and technologies require a firm's capability to explore the storehouse of technology over time (Garud and Nayyar, 1994). For example, big pharmaceutical firms now hire specialty biotech companies to put their previously discarded experimental compounds, some of which failed clinical trails as long as 20 years ago, through series of new tests. They hope that a then useless compound intended for one treatment may be highly useful treating something entirely different nowadays (Simons, 2006).

The third dimension is the *spatial (geographical) dimension*, which refers to the knowledge search crossing physical space. There are different reasons why this spatial dimension matters. First, the availability of common resources within a region is related to agglomeration economies (Saxenian, 1994). Second, since "knowledge" is more tacit than "information", knowledge, particularly sticky-knowledge (Von Hippel, 1994; Szulanski, 1996), is more likely to be transmitted within a small geographical area where organizations have sufficient interactions and joint practices (Asheim and Isaksen, 2002). Third, the geographical dimension is usually tightly related to the institutional and culture dimension (Knoben and Oerlemans, 2006). Due to the differences among countries with respect to culture, customs, and regulations, learning tends to be more difficult and the return to learning might be more uncertain across different institutional regimes than within the same institutional regime. At the macro level, the spatial dimension is a matter of national difference because particular countries develop relatively stable and distinct trajectories of technological specialization and display different patterns in R&D (Le Bas and Sierra 2002). For example, Phene *et al.* (2006) distinguish knowledge sources between "international" and "national" origin. The search for proximate technology from national origin is analogous to exploitation, and the search for distant technology from international origin is analogous to exploration[2].

Based on the review, I suggest that exploration and exploitation can be defined in two different domains. First, the 'function domain' defines exploration and exploitation according to the unique nature of a specific value chain function (Lavie and Rosenkopf 2006). Second, the 'knowledge distance domain' takes a knowledge searching perspective and defines exploration and exploitation according to the relative distance between the new knowledge and the existing knowledge base of a firm. These two domains, respectively, corresponds to Gupta and his colleagues' (2006) suggestion that exploration and exploitation should be defined according to the type or amount of learning. Further, these two domains are highly related to and embedded within each other. In sum, from the knowledge search perspective, exploration and exploitation is defined according to the knowledge distance between the existing knowledge of a firm and the new

[2] At the micro-level, one could consider inter-organizational learning as more 'distant' or more exploratory than intra-firm learning. While reusing a firm's own knowledge does not necessarily involve spatial distance, acquiring knowledge from other firms inevitably crosses space. For example, Rosenkopf and Nerkar (2001) define the degree of exploration depending on whether knowledge search spans organizational and technological boundaries. Search with the strongest exploratory nature is search for distant technology from outside the organization. The least exploratory search is local technology search from inside of the organization.

knowledge that a firm is searching along any of the three dimensions of knowledge space. Search locally is exploitation and search distantly is exploration. Since this perspective concerns the amount of learning, exploration and exploitation can be operationalized as a continuous measure along any of the three dimensions of the knowledge space, while the value chain function perspective usually treats exploration and exploitation as a dichotomous measure. Figure 1 depicts the relationships between these two perspectives. The main challenge in defining exploration and exploitation is how to integrate the value chain function perspective and the knowledge distance perspective, taking the level of analysis into account.

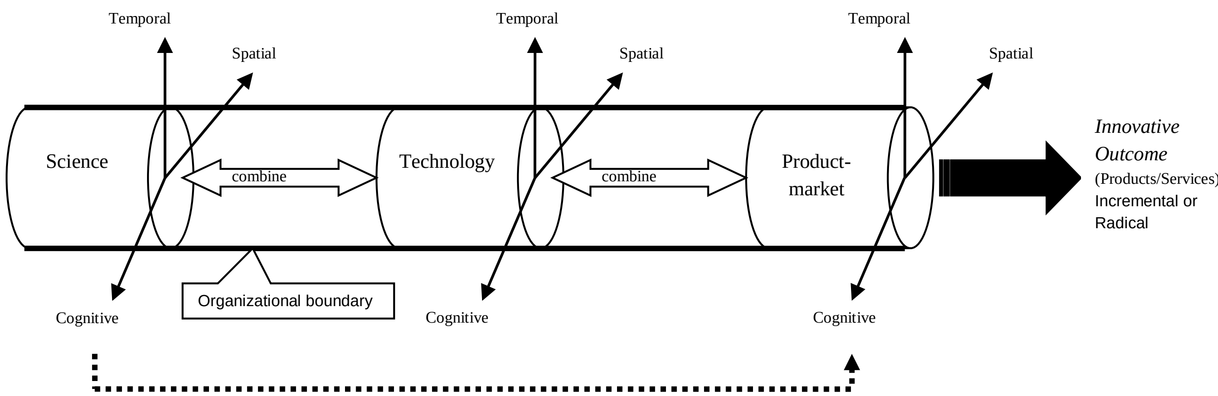

Figure 1: An Integrated Framework for Studying Exploration and Exploitation from Different Perspectives

Having the distinction of perspective of knowledge domain along value chain function and knowledge search distance perspective in interpreting exploration, an interesting sub-research question arises,

How does distant knowledge searching in more than one dimension affect the exploration in technological innovation of a firm, while taking the more than one knowledge domain along value chain into account?

Chapter 3 tries to tackle this challenge by investigating the effects of knowledge distance in cognitive dimension (industry difference) and spatial dimension (country difference) on a firm's exploration. Exploration here is purposefully interpreted and specified in chapter 3 as *pioneering innovations.* Pioneering innovations are those innovations that are technologically novel in the industry and introduced world-first in the market. The rationale for using pioneering innovations a proxy for exploration in this study is as follwing: In the existent literature, exploration and exploitation have been usually used as synonymous with "radical innovation" and "incremental innovation", respectively (Jansen *et al.*, 2006; Benner and Tushman, 2003). Many researchers have focused on the *technological* novelty when defining radical innovation (Dewar and Dutton, 1986; Ahuja and Lampert, 2001; Nerkar and Roberts, 2004). In the first place, in contrast to incremental innovations, radical innovations represent a fundamental departure from existing practices (Dewar and Dutton, 1986; Tushman and Anderson, 1986). The criterion here is whether the innovation is novel or based on existing practice. However, the novelty criterion for innovations should not only be judged in the *technological* domain, but also from a *product-market* perspective. If exploration has to be represented by certain types of innovation, one needs to consider both the technological and the market novelty of the innovation. It has been accepted that an innovation is the unique combination of technological novelty and appropriate market access (Fleming, 2002; Nerkar and Roberts, 2004). Therefore, slightly different than the definition of radical innovation in the existent literature which has focused on the technological novelty of innovations, I emphasize the market-side of novelty with regard to the definition of pioneering innovations. A typical characteristic of pioneering innovations is that they are marketed first in the world. To market a technological invention first in the world, a firm inevitably needs to take great risks and deal with a considerable level of uncertainty, which is highly exploratory. The merit of the definition of pioneering innovation is that it comprises of two domains of knowledge, i.e., the technology and the product-market knowledge. In such a way, I link two knowledge domains along value chain and knowledge search distance perspective in one single piece of study.

The discussion here on exploration with regard to the knowledge domain along value chain and knowledge search distance perspectives is rather based on a resource-based research tradition. The underlying logic is as following: Innovation by organizations is often a process of producing novel combinations of information, knowledge and resources (Schumpeter, 1934). To undertake technological exploration, firms need to search various sources of new knowledge within or beyond their organizational boundary. Technology and market practice are considered as crucial resource for firms to explore in technological innovations. The findings in this chapter confirms the theoretical arguments in the literature that for exploration, the innovating firm needs to maintain wide search scope and sufficient level of spatial proximity (Nooteboom 2004b).

1.4 Competition

While distant knowledge searching based on the resource-based view is a crucial endogenous factor that may have influences on a firm's exploratory learning in technological innovation, competition is an important exogenous factor (Garcia *et al*. 2003). The distant knowledge searching of a firm and its correspondent governance modes is contingent upon the competitive context in which the firm is operating. While a resource-rich firm under low pressure of competition may have the organizational slack to search for exploratory opportunities, it could also be forced to focus on exploitation under strong competition. Therefore, the influence of competition on a firm's exploration in technological innovation has drawn my attention. The third sub-research question, thus, arises hereby,

How does competition influence a firm's exploration in technological innovations?[3]

[3] Certainly, there are many reasons to believe that the outcomes of exploration will also reshaped the competitive context in the market. However, since the focus of this thesis is on how various factors influence a firm's exploration in technological innovations, then the inversed relationships are out of the scope of this thesis.

Although there have been many studies in the extent literature on the relationships between competition and innovation, the empirical evidences on the relationship between competition and innovation have remained inconclusive. On the one hand, the Schumpeterian viewpoint credits that the large firms with substantial monopoly market power have resources and incentives to innovate. On the other hand, it is also possible for a monopolist to have incentives to suppress subsequent innovation (Weinberg, 1992). The argument from Arrow (1962) that a perfectly competitive market is more likely to foster innovation than a monopoly market has been supported by some empirical studies, which found a positive linear effect of competition on innovation (Blundell *et al*., 1999). To resolve these contrary theoretical arguments, it is suggested that there is no unambiguous evidence of a generally valid relationship between competition and innovation. The inquiry on the relationship between competition and innovation has been argued to be relative and meaningful when the competition context and the type of innovation activities are specified (Baldwin and Scott, 1987; Tang, 2006). In response to this theoretical suggestion and to extend our insights on the relationships between competition context and innovation, in Chapter 4 I try to investigate the specific relationship between foreign *competition* and *pioneering innovation*. The specific relationship between foreign competition and pioneering innovation is highly relevant and important because, firstly, one of the most important changes in the past few decades is the globalization of markets and industries. The particular change in competitive conditions, especially foreign competition, is likely to change a firm's business strategy to remain competitive (Wiersema and Bowen, 2008). Secondly, technological innovations can be used as either defensive or offensive strategy to sustain a firm's competitive advantage (Burgelman *et al*., 2004). Under foreign competition in domestic market, firms may explore novel technological opportunities and race to bring the innovation into the market for the first time in the world, which we define as the *pioneering innovation*. The pioneering innovation is a specific type of exploration. Although numerous studies have investigated the economic influence and competitive implication of increased foreign competition in domestic market (Caves, 1996; Chung, 2001), there is little insight on the relationship between foreign competition and pioneering innovation.

1.5 External corporate venturing partnerships: The governance perspective

From a resource-based tradition, firms' innovation performance is likely determined by both internal and external resources. First, a firm's internal resource such as R&D expenditure, organizational structures and culture make some firms more innovative than others (Parahalad and Hamel, 1990; Henderson and Clark, 1990; Van den Bosch, *et al.* 1999). Second, since it is less and less likely that a single firm can possess all necessary knowledge and capabilities for innovation in a business world characterized as rapid technology change, consumer preference shift and high uncertainty, firms need to gain critical access to information and technology through various inter-firm relationships. Companies are increasingly using external corporate venturing to learn from knowledge sources beyond the boundary of the firm (Rosenkopf and Nerkar, 2001). Since firms are more often to search external knowledge source outside of their organizational boundaries, the governance of inter-firm relationships turns to be another important issue with regard to exploration in technological innovation. External corporate venturing, including corporate venture capital (CVC) investments (Dushnitsky and Lenox, 2005; Keil *et al*., 2008), alliances (Gulati, 1998), and mergers and acquisitions (M&A) (Ahuja and Katila, 2001; Puranam and Srikanth, 2007) has been found positively related to the innovation performance of firms and has become a noteworthy vehicle for exploration (Schildt *et al*., 2005; Lavie and Rosenkopf, 2006; Lin *et al*., 2007).

The interactive nature of innovation and organizational learning between firms requires appropriate governance to realize the potential of inter-organizational relationships and control the relational risks. The competence perspective (resource-based view) of innovation has been complemented by the governance perspective in the literature on organization and innovation (Gulati, 1995; Dyer and Singh, 1998; Colombo, 2001; Nooteboom 2004a). Various studies have attempted to incorporate the competence perspective and governance perspective in explaining firm performance. For instance, Gulati (1995) examined the relationship between resources interdependence and alliance formation from a competence perspective and the relationship between relational factors and alliance formation from a governance perspective. Dyer and Singh (1998) indicated that a firm's critical resource may span firm boundaries and the analysis for understanding competitive advantage should take both competence and governance into account. The dialog between Williamson (1999) and Nooteboom (2004a) intensified the emergence of an integration of competence perspective and governance perspective in organization studies. To follow this research direction, I raise another sub-research question hereby,

How does a firm's external corporate venturing partnership affect its exploration in technological innovation? Which governance modes are more appropriate for exploration?

Although many studies have tried to tackle this issue (e.g., Schildt *et al*., 2005; Van de Vrande *et al*., 2008), in Chapter 5 I try to answer this question in a unique way by investigating the effects of external corporate venturing, including corporate venture capital (CVC), alliances and mergers and acquisitions (M&A), on two different types of exploratory learning, i.e., *exploration from partners* (EFP) *and exploration beyond partners* (EBP), which has not receive much research attention in the literature, to my knowledge. An innovating firm could not only explore new technologies from its corporate venturing partners (EFP), but also explore new technologies from the organizations, with which the innovating firm has had no prior venturing relationships (EBP). When an innovating firm explore beyond the corporate venturing partnerships, the existing corporate venturing partnerships may have impact on an innovation firm's exploration beyond partners by acting, for instance, as an information pipe, a reputation reference, or a complementary knowledge source (Podolny, 2001; Gulati, 1998). It is interesting and important to study this issue because the existent literature has analyzed in detail the role of external corporate partners with regard to external search of knowledge *from* corporate venturing partners, but we know little about how external venturing partnerships could play their roles for an innovating firm to explore technological knowledge embedded in other organizations with which it has *no* venturing relationships.

1.6 Contribution

The main contribution of this thesis is that it provides us with some new insights on the influences of different factors on a firm's exploration in technological innovation. To be more specific, firstly, chapter 3 focuses on the influences of inter-industry and country differences between the innovating firms and their suppliers on a particular type of exploration—pioneering innovation. The inter-industry differences and country differences stand for two different dimensions of knowledge search. And the definition of pioneering innovation explicitly recognizes the importance of technological and market novelty in exploratory innovation, which avoids the fuzzy usage of "breakthrough or radical innovation" as used in other studies (Ahuja and Lampert 2001, Phene *et al*., 2006). The combination of two different dimensions of knowledge search and both technological-side and market-side of exploratory innovation is an attempt to bring insights on how knowledge search (as a learning process) leads to exploratory innovations (as innovation outcomes). Secondly, chapter 4 is one of the few empirical investigations on the relationship of a specific pair of competition and innovation—foreign competition and pioneering innovation. It explains how innovating firms will react to different levels of foreign competition in the domestic market by undertaking exploratory technological innovations to leapfrog the pressure of foreign competition. Finally, chapter 5, for the first time in the literature, conceptually distinguishes exploration *from* partners and exploration *beyond* partners. It empirically investigates the different effects of external corporate venturing partnerships and the level of integration in the venturing governance modes on a firm's exploration from partners and exploration beyond partners. It provides completely new insights on the role of external corporate venturing partnerships for an innovating firm to explore technological knowledge embedded in other organizations with which it has *no* venturing relationships.

This thesis also bears many managerial implications. Firstly, the findings of this thesis suggest that, to enhance the performance of exploration in technological innovation, firms need to explore various resources outside of the organizational boundary. Firms should actively search for new knowledge across industry boundaries and geographic locations. Secondly, firms should learn how to combine the effects of inter-industry differences and country differences in supplier relationships and maximize the likelihood to create pioneering innovations. Firms can develop a strategy to enhance innovations by seeking suppliers from unfamiliar industries but preferably in the domestic or neighbouring markets. Next, this thesis also advises managers how to compete by exploring new technological and market opportunities rather than only focusing on improving efficiency and exploiting the existing technology competence, when more and more foreign competitors rush into the domestic market. Last but not least, firms must pay attention to the important role of external corporate venturing partnerships with respect to the exploratory learning not only from the partners but also from other organizations with which it has no prior venturing relationships. Firms should also develop capabilities to better manage the external corporate venturing partnerships and use them as radars to allocate the new technological opportunities, as a prism to identify the relevance and complementarity of new technologies, and as a reputation mechanism to justify the exploration beyond partners.

1.7 Outline

The remainder of this thesis is organized as follows. Chapter 2 will describe the data that was used to analyze the questions raised in this thesis. Chapter 2 describes the data collection process, the sources that were used and the selection of samples for the analyses. Chapters 3, 4 and 5 will then each tackle one of the sub-questions as described earlier. Chapter 3 focuses on the influences of inter-industry and country differences between the innovating firms and their suppliers on a particular type of exploration—pioneering innovation. Chapter 4 investigates the relationships between foreign competition and pioneering innovation. The particular role of technological distance on exploration will be repeatedly discussed in these chapters. Chapter 5 investigates the effects of external corporate venturing, including corporate venture capital (CVC), alliances and mergers and acquisitions (M&A), on two different types of exploratory learning – *exploration from partners* (EFP) *and exploration beyond partners* (EBP). Chapter 6 synthesizes the results, followed by a discussion on how these results have provided us the answers to the research questions. The chapter concludes with the limitations of this study and some suggestions for the future research on this topic.

Chapter 2

Data and Sample

2.1 Data

For this thesis, I used two different sources of dataset. To investigate the effects of industry and country differences and foreign competition on exploration in technological innovation in chapter 3 and 4, I used a Canadian Technological Innovation Dataset (hereinafter ‘Canadian Data’). To investigate the relationships between external corporate venturing partnerships and two different types of exploration in chapter 5, I used a unique dataset on external corporate venturing partnerships and patent activities in the pharmaceutical industry (hereinafter ‘Corporate Venturing Data’), which was collected by Dr. Vareska van de Vrande for her doctoral thesis in 2007. Hereby, I introduce the Canadian Data and the Corporate Venturing Data.

2.2 The Canadian Data

The dataset used for this study is the Canadian Technological Innovation Dataset It is a *population* survey of innovations (known to experts and trade journals). It is a longitudinal dataset covering 2000 new or improved industrial products or processes introduced in Canada from 1945 to 1980. It involves 550 innovating firms and roughly 2500 other companies (customers and suppliers) that were related to the innovating companies with respect to the corresponding innovations. The Canadian Data covers the most significant innovations in terms of technological novelty. In other words, the innovations covered in the Canadian data were all significant technological advancements that depart from previous practices at the industry level. Furthermore, innovations were also categorized according to their novelty in market introduction. Respondents to the questionnaire were asked if their company was the first to market this innovative product in Canada or not. If so, a further question asks whether the same or similar product had been marketed or used outside Canada before. In this thesis, I label those innovations that were introduced in Canada first and had no similar products/services introduced outside Canada before as *pioneering innovations* (approximately 750 world-first innovations among those 2000 innovations in the Canadian Data). I label those innovations that were introduced in Canada first but similar products had been introduced outside Canada before as *new-to-Canada innovations*. The remaining innovations are labeled as *new-to-firm-only innovations*.

The Canadian Data also contains extensive information of the following: the year of commercial introduction, the year of first world introduction, first user firms and industries, competitors, locus of development and contractors. Three key aspects of the Canadian Data ensures that it is representative and appropriate for researches with respect to the role of inter-industrial and geographic difference for firms in different sizes and industries. Firstly, it represents the inter-industrial exchange in Canadian industries. As a result, the data covers 65% of industrial production. Secondly, within the industries covered, firms were of various sizes in terms of number of employees. Finally, the firms covered are representative in various regions in Canada for all each industry.

Setting up of the Canadian Dataset[*]

The Canadian Data was set up by two approaches simultaneously. The first approach was the establishment of a population of innovating enterprises with reports on their most significant innovations using knowledgeable sources, including experts, trade journals, R&D directories, patent holder, etc. The second approach was a random sample survey to insure the representativeness of the survey for Canadian industries.

To establish the population of innovative firms and surveying the population, four sources were used: industrial experts, trade journals, R&D performers and patent holders. All firms mentioned by any of these four sources could be expected a priori to be innovators. Firstly, experts were asked to identify the significant innovations in their area of expertise, and to give dates and firm names associated with these innovations. Then, after this first step, the innovating firms were approached and asked to confirm their innovations. Because the Canadian research team found in Canada the knowledge of experts were usually narrowed down to one or two product lines within an industry or restricted to even one or two firms, they quickly decided to use trade journals as a second and parallel source of screening innovations. These 48 selected trade journals were screened from 1945 to 1975 for descriptions of innovations related to the identified firms. These two sources gave the names of around 1300 firms. A directory of industrially performed R&D centers was used in the survey of experts. Based on the information from this directory of R&D, all R&D performing firms in Canada were surveyed (approximately 2000 firms). Canadian resident firms which were holders of patents from 1972-1977 (approximately 1000 firms) also received the survey. Ontario Development Corpration, Centre de Recherche Industrielle du Quebec provided additional 1200 names of firms that were likely to be innovative. Afterwards, over one thousand innovating firms were sent over three thousand questionnaires in accordance with their innovations. Respondents were asked to confirm the description of the innovations, to reveal the date of commercialization, and to indicate who were the first customers and the key suppliers to the innovation (if any). Other control questions were also asked, such as degree of novelty of the innovation, the competitors, the size of the firms and the industries in which the firms are active (SIC). The response rate was about 70% (for a detailed look of the questionnaire, see Appendix II).

However, the first approach alone was not able to ensure the representativeness of the screened population with respect to the industries in Canada. Table 1 depicts a fraction of the industries covered by the first survey approach with regard to the representativeness of firms in different sizes. Having assessed when and where the population based on the first survey approach was unrepresentative of Canadian industry, the research team used a second method: a random sample survey. The random sample survey served as a supplement to

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[*] This part is adapted from: Chris DeBresson and Brent Murray (1984). "Innovation in Canada- A retrospective survey: 1945-1978, vol. II. Pointers to the study of innovation in Canadian industry: The Canadian Innovation Data Base". *Internal publication reported to the Science Council of Canada.*

the first survey approach. The random sampling was done by industry according to two criteria, namely, firm size and geographic location of the firms. For instance, the population survey did not indicate any innovations in textiles and leather industry. By the random sampling survey, one could found out whether there had been innovations in that industry.

Table 1: Assessment of coverage of industries by the size of firm

	Size (in terms of number of employees)			
Industry	**0-19**	**20-199**	**200-999**	**+1000**
Miscellaneous metal mines	UR	OK	OR	OR
Petroleum & Natural gas	UR	OK	OR	OR
Asbestos mines	OK	OK	OK	OK
Meat & poultry products	UR	OR	OR	OR
Miscellaneous food	UR	OK	OR	OR
Beverage	UR	UR	OR	OR
Plastics fabricating	UR	OR	OK	N/A
Iron & Steel mills	UR	UR	OR	OR
Agricultural implements	UR	OR	OK	OR
Aircraft & aircraft parts	UR	OR	OR	OR
Motor vehicle parts	UR	OR	OR	OR
Railroad Rolling Stock	UR	UR	OR	OK
Electrical industrial equipment	UR	OR	OR	N/A
Pharmaceuticals	UR	OR	OR	OK
Scientific & professional equipment	UR	OR	OR	OK

* UR= Under Representative; OK= Normal Representative; OR=Over Representative.

** The Business Register's file of all Canadian business entities by industry was used to assess the representativeness of the coverage.

In order to be representative about the technological innovations in the Canadian industry, the random sample approach started with choosing those industries which had the most interactions with each other through the supplier-user linkage within the Canadian economy. The underlining assumption was that the industries which have many interactions with the industries of their suppliers and users could very likely be innovative because the technological inputs from the suppliers and the market demand from the users are the key determinants that lead technological development ahead within an economy. Thus, the random sampling chose the following industries: a) industries which were significant domestic suppliers to another; b) industries which supplied a variety of user industries; c) industries which used inputs from a variety of domestic supplying industry; d) those which were significant suppliers to the government; e) and the important exporter industries. As a result, the random sample approach covered 79 industries (see Appendix III). Among these 79 industries, the coverage of the firms in the population, which was the result of the first innovating screening approach, were different. In some industries, all the firms in the population had been covered, and in some other industries, very low percentage of firms in the population had been covered (see Appendix IV).

The Canadian Data surely had its shortcome in its design. The survey was essentially a picture of industrial technological innocation that still existed in 1978, when the survey was conducted. The research team could directly survey only those firms which still existed in 1978. On the one hand, in order to account for major innovations in a national economy, a few decades might be the appropriate time frame. On the other hand, the nature of the survey method inevitable favored the innovations generated in later years than those in the early years. As a result, the Canadian Data was not evenly distributed over time, with 80% of the data was from after 1960. One could not infer from this, however, the rate of Canadian innovation had accelerated since 1960, although this might be the case. The memory of the respondents was skewed towards the recent past. The only reasonable assumption one could make is that the memory of the respondents biases the recent past to the same extent for all industries. Moreover, many enterprises might just bankrupt during these four decades and their technological innovations had been absorbed by other firms.

To reduce the effects of these biases, I firstly excluded the innovations for which the respondents failed to indicate whether an innovation is *new-to-world*, *new-to-Canada* or *new-to-firm-only*; secondly, I also eliminated the innovations for which the answers to the questions with respect to the novelty of the innovation were illogical. This is because these cases are mostly likely to occur when the respondents were asked to recall the innovations introduced in the early years. The selection of the unit of observation varies from chapter to chapter in this thesis, depending on the research questions. For chapter 3 and 4, I applied different methods to select the unit of observation from the Canadian Data, which will be explained in detail in each chapter.

2.3 Corporate Venturing Data

The Corporate Venturing Data was framed specially for the studies on external corporate venturing and innovation. It uses a large amount of secondary data srouces and focus on the pharmaceutical industry. The pharmaceutical industry was chose for investigating the relationships between external corporate venturing and exploration in technological innovations because, 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. Moreover, firms in the pharmaceutical industry are more active in pateting than other industries (Bessen and Meurer 2008). This feature of pharmaceutical industry makes patent citation data more representative and reliable for technological innovations of firms, which allow us researchers to use patent citation data to study the technological innovations in a more confident manner.

The database used in the Corporate Venturing Data was 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.

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.

US PTO

The United States Patent and Trademark Office patent databases include full-text information for all patents applied for in the US. 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. 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).

The first step in setting up the database was the selection of firms. To select the innovating 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 researchers to select both private and public firms. First, the largest companies were selected 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.

After selecting the innovating 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 Thomson ONE Banker was used 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, only technological M&A and minority holdings were included in our sample, following the method by Ahuja and Katila (2001). This method requires technological M&A 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 study is slightly different than the one used by Ahuja and Katila (2001), since there has been no access to the press releases concerning the M&A deals, only deals in which the partner has applied for at least one patent were included.

Financial data was gathered using Worldscope, including sales and R&D expenses. 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).

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 2).

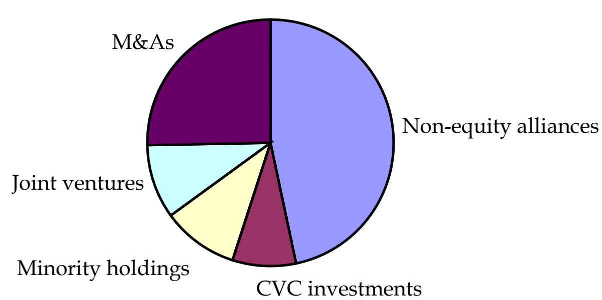


Figure 2. Distribution of different governance modes

2.4 Variables

In this thesis, a considerable number of variables have been defined and operationalized in order to test the hypothesized relationships between different consructs. Appendix V provides an overview of the variables used in this thesis. A more detailed description of the operationalization of these variables can be found in the respective chapters.

Chapter 3

The Effects of Inter-industry and Country Difference in Supplier Relationships on Pioneering Innovations*

3.1 Introduction

Innovative firms are increasingly generating new knowledge in collaboration with partners. Studies on strategic management and innovation have recognized that innovation is an interactive, cumulative and cooperative phenomenon occurring between different organizational actors (Powell et al., 1996; Gulati, 1999; Nooteboom, 2000; Freel, 2003; Zaheer and Bell, 2005). A large number of studies have paid attention to the role of strategic alliances and corporate venturing in generating technological innovations (Rothaermel and Deeds, 2004; Hagedoorn and Duysters, 2002). Other scholars have investigated the role of customers in generating innovations (Narver and Slater, 1994; Christensen and Bower, 1996). Complementary to these research efforts, this chapter focuses on the role of suppliers as collaborators in the innovation process. More precisely, we analyze how supplier relationships are likely to result in pioneering innovations that are not only technologically novel, but are also first introduced to the world.

The novelty of innovations lies in the differences between the component elements, or the novel ways in which these elements are recombined (Nooteboom, 2000). The important role that knowledge differences play in respect of a firm's innovation performance has been widely discussed in the existing innovation literature (e.g., Jaffe and Trajtenberg, 2002; Rosenkopf and Nerkar, 2001; Ahuja and Lampert, 2001; Katila and Ahuja, 2002). Dissimilar external knowledge comes from having different resources, which can be investigated in respect of different dimensions. We focus on two dimensions that might have major influences in explaining the likelihood of pioneering innovations. Firstly, knowledge differences between the innovating firms and their suppliers can be explained by the inter-industry difference between them (Dosi, 1988; Romeo, 1975), which depicts the cognitive dimension of knowledge difference. Secondly, firms' geographic localization matters in innovation as well (e.g., Asheim and Isaksen, 2002). Innovating firms and their suppliers do not necessarily originate from the same country. Country difference captures the differences between the national contexts in which firms are located (Phene et al., 2006). Our focus on the roles of inter-industry difference and country difference as sources of dissimilar knowledge in respect of generating pioneering innovations also reflects the call for more insight into the interplay between sectoral and national patterns of innovation, which is still under-developed in the literature (Morgan, 2004).

* This chapter is based on: Li, Y., Vanhaverbeke, W. and Nooteboom, B. "The Effects of Inter-industry and Country Difference in Supplier Relationships on Pioneering Innovations", paper presented on the Academy of Management annual meeting 2008, Anaheim, CA, USA.

To examine the roles of inter-industry and country difference on pioneering innovation, we confine our research to the relationships between the innovating firm and its suppliers. Besides strategic alliances, corporate venturing and customers, the supplier relationship is an important source of creativity in innovation. Nevertheless, the relationship between supplier involvement and firms' innovation performance remains unclear in the literature. Research on supplier involvement has addressed the importance of involving key suppliers in new product development projects (e.g., Dyer, 1996, Handfield et al., 1999; LaBahn and Krapel, 2000; Takeishi, 2001). However, other researchers have found that supplier involvement may not always have a positive effect on new product development project because supplier involvement requires greater complexity for project management (Wynstra, 1998; Wynstra and ten Pierick, 2000). In this chapter, we use the knowledge difference perspective to investigate the complexity of the interactions between suppliers and the focal firms' innovation performance. The central research question of this chapter is therefore: What are the effects of sectoral difference and country difference between the innovating firm and its suppliers on a firm's ability to generate pioneering innovations?

This article is organized as follows. Firstly, we define pioneering innovations. Secondly, we provide the theoretical background on sectoral and country dimensions regarding knowledge difference and how suppliers are involved in generating pioneering innovation. Thirdly, we develop several hypotheses based on the existing literature. Next, we present the data and estimation methods with which to test the hypotheses. Finally, we discuss the results and draw conclusions for our research.

3.2 Theory and Hypotheses

3.2.1 Pioneering innovation as a specific type of exploration

Innovations are critical driving forces for firms to engage in corporate growth and new business development. Before we explain theories and build hypotheses, it is important to define what pioneering innovations refer to with regard to exploration in this chapter and in chapter 4. In the existent literature, exploration and exploitation have been usually used as synonymous with "radical innovation" and "incremental innovation", respectively (Jansen *et al.,* 2006; Benner and Tushman, 2003). In the first place, in contrast to incremental innovations, radical innovations represent a fundamental departure from existing practices (Dewar and Dutton, 1986; Tushman and Anderson 1986). The criterion here is whether the innovation is novel or based on existing practice. Many researchers have focused on the *technological* novelty when defining radical innovation (Dewar and Dutton, 1986; Ahuja and Lampert, 2001; Nerkar and Roberts, 2004). For instance, Greve (2007) measured exploration as the number of innovations that involved the development of new technology that is 'new to the firm", and exploitation as all other types of innovations. However, if exploration has to be represented by certain types of innovation, one needs to consider both the technological and the market novelty of the innovation. It has been accepted that an innovation is the unique combination of technological novelty and appropriate market access (Fleming, 2002; Nerkar and Roberts, 2004). An invention only becomes a successful innovation if it has marketable use. The novelty criterion for innovations should not only be judged from the *technological* domain, but also from a *product-market* perspective. Therefore, slightly different than the definitions of radical innovation in the existent literature which has focused on the technological novelty of innovations, we emphasize the market-side of novelty with regard to the definition of pioneering innovations. A typical characteristic of pioneering innovations is that they are marketed first to the world. To market a technological invention first in the world, a firm inevitably needs to take great risks and deal with a considerable level of uncertainty, which is highly exploratory.

Therefore, in this chapter, we define those product innovations that are technologically new at the industry level and introduced first to the world as *pioneering innovations*. This definition considers both the technological and market novelty of innovations because, contrary to technological inventions, innovations require not only scientific and technological knowledge, but also product-market knowledge (Chesbrough, 2003).

3.2.2 Diverse external knowledge from different industries and nations

Innovating firms are increasingly generating new knowledge in collaboration with partners. Innovation is an interactive, cumulative and cooperative phenomenon occurring between different organizational actors (Powell et al., 1996; Gulati, 1999; Nooteboom, 2000; Freel, 2003; Zaheer and Bell, 2005). The traditional *closed* innovation process, based on economies of scale in R&D, is in many companies gradually being replaced by a more open innovation process in which different innovation partners work together (Chesbrough, 2003). External knowledge is crucial for innovation because, in the first place, any innovation is considered the result of a recombination of component elements (Schumpeter, 1934; Henderson and Clark, 1990; Kogut and Zander, 1992). Single organizations usually do not possess all the knowledge to undertake innovation internally. Innovations, in this case, can only be achieved by collaborating with enterprises that have different knowledge bases (Nieto and Santamarí, 2007). Firms differ regarding R&D, production efficiency, input and output of innovation, technological capabilities, etc. (Dosi, 1988). Difference in knowledge is a crucial condition for learning and innovation to produce a Schumpeterian 'novel combination' (Nelson and Winter, 1982). Thus, pioneering innovations, which create growth opportunities for the firm by combining new technologies with new market approaches, are more likely to emerge when inter-organizational interactive learning takes place.

Differences in the knowledge-base between the innovating firm and its partners can split into multiple dimensions. For example, various researchers have studied the role of knowledge differences between partners regarding the likelihood of breakthrough innovations in terms of technological distance (e.g., Ahuja and Lampert, 2001; Nerkar and Roberts, 2004; Phene *et al*., 2006). The technological distance is usually measured by means of differences in patent classes or patent citations. However, technological distance is only one of the various dimensions in which innovating firms and their collaborators differ from each other.

The uneven distribution of economic competence is not only firm-specific, but also industry-specific (Nelson, 1991). Diversity between industries takes the form of R&D, production efficiency, market structure, innovation, technology intensity, resource endowment, etc. (Dosi, 1988). Industries also differ in the degree to which firms are able to capture the rents generated by their innovations (Anand and Khanna, 1997; Teece, 1986). These differences accumulate over time due to organizational inertia and path dependence (Nooteboom, 2000). The aggregation of these differences across industries results in the inter-industry differences in the knowledge base. Therefore, we focus on the inter-industry difference as an aggregated dimension along which firms differ from each other. Differences between firms along the industrial dimension may create a potential for novel combinations.

However, searching for external new knowledge inevitably involves a geographic dimension. In the global market context, geographic proximity plays an important role in knowledge flows (Verspagen, 1993). At the macro level, geographic dimension is a matter of differences between nations. Differences between countries with respect to language, institution, and culture may form obstacles regarding communication and coordination between firms (Kress, 1992; Lundvall, 1992; Nelson, 1993; Chesbrough, 1999; Oliver, 1997; Hofstede, 1980; Herrera and Nieto, 2008). The literature on international business has found inconsistent evidences for the role of country difference on firm performance (Park and Ungson, 1997; Meschi and Riccio, 2008). Therefore, the role of country difference regarding pioneering innovation deserves careful investigation as well. In this chapter, we focus on a specific collaborative relationship—suppliers relationship—to examine the influence of the interplay between sectoral and national patterns of innovation.

3.2.3 Innovation with supplier involvement

Firms have various types of collaborative relationships. The various natures of inter-firm relationships determine the differences in the way mutual learning occurs, which, in turn, have different implications for innovation performance. The customer and supplier relationship is one of the most important industrial relationships. Studies on market orientation, supplier involvement and firm performance are by no means new in marketing research literature (e.g., Jaworski and Kohli, 1993; Narver and Slater, 1990, 1994; Von Hippel, 1986; Lundvall, 1986; Dyer, 1996; Handfield *et al*., 1999; LaBahn and Krapel, 2000; Wynstra and ten Pierick, 2000; Takeishi, 2001). Many firms have increasingly realized that supplier involvement in new product development is critical to reduce costs and the concept-to-customer development time, to improve quality, and, most importantly, to provide innovative knowledge that can facilitate innovations (Chang et al., 2006). For example, Chrysler Corporation pre-sourced 95% of the parts required for production and chose suppliers before the parts were even designed (Handfield *et al*., 1999, pp60). Selected component suppliers are sometimes invited to participate in new product development. Of all the inputs of suppliers, technology and know-how are probably the most important elements (Håkansson, 1982; von Hippel, 1988).

Each industry has its unique knowledge base. While the learning opportunity lies in the differences between the industries in which the innovating firms are active, the question is how knowledge difference between the innovation firm and its suppliers contributes to the generation of pioneering innovation across industries. From the Schumpeterian perspective, new knowledge is created from the combination of new components, or new ways of recombining existing components (Schumpeter, 1934; Henderson and Clark, 1990). Pioneering innovations require firms to apply completely new technology to create a new market, which is a highly exploratory activity (March, 1991). Exploration is usually defined as consisting of activities that search for unfamiliar, distant, and remote knowledge (Benner and Tushman, 2002; Rosenkopf and Nerkar, 2001; Ahuja and Lampert, 2001; Katila and Ahuja, 2002). Firms with large inter-industry difference in their knowledge base are more likely to obtain access to complementary information, resources and knowledge. Therefore, we hypothesize:

Hypothesis 1: Inter-industry difference between the innovating firm and its suppliers has a positive effect on the likelihood of generating pioneering innovations.

However, as novelty is a source for innovation, firms also need sufficient organizational capabilities to digest novel knowledge and to develop it into marketable products or process. At the organizational level, this critical organizational capability has been recognized as absorptive capacity (Cohen and Levinthal, 1990). Absorptive capacity includes organizational capabilities to assimilate externally developed information, to internally distribute it, and implement knowledge in various activities. Due to different experiences, technologies, markets and organizational histories, organizations have different foci, which yield cognitive distance between organizations (Nooteboom, 1999, 2000, 2004). On the one hand, learning takes place where there are differences in knowledge. On the other hand, too large cognitive distance makes basic mutual understanding unachievable (Gilsing and Duysters, 2008). Many studies have found that though difference in knowledge is a crucial condition leading to novelty in innovation (Nelson and Winter, 1982), it also has a negative effect on absorptive capacity because it creates learning problems resulting from the lack of basic mutual understanding between each other. For instance, Stuart (1998) argues that the most valuable alliances are those with similar knowledge foci and/or operating in similar markets, whereas distant firms are inhibited from cooperating effectively. Similarly, the diversification literature argues that firms learn most from alliance partners with related knowledge and skills (Tanriverdi and Venkatraman, 2005). Goerzen and Beamish (2005) found that the diversity of an MNE's alliance network has a negative impact on its economic performance since the challenge of managing an increasingly complex alliance network could overwhelm the marginal benefits. These studies have revealed the importance of cooperation between firms with a minimum degree of similarity in their knowledge base in order to maintain sufficient absorptive capacity.

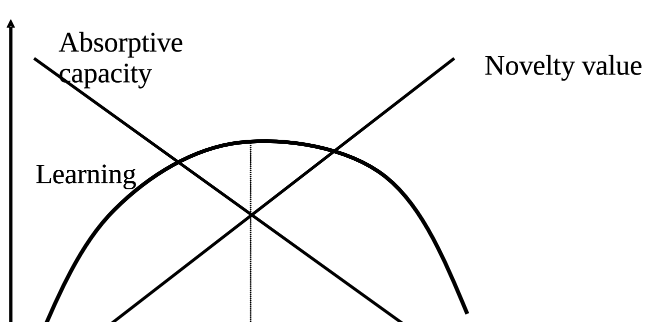


Figure 3: Implications of cognitive distance on novelty and absorptive capacity (source: Nooteboom 1999).

Given the possible positive effect of knowledge difference on novelty and the possible negative effect on firms' absorptive capacity, the combined effect of cognitive distance on innovation is expected to be a curvilinear function of innovation performance (see figure 3). While the concept of cognitive distance represents the general knowledge difference between social actors, the inter-industry difference between the innovating firm and its suppliers can be interpreted as one of the specific dimensions of cognitive distance. Hence, the rationale for cognitive distance regarding innovation can be applied to inter-industry difference as well. Accordingly, we hypothesize:

Hypothesis 2: Inter-industry difference between the innovating firm and its suppliers has a curvilinear effect (inverted U shape) on the likelihood of generating pioneering innovations.

Besides the knowledge difference based on different industries, the innovating firm and its suppliers that are involved in innovation are also subject to the different national contexts, if any suppliers are foreign. The literature on international business has found inconsistent evidences regarding the role of country differences on firm performance. For instance, Park and Ungson (1997) found national culture difference to have a positive effect on the survival of international joint ventures, while Meschi and Riccio (2008) found national culture differences between local and foreign partners to have a negative effect on the stability of international joint ventures.

To investigate the effect of country difference on innovation, we argue that it is necessary to carefully examine the various facets of country difference besides national cultural difference. The difference between countries takes on specific national characteristics due to different institutions (Morgan, 1997), culture (Hofstede, 1980), language (Kress, 1992), technology specialization (Frost, 2001), etc. These different factors of country differences may jointly affect the learning and innovation between the focal firm and its suppliers, while some factors may have a somewhat stronger effect than others due to the specific type of innovation activity.

In respect of pioneering innovation, national technology specialization of suppliers may, on the one hand, provide innovating firms with stimuli and resources resident in the heterogeneous country environments in which they operate (Frost, 2001). On the other hand, the differences in institution, culture and language may have major effects that hinder the generation of pioneering innovation. This is due to pioneering innovations usually departing from the existing knowledge base and creating a new technology trajectory and market segment. This trajectory and segment are usually unique and specific, and therefore not suitable for mass production (Nooteboom, 2000). Therefore, the unique feature of pioneering innovations usually lies in sticky knowledge (Von Hippel, 1994; Szulanski, 1996), which is more likely to be transmitted within a close geographical area with sufficient interactions and joint practices (Asheim and Isaksen, 2002). Sticky knowledge requires close communication between the innovating firm and its suppliers, thus it is better to choose suppliers from countries with a similar language and culture. Furthermore, from a transaction cost economy perspective, if the result of pioneering innovation is highly uncertain, innovating firms should choose suppliers from nearby countries for cost economization's sake. Consequently, we argue that specifically in respect of pioneering innovations, the negative effect of country difference due to communication and coordination concerns may overwhelm the possible positive effect due to national technology specialization. Hence, we postulate:

Hypothesis 3: Country difference between the innovating firm and its suppliers has a negative effect on the likelihood of generating pioneering innovations.

3.3 Variables and Method

The dataset used for this chapter is the Canadian data. The description of the data can be found in chapter 2. To test the hypothesized relationships in this chapter, we applied three criteria to select a sample from this Canadian data. Firstly, we eliminated the innovations whose innovating firm had no suppliers because we are interested in industry and country differences between the innovating firms and their suppliers[4]. Secondly, we also eliminated those innovations for which the respondents failed to indicate whether an innovation is new-to-world, new-to-Canada or new-to-firm-only. Finally, suppliers of innovating firms supplied different types of resources. Such resources can be categorized as financial support, raw materials, technology, engineering and joint development. We excluded the innovations for which the innovating firm's suppliers only provided financial support or raw materials, because we assume that little mutual learning occurs between innovating firms and suppliers in such cases. This selection finally results in 510 usable observations.

3.3.1 Dependent variable

[4] Those eliminated were completely internally developed and consumed innovations which did not use any external supply and were not introduced to the market.

The dependent variable is a binary variable which indicates whether an innovation is pioneering or not. By definition, pioneering innovations are not only novel in terms of technology, but the innovating firm also explores new market opportunities. Innovations are labeled into three categories depending on their novelty: new-to-world, new-to-Canada, and new-to-firm only. The new-to-world innovation is not only technologically new for the innovation firm, but is also introduced to a completely new market for the first time worldwide. New-to-firm-only innovations are technologically new to the innovating firm, but similar products have been introduced to Canada. The new-to-Canada innovations usually represent the early adoption of advanced technologies, which have been developed in US in most cases. Therefore, we define those innovations that were introduced to Canada first and with regard to which no same or similar products/services had been introduced outside Canada previously, as the pioneering innovations (new to the world), while the rest of innovations are not pioneering ones.

3.3.2 Independent variables

The explanatory variables are the 'inter-industry difference' between the innovating firm's and its suppliers' primary industry and the 'country difference', which entails language, institution and cultural differences between the innovating firm and its suppliers.

Inter-industry difference. The only consistent information that may approximate the diverse knowledge base between industries that we can obtain from the original Canadian data is the SIC code for the innovating firms, suppliers and customers. Firms that are active in a particular industry continually invest and undertake commitments to improve their technological capabilities. Owing to organizational inertia (path dependence) and limited resources, firms in a particular industry accumulate similar knowledge, which is specific to the industry. Firms therefore inevitably distinguish their knowledge base from those of firms in other industries. Firms positioned at different stages of an industry's value chain enjoy complementary or related technologies that provide them with a certain degree of common knowledge despite differences in their specialties. Finally, firms in totally different industries have completely different knowledge bases and technological capabilities (Romeo, 1975; Cohen and Levinthal, 1989). Following Keil *et al*. (2008), who demonstrate that the SIC code is a satisfactory proxy for knowledge relatedness between firms, we use the information provided by the SIC code to construct a measurement for diverse knowledge between industries.

The Canadian data has used a unique 3-digit hierarchical classification system to indicate the main industry in which the firms are active. A difference between two companies in the SIC's first digit indicates that these two companies have the largest possible difference. If firms' first digit SIC codes are the same, but differ in respect of the second, we assume that the difference has a medium value. If the SIC labels only differ regarding the third digit, we assume that the industries to which the firms belong are very similar. Of course, firms with the same SIC code belong to the same industry and are assumed to have a common knowledge base. If an innovating firm has more than one supplier, we calculated the mean value for the inter-industry difference between the innovating firm and all its suppliers.

Country difference. Knowledge evolves in a distinctive manner in each national context (Phene *et al*., 2006). Since our hypotheses are based on a communication perspective, it is logical to measure country difference from various dimensions that are crucial for collaborative learning and communication. When firms are involved in collaborative learning, a few factors inevitably affect their learning process and the outcome of learning. First of all, *language* plays an important role to ensure good communication between technical personnel and managers from different firms and to cultivate an innovative culture (Kress, 1992). Secondly, countries also differ regarding *institutional factors*, which are also found to be crucial for innovation (Lundvall, 1992; Nelson, 1993; Chesbrough, 1999; Oliver, 1997). Finally, Hofstede's (1980) *culture* parameters, which have been widely used in strategic management studies, measure national culture difference in a unique manner. Therefore, we measure country difference in terms of language, institution and Hofstede's culture parameters[5]. We first developed a continuous scale to measure the average language differences between the innovating firm and its suppliers, based on whether the firm is French-speaking, English-speaking, speaks other languages that use the Latin alphabet or speaks non-Latin alphabet languages. Secondly, we also introduced a continuous scale to capture the average institutional differences between the innovating firm and its suppliers, based on whether the firms are in Canada, Commonwealth nations or non-Commonwealth nations. Finally, we used the score of each nation's culture parameter as developed by Hofstede to measure the average culture differences between the innovating firm and its suppliers. Thereafter, we conducted a factor analysis to determine whether there is a common factor regarding country difference. The result indicates a single factor is sufficient to capture almost 88% of the variance in country difference (see table 2). Thus, we used one variable to measure country differences. The factor score is the value of this variable.

Table 2. Factor analysis for measuring Country Difference

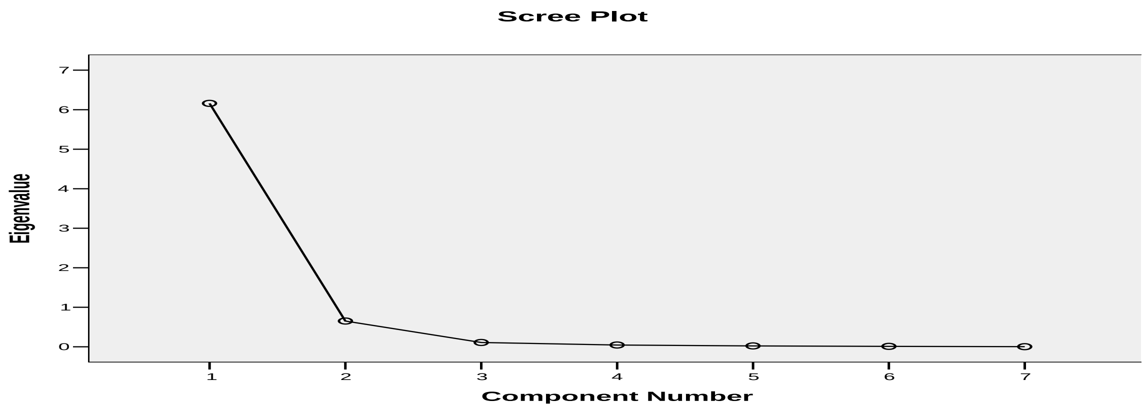
Total Variance Explained (Supplier relationship)

Component	Initial Eigenvalues	Extraction Sums of Squared Loadings

[5] A detailed explanation of the scales for language difference, institutional difference and Hofstede's culture parameters is available upon request.

	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	6,160	87,999	87,999	6,160	87,999	87,999
2	,652	9,308	97,308			
3	,108	1,548	98,856			
4	,045	,640	99,496			
5	,022	,314	99,809			
6	,011	,151	99,960			
7	,003	,040	100,000			

Extraction Method: Principal Component Analysis.



3.3.3 Control variables

Firm size. Firms of different sizes innovate differently. In the classical Schumpeterian argument, companies' innovation performance increases more than proportionally with firm size due to large firms simply having more resources. They are most likely to be more effective in respect of innovation than small firms and will therefore dominate the market. Small companies may be more likely to explore new technological areas by innovating in less crowded areas (Almeida and Kogut, 1997). Further, firm size is also related to the capacity to cooperate, which is crucial for inter-organizational learning and absorptive capacity (e.g., Shan, 1990; Powell and Brantley, 1992). Since firm size has been shown to influence firms' innovation performance, it is important to control for this variable. We measure firm size using the number of employees as also done in prior research (e.g., Goerzen and Beamish, 2005). We use an ordinal scale to measure the size of a firm, which is derived directly from the questionnaire of the Canadian survey (size=1 for 0-19 employees, size=2 for 20-199 employees, size=3 for 200-499 employees, size=4 for 500-999 employees, and size=5 for more than 1000 employees).

Prior Experience. Innovating firms also differ in their experiences in respect of generating radical innovations. On the one hand, firms with more successful experiences accumulate knowledge on how to cooperate with suppliers and how to deal with divergence, conflicts and compromises. These firms' enhanced absorptive capacity is more likely to lead to new ideas being generated. On the other hand, successful experience may also trap innovating firms in exploitative innovations instead of exploratory innovations (Ahuja and Lampert, 2001; Audia and Goncalo, 2007). Therefore, we need to control for the effect of prior experience in generating radical innovations. We define prior experience as the ratio of the number of new-to-world innovations to the total number of innovations for the past 10 years.

SIC category of innovating firms. There are innovating firms in all industries. Earlier studies have found that firms in different industries vary in their appropriability regime, which is the degree to which firms are able to capture the rents generated by their innovations (Anand and Khanna, 1997). The appropriation concern constrains firms' motivation regarding producing radical innovations, depending on whether the appropriability regime of industry is loose or tight (Teece, 1986). Thus, we control for the innovating firms' industry. We use nine dummy variables (the default is the industry that has a SIC code of which the first digit is a zero) to measure whether or not an innovating firm is active in a broad industry category. The SIC code is an approximation of the industry in which a firm is active. For instance, if the SIC codes of two innovating firms are 351 and 472, respectively, a dummy variable representing a "300" industry category will have a value of "1" for the former and "0" for the latter. A dummy variable representing a "400" industry category will have a value of "0" for the former and "1" for the latter.

Time. The Canadian dataset contains innovations from 1945 until 1980. Time may have an effect on the likelihood of radical innovation as well. On the one hand, one could argue that firms benefited from the more advanced technology in the 1970s compared to 1940s due to the increasing prominence of science and technology in creating competitive advantage. Hence, we expect that the chance of introducing pioneering innovations might be higher at the end of the observation period. On the other hand, it is also possible that in the later years, it was more difficult to introduce pioneering innovations because the world market and technology were far better developed than in the early years, so that there were fewer opportunities to introduce pioneering innovations. We use three alternative measures to control for the effect of time. We first introduce three dummy variables (default is the 1940s) to represent any decade-specific effects on the dependent variable that are not captured by the independent variables. Secondly, instead of using dummy variables for the four decades, we used dummy variables to control for the consecutive five-year period. Finally, we also use a trend variable for years.

3.3.4 Method

Our data has no skewed distribution with respect to the dependent variable (with 39 percent of the sample valued at '1', and 61% percent at '0'). We use a binary logistic regression model to test our hypotheses, given the binary nature of the dependent variable.

3.4 Results and Discussions

The descriptive statistics and correlations between the variables are presented in table 3. First, we found that the innovating firm tends to have suppliers that are of medium level of inter-industry differences, i.e. they have the same first digit in the 3-digit SIC but the second digit is different (average inter-industry difference of 1.888). Second, since we use the factor score as the value for the 'country difference' (including dimensions as language, institution and Hofstede’s culture parameters), this variable is normally distributed with zero mean and 1 as standard deviation. Next, inter-industry difference is positively correlated and country difference is negatively correlated with pioneering innovation (correlations 0.214 and -0.206, respectively), which is in line with our expectations. For the control variables, the average size of innovation firms is 3.16, which means a firm with slightly more than 500 employees. We found no high correlations between any pairs of variables, thus multicollinearity problem is not concerned.

Table 3. Descriptive statistics

Correlations[a.]

	Radical Innovation	Inter-industry difference	Country Difference	Prior Experience	Firm Size
Radical Innovation	1				
Inter-industry difference	,214	1			
Country Difference	-,206	-,392	1		
Prior Experience	,082	,076	-,063	1	
Firm Size	-,128	-,317	,297	,162	1
Mean	,390	1,888	0.000	0,196	3,160
s.d.	,489	1,247	1.000	0.330	1,483

N=510,

[a.] Dummy variables *Decade* (D50, D60, D70) and *Industry category* (SIC00, 01, 02 through 09) as control variables are not listed in the table.

Table 4 presents the results of binary logistic regression to test our hypotheses[6]. All models meet the Hosmer-Lemeshow test, which means they all have non-significant chi-square, indicating that the data fit the models well. We started with a base-line model with only control variables included in the regression, and then introduce country difference, inter-industry difference and the quadratic terms of inter-industry difference into the model step by step. Compared to the base-line model, the likelihood ratio test shows that other models

[6] Instead of using the four separate dummy variables for four *Decades*, we also used two different ways to control the effect of time. First, we introduce a *Year-trend* variable with continuous measure of year; second, we used dummy variables to control every five years. The results show that the model fit and significance of effects for each main variable are similar to the models using four separate dummy variables for four decades. Therefore, hereby we only report the results by using four separate dummy variables for decades. We also try to include the interaction term of country difference and inter-industry difference into the model. The results show that by introducing the interaction term, the model fit decreases and the interaction term does not have any significant effects on the dependent variable in any case.

have stronger explanatory power. The results demonstrate some support for our hypotheses. First, the coefficients of inter-industry difference have a positive sign and statistically significant (model 3, 4, 5 and 6, respectively, $\beta = 0.349$, $p<0.01$; $\beta = 0.300$, $p<0.01$; $\beta = 0.890$, $p<0.05$; $\beta = 0.779$, $p<0.05$). Thus, Hypothesis 1 is supported. Second, we include the quadratic term of inter-industry difference in model 5 and model 6 (the full model). The coefficients show a negative sign but not statistically significant. Thus, hypothesis 2 found only partial support. A possible reason for this is perhaps that the measurement of inter-industry difference using SIC constrains this variable from having large values. Thus, we only found the upward side of the inverted U-shape relationship (which is demonstrated by the positive effect of inter-industry difference on pioneering innovation), but not the downward side of the slope. It is also possible that the key source of creativity lies in the technology distance between firms, regardless in which industry a firm is active. Therefore, using SIC-codes may not well represent the differences in technology profiles between the innovating firm and its suppliers. Finally, the coefficients of country difference have a negative sign and are statistically significant (model 2, 4 and 6, respectively; $\beta = -0.313$, $p<0.01$; $\beta = -0.220$, $p<0.1$; $\beta = -0.220$, $p<0.1$). Thus, hypothesis 3 is supported.

We also found that the coefficient of firm size has a negative sign and the coefficient of prior experience has a positive sign. Both of them have a significant effect in the base-line model (Model 1, respectively, $\beta = -0.176$, $p<0.05$; $\beta = 0.529$, $p<0.1$). That implies that, first, during the period of 1940's till 1980's small Canadian firms are more likely to generate pioneering innovations while large firms are usually trapped with what they are good at although they might have greater resources than the small firms. This finding is in line with some arguments in the existing literatures (e.g., 'disruptive technology' by Christensen, 1998). Second, firms with greater successful experiences in generating pioneering innovations perhaps learn how to deviate from their existing knowledge base and feel more comfortable to explore new opportunities. This implication is different than some viewpoints in the existing literature on exploitation and exploration (e.g., March, 1991; Audia and Goncalo, 2007), which argue that successful exploration leads to exploitation and eventually drives out further exploration. We argue that in the short run, to maximize the benefit of radical innovation, the following-up of exploitation right after exploration is inevitable. However, in a long run, firms with successful experience in making radical innovations benefit from high return, which gives firms strong incentive to explore again to find the new wave of profit. With their successful experience, they are more likely to know how to escape their own knowledge traps and ensure survival in the long run.

3.5 Conclusions

This study investigates the impact of knowledge difference between firms on the likelihood for a firm to generate pioneering innovations. It decomposes the knowledge differences into two dimensions: the industrial dimension and the geographic dimension in national context. We argue that inter-industry difference may have a positive effect. The impact of country difference was explained based on two different lines of argument. On the one hand, innovating firms may need to seek meta-national advantage by choose suppliers globally. On the other hand, due to the sticky knowledge inherent in pioneering innovations, large country difference may hinder the communication and coordination. The result shows that the country differences have a negative effect on the likelihood of generating pioneering innovations, which implies that the learning and communication concern may overwhelm the possible positive effect based on the technology specialization across nations. Furthermore, the theory of organizational cognitive distance (Nooteboom, 1999, 2000) is used to explain why that the inter-industry difference between the innovating firm and its suppliers has a curvilinear effect (inverted U-shape) on the likelihood of pioneering innovations.

Our study contributes to the existing literature in several ways. First, studies on the influence of knowledge difference usually use patent data to measure technological distance or geographical proximity, which inevitably overlook the distinctive industrial relationships between firms (such as Ahuja and Lampert, 2001; Nerkar and Roberts, 2004; Phene et al., 2006). Other studies that investigate the relationship between customer orientation, supplier involvement and innovation fail to explore the impact of external knowledge differences between firms in multiple dimensions (such as Johnsen et al., 2006). Our paper, thus, investigates the specific relationship between innovating firms and their suppliers.. It focuses on the influence of inter-industry and country difference between the innovating firms and their suppliers on a particular type of innovation—pioneering innovation. The findings of our analysis are not completely in line with the existing literature, which may suggest the importance of distinguishing certain types of inter-firm relationships when examining the role of knowledge differences between firms in respect of firms' innovation performance. Secondly, this chapter explicitly clarifies the definition of 'pioneering innovation' by recognizing its technological and market novelty. In this way, it avoids the fuzzy use of 'breakthrough or radical innovation' as used in other studies (Ahuja and Lampert 2001, Phene *et al*., 2006). Next, the findings of our analysis refute the thesis of 'death of geography', which claims diminishing differences between nation-states because of the growing role of multinationals and the increasing market globalization (Ohmae, 1990). We found that large country differences between innovating firms and their suppliers hinder the likelihood of creating pioneering innovations.

Our findings also provide several important implications for innovation management. Firstly, to enhance the likelihood of generating pioneering innovations, firms need to explore various resources outside of the organizational boundary. Firms should actively search for new knowledge across industry boundaries and geographic locations. Generally speaking, firms should develop and maintain sufficient similarity in searching external knowledge resource along sectoral and geographic dimensions to assure basic absorptive capacity, meanwhile opening up the variety to allow novelty. Secondly, firms should understand how to differentiate knowledge searching strategy accordingly in supplier relationships. On the one hand, it is beneficial to search for suppliers from distant industries due to the value of new knowledge elements and new ways of recombination. On the other hand, for the sake of communication, coordination and logistic cost, the innovating firms should choose suppliers from unfamiliar industries that are located in Canada or nearby countries. Firms should learn how to combine the effects of inter-industry differences and country differences in supplier relationships and maximize the likelihood to create pioneering innovations. Firms can develop a strategy to enhance innovations by seeking suppliers from unfamiliar industries but preferably in the domestic or neighbouring markets.

Our study also has several limitations. Firstly, the data is collected for the period of the 1940s till 1980s, when IT technology has not been well developed yet. One can reasonably expect that communication between firms is much easier than ever by means of IT technology in the 21 century. Thus the negative effect of country difference on absorptive capacity may be decreased if tacit knowledge is not a major concern. Whether country difference still plays the same role for stimulating innovation as we reveal in this chapter may be questionable in the new era. It will be interesting to test same hypotheses with more recent data. Secondly, the innovating firms in our dataset are all Canadian firms. Thus it is an open question whether our findings can be generalized. We argued in the previous sections that each country holds its unique endowment for innovation (Nelson, 1991). Studies using data of innovating firms from various countries may increase the generalizability of the findings. Finally, we found that, in general, the coefficients of the squared term of inter-industry differences are not significant. This unexpected result could be an artefact as our measure of inter-industry differences using SIC-code is only a raw proxy. Constrained by the original design of the Canadian survey, we could not develop a more precise measure. Future research that uses other measures to indicate inter-industry difference may deliver a better understanding of the impact of inter-industry difference between innovating firms and their suppliers. Patent data might be a help in that respect.

This chapter highlights the fundamental issue of utilizing diverse external knowledge as resources for radical innovations. The findings show that the value of external knowledge in collaboration with suppliers is affected by the inter-industry differences and by the geographical proximity between the innovating firms and their suppliers. This chapter, on the one hand, explains that the strategy to search for new external knowledge should be appropriate with the underlying industrial relationship; on the other hand, brings new insights for managing suppliers' involvement in respect of pioneering innovation by considering suppliers' industrial and national differences between the innovating firms and their suppliers.

Table 4: Binary logistic regression—Effects of Inter-industry and Country difference on the possibility of generating radical innovations [a]:

Variable	Model 1 (Base)	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Intercept	-20.324 (40195.817)	-20.239 (40193.159)	-21.769 (40189.789)	-21.502 (40202.228)	-20.522 (40195.676)	-21.728 (40186.765)	-21.761 (40190.963)
Country difference		-0.313*** (0.109)		-0.220* (0.113)	-0.311*** (0.108)		-0.220* (0.113)
Country difference^2					0.195 (0.218)		0.218 (0.221)
Inter-industry difference			0.349*** (0.096)	0.300*** (0.101)		0.890** (0.387)	0.834** (0.396)
Inter-industry difference^2						-0.178 (0.123)	-0.177 (0.125)
Firm Size	-0.176** (0.072)	-0.120 (0.076)	-0.096 (0.075)	-0.069 (0.078)	-0.117 (0.077)	-0.109 (0.076)	-0.079 (0.079)
Prior experience	0.529 * (0.306)	0.417 (0.312)	0.423 (0.310)	0.355 (0.314)	0.412 (0.312)	0.425 (0.309)	0.351 (0.314)
Likelihood ratio test (relative to model X)	--	18.65*** (model 1)	13.81*** (model 1)	27.60*** (model 1)	0.801 (model 2)	2.10 (model 3)	11.78*** (model 5) 14.53*** (model 6)
Cox & Snell R^2	0.089	0.106	0.115	0.123	0.107	0.118	0.128

N=510,

* $p< 0.1$; ** $p< 0.05$; *** $p< 0.01$

[a]. Coefficients for dummy variables *Decade* (D50, D60, D70) and *Industry category* (SIC00, 01, 02 through 09) as control variables are included in all models, but not listed in the table.

Chapter 4

The Relationships between Foreign Competition, Absorptive Capacity and Pioneering Innovations*

4.1 Introduction

Competition has been recognized as a major driving force behind the successes of organizations (Alderson, 1965; Porter, 1980; Nelson and Winter, 1982). A competitive paradigm has been prevailing in the strategic management theory and practice (Caves, 1996; Porter, 1980). In the context of Schumpeterian competition (Schumpeter, 1934), a firm's long-run success is no longer merely a matter of improving the effectiveness and efficiency of existing businesses. More importantly, the sustainability of competitive advantage will depend on the extent to which the firm is able to develop capabilities to innovate (Nelson, 1991).

The relationships between competition and innovation have drawn great attention from economists and strategic management researchers (Amendola *et al*., 2000; Aghion *et al*., 2005; Tang, 2006; Greenhalgh and Rogers 2006; Smith and Sharif, 2007). However, the empirical evidences on the relationship between competition and innovation remain inconclusive. On the one hand, the Schumpeterian viewpoint credits that the large firms with substantial monopoly market power have resources and incentives to innovate. On the other hand, it is also possible for a monopolist to have incentives to suppress subsequent innovation (Weinberg, 1992). The argument from Arrow (1962) that a perfectly competitive market is more likely to foster innovation than a monopoly market has been supported by some empirical studies, which found a positive linear effect of competition on innovation (Blundell *et al.*, 1999). To resolve these conflicting theoretical arguments, it is suggested that there is no unambiguous evidence for a generally valid relationship between competition and innovation. The inquiry on the relationship between competition and innovation is argued to be relative and meaningful when the competition context and the type of innovation activities are specified (Baldwin and Scott, 1987; Tang, 2006). In response to this theoretical suggestion, we focus on the relationships between foreign competition and pioneering innovation in this study.

A better understanding of the relationships between foreign competition and pioneering innovation has been more and more important for firms due to the globalization of markets and the shortening of technology life cycles. One of the most important changes in the past few decades is the globalization of markets and industries. The continuous changes in competitive conditions, especially foreign competition, are likely to

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change a firm's business strategy to remain competitive (Wiersema and Bowen, 2008). Technological innovations can be used as either a defensive or offensive strategy to sustain a firm's competitive advantage (Burgelman *et al*., 2004). Under foreign competition in their domestic market, firms may explore novel technological opportunities and race to bring the innovation into the market. The technological innovations that are technologically novel to the innovating firm and are introduced for the first time in the world are defined as *pioneering innovations*. Although numerous studies have investigated the economic influence and competitive implications of increased foreign competition in the domestic market (Caves, 1996; Chung, 2001), there is little insight on the relationship between foreign competition and pioneering innovation. The main purpose of this study, thus, is to investigate how foreign competition may influence the likelihood in generating pioneering innovation of a firm. We use a dataset of innovations in Canada.

While foreign competition may provide incentives for a firm to bring about pioneering innovations, it is also critical for a firm to have sufficient absorptive capacity to value, assimilate and explore new knowledge (Cohen and Levinthal, 1990). Under the same competitive conditions, firms with different levels of absorptive capacity vary in their capability to absorb external information from the competitive market and in their capability to transfer technological opportunities into innovations. Therefore, we suggest that the specific relationships between foreign competition and pioneering innovation are contingent upon the absorptive capacity of firms. When the level of foreign competition increases, firms with greater absorptive capacity will more likely to respond to the pressure by developing new technological and market opportunities.

This chapter contributes to the literature on competition and innovation by investigating the specific relationships between foreign investments and pioneering innovation. In addition, we consider the role of absorptive capacity for the relationships between foreign competition and pioneering innovation. Moreover, we operationalize the intensity of foreign competition by measuring a firm's perception of its competitive conditions rather than using industry-level statistics, such as market share and profit persistence, because the perception of competition provides a better representation of the perceived competitive conditions, upon which managers apply corresponding innovation strategies (Tang, 2006).

This chapter is organized as follows. Firstly, we provide the theoretical background on the general relationships between competition and innovation. Secondly, we extend the general arguments on competition and innovation into a specific setting, i.e., the foreign competition in the domestic market and pioneering innovations that are technologically novel to the firm and being introduced to the market for the first time in the world. Furthermore, we explain the direct or indirect effects of absorptive capacity on pioneering innovations. Next, we present the data and estimation methods to test the hypotheses. Finally, we discuss the results, draw some conclusions, and make suggestions for future research.

4.2 Theory and hypotheses

4.2.1 Competition and Innovation

The relationships between competition and innovation have drawn great attention from strategic management theory and industrial economics (Amendola *et al*., 2000; Aghion *et al*., 2005; Tang, 2006; Greenhalgh and Rogers, 2006; Smith and Sharif, 2007). Firstly, *competitive advantage* has been the central theme in the strategic management theory and practice (Caves, 1996; Porter, 1980). Competitive advantage is realized either when a firm gains an advantageous position in an industry or when it mobilizes and deploys core competences (Prahalad and Hamel, 1990). One of the most important ways to achieve competitive advantages is to innovate (Barney, 1991). Technological innovations can be used as either a defensive or an offensive strategy to sustain a firm's competitive advantage (Burgelman *et a*l., 2004). In the context of Schumpeterian competition (Schumpeter, 1934), a firm's long-term success is not only a matter of maintaining and increasing effectiveness and efficiency in their existing businesses. More importantly, the sustainability of competitive advantage will depend on the extent to which the firm is able to develop capabilities for innovation (Nelson, 1991).

Secondly, economists have developed different viewpoints on the relationships between competition and innovation, but the empirical evidence on the relationships between competition and innovation remains inconclusive. On the one hand, the Schumpeterian viewpoint credits the large firms with substantial monopoly market power, which implies little competition on the market, have resources and incentives to innovate. Firms tend to innovate because they seek profitability that arises from monopoly power (Grossman and Helpman, 1991). The profit from monopoly power will be reinvested in R&D, which leads to more innovations. On the other hand, it is also possible for a monopolist to have incentives to suppress subsequent innovation (Weinberg, 1992). The argument from Arrow (1962) that a perfectly competitive market is more likely to foster innovation than a monopoly one has found support in some empirical studies, which found a positive linear effect of competition on innovation (Blundell *et al*., 1999). It is argued that the incentives for innovation depend not much upon post-innovation rents, which is the profitability a firm can gain after introducing the innovation, but rather upon the *difference* between *post-innovation* and *pre-innovation* rents of firms (Aghion *et al*., 2005). In other words, under competitive pressure, firms compare the profitability before innovation and the possible profitability after innovation. Suppose that intensive competition drives the pre-innovation rents down to a certain level that is definitely lower than the possible economic rents after innovation, a firm will be encouraged to innovate.

The negative and positive relationships between competition and innovation, suggested by Schumpeter and Arrow, respectively, both hold their merits. However, other researchers suggest that the relationships between competition and innovation are dependent on other factors, such as technological or institutional conditions (Levin *et al*., 1985). It is also suggested that there is no unambiguous evidence for a generally valid relationship between competition and innovation. The inquiry on the relationship between competition and innovation is argued to be relative and meaningful when the competition context and the type of innovation activities are specified (Baldwin and Scott, 1987; Tang, 2006). In the following sections, we consider a specific competition context, i.e., the foreign competition in domestic market, and a specific innovation type, i.e., the pioneering innovation. We also investigate the role of a firm's absorptive capacity with regard to the relationships between foreign competition and the chance that firms come up with pioneering innovation.

4.2.2 Foreign competition and Pioneering Innovation

Foreign competition in the domestic market usually takes two forms: (1) imports of foreign-produced goods; (2) sales by affiliates of foreign-owned companies that produce within or outside of the domestic market (Wiersema and Bowen, 2008). Under foreign competition, the competitive landscape in the domestic market is, in a sense, no longer "domestic". It reshapes the competition context in the domestic market into a battle field with not only domestic players but also international rivals. Domestic firms usually have to compete with imported foreign goods on cost-price advantage and with those multinationals who seek international diversification on quality and innovation (Caves, 1996; Chung, 2001). To outperform foreign competitors, a domestic firm may simply adapt the most recent technology and replicate competitors' products and strategy or improve efficiency and reduce costs. However, this strategy is usually not sustainable and in most cases not sufficient to maintain competitive advantage. Firms need to explore novel technologies and race to bring innovations into the market first in the world. In this chapter, we define a product innovation that is technologically novel and is brought into the market for the first time in the world as *pioneering innovation*. This definition considers the technological and market novelty of innovations because innovations, different than technological inventions, require not only scientific and technological knowledge but also product-market knowledge (Chesbrough and Rosenbloom, 2002)[7].

The relationships between foreign competition and pioneering innovation should be examined through the change in competition intensity and its impact on the motivation of firms with regard to innovation. Scholars in innovation management have found two major motivations for which firms innovate. On the one hand, organizations are assumed to have a performance goal. If the actual performance is lower than this performance goal, firms search for solutions to the problem. This is so-called "problemistic search" (Cyert and March, 1963). On the other hand, if the actual performance exceeds the goal, "organizational slack" accumulates. With organizational slack, firms relax organizational control and encourage search activities that cannot be justified in terms of their expected return for the organization. They are initiated because of their attractiveness to some individuals or units in the organization and tolerated because the firm is currently successful in achieving its performance goals (Levinthal and March, 1981). These two motivations correspond to the contradictory arguments on how market competition can stimulate innovation. On the one hand, the Schumpeterian argument favors that the society must accept static monopoly welfare losses in order

[7] For more detailed discussion on the definition of pioneering innovation, refer to chapter 3.

to gain increased investment in innovation and, in turn, lead to dynamic welfare gains. This view is in line with the "organizational slack" motivation of innovation. On the other hand, Arrow (1962) asserted that strong competition creates a "problemistic" situation for firms, which provides firms with a greater incentive to innovate than in a monopoly market. This viewpoint is in line with the "problemistic search" motivation of innovation.

Let's consider the relationships between foreign competition and the incentive to introduce pioneering innovation. Foreign competitors are in most case the multinationals with international diversification strategy. They have abundant resources and technological capabilities. They may seek aggressive market entry strategies by introducing products with best quality for cheaper price or introducing new products with a high price to seek higher margins. Another kind of foreign competition consists of the imported goods from low-wage countries. They compete with domestic firms in cost and price. These two types of foreign competitors, jointly or separately, decrease the industry profit margins and impose great pressure for domestic firms for greater efficiency (Chung, 2001). As a result, the Schumpeterian monopoly over resource and market power diminishes when foreign competition intensifies. Domestic firms will immediately be engaged in struggling with the competition by reducing cost, improving efficiency or quickly adapt the latest practices in the industry in reaction to the foreign competition (Caves, 1996; Driffield and Munday, 2004). Some domestic firms might even be driven out of business (Caves, 1996). The incentives to explore new technological and market opportunities with organizational slack are less and less likely to work. Therefore, one would expect a downward slope of the likelihood of pioneering innovation with the increase of foreign competition intensity. However, with the ever-increasing foreign competition, domestic firms may realize that competing in cost and price is not an effective strategy in the long run. Foreign competition in the domestic market creates a "problemistic motivation" for firms to innovate. To outperform the foreign competitors, local firms are forced to use pioneering innovation to defend their existing competitive advantage or create a new ground for competitive advantage. Previous studies found that intensive foreign competition leads to changes in the rate of technological developments in an industry (Scherer and Hub, 1992). In the context of foreign competition, incremental innovation might not be enough to sustain or regain competitive advantage. One needs to introduce new technological innovation into the market before your foreign competitors do. In other words, overly intensified foreign competition encourages firms to explore novel opportunities to "escape the competition" (Aghion *et al*., 2005). Therefore, one would expect that the likelihood of pioneering innovations might increase again when foreign competition continues to intensify from a moderate to a high level.

The relationships between foreign competition and the incentive to introduce pioneering innovations perhaps can also be explained through the lens of *resource-advantage theory* (hereinafter "R-A theory", Hunt and Morgan 1997; Hunt, 1997a, b). R-A theory is an evolutionary, disequilibrium provoking and process theory of competition, in which innovation and organizational learning are endogenous. At its core, the R-A theory, on the one hand, recognizes not only the inter-industry but also the intra-industry heterogeneous demands with respect to consumers' tastes and preferences. On the other hand, many of the resources of firms within the same industry are also significantly heterogeneous and relatively immobile. These heterogeneous, imperfectly mobile resources, combined with heterogeneous demands, imply significant diversity as to the levels of profitability of firms within the same industry. Firms learn through competition in a way that they get feedback from relative financial performance, which signals the relative market position of firms in the same industry. The signal of relative market position, in turn, signals where the relative resources are. It consists of the constant struggle among firms for a comparative advantage in resources that will yield a marketplace position of competitive advantage and, thereby, superior financial performance. Once a firm's comparative advantage in resources enables it to achieve superior performance through a position of competitive advantage in some market segment(s), competitors tend to neutralize and/or leapfrog the advantaged firm through acquisition, imitation, substitution, or innovation. Therefore, the R-A theory consider innovation as an outcome of competition.

The R-A theory identifies two different kinds of innovative activities: the proactive one and the reactive one. Proactive innovation is a genuinely entrepreneurial and exploratory attempt to discover, to understand, and to satisfy the latent needs of customers (Naver, Slater and MacLanchlan, 2004) by developing new technology. In contrast, reactive innovation is directly prompted by the learning process of firms' competing for the patronage of market segments. It occurs when inferior financial performance signals firms that their comparative disadvantage in resources has resulted in their positions of competitive disadvantage in the marketplace. Reactive innovation corresponds to the “problemistic search” argument as one of the motivations to innovate by firms.

The original R-A theory argues that although proactive innovation is motivated by the expectation of superior financial performance, it is not prompted by specific competitive pressures. To some extent, it reflects the “organizational slack” argument in organizational learning theory. However, in this chapter, we extend the scope of proactive innovation to those innovation attempts under *extremely* high competitive pressure in which firms have to explore completely new market opportunities in order to escape the competition, as we will explain further in Figure 4. Figure 4 depicts the relationship between the likelihood of pioneering innovation and the intensity of foreign competition, where proactive and reactive innovations prevail at different level of foreign competition. When the level of foreign competition is low, firms may make investments in pioneering innovations which are purely based on a proactive purpose because these firms enjoy competitive advantages in their markets (Proactive Innovation I in Figure 1). With foreign competition increasing to a moderate level, firms switch to undertake reactive innovation. At the beginning, firms may choose to acquire the prevailing technology in the market, imitate or adapt the best practices of their better-performing competitors. The likelihood that a firm invests in pioneering innovations will decrease (Reactive Innovation I in Figure 4). As foreign competition continues to rise, firms realize that simple acquisition, imitation and adaptation of technology and market strategy are not sufficient to gain competitive advantage. They tend to react to the competitive pressure by finding an equivalent or even superior resource to replace the existing resource base. Although this type of innovation strategy may sporadically leads to some pioneering innovations, it is still not very likely for firms to invest in pioneering innovations (Reactive Innovation II in Figure 4). Finally, we argue that if foreign competition continues to intensify to an extremely high level, firms will be forced to go beyond the reactive approaches and decide to trade off its limited resources to invest in completely new and latent market segments. To introduce pioneering innovations for the first time in the world could be the only way to escape the severe foreign competition. Therefore, at the high level of foreign competition, the likelihood of pioneering innovation may again increase. We argue that this kind of approach, although is under strong competitive pressure, is highly proactive because firms have to leapfrog the advantaged competitors by changing their existing market position and finding a new segment that has not been explored before by other firms (Proactive Innovation II in Figure 4)[8].

Based on these arguments, we suggest that the relationships between foreign competition and pioneering innovation take form of a U-shaped curve. In other words, the likelihood for a firm to undertake pioneering innovation will decrease when foreign competition intensifies from a low to a moderate level, and it starts increasing again when foreign competition continue to intensify from a moderate to a high level. This view reconciles the seemingly contradictory arguments of Schumpeter and Arrow by reflecting the organizational learning literature and the R-A theory. We hypothesize accordingly,

H1: The relationship between foreign competition and pioneering innovation is nonlinear. It depicts a U-shaped relationship with the slope negative at the low and moderate levels of foreign competition but positive at the high levels of foreign competition.

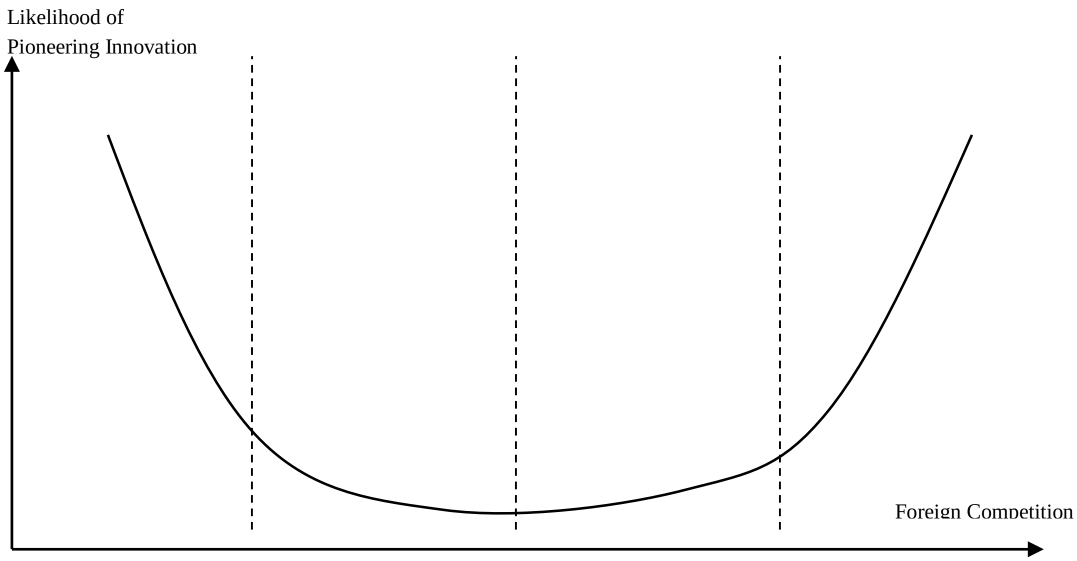
4.2.3 The role of absorptive capacity

The importance of absorptive capacity (hereinafter ACAP) has been recognized in the research fields of strategic management, technology management and international business (Mowery and Oxley, 1995; Liu and White, 1997). Absorptive capacity refers to a firm's ability to value, assimilate and apply new knowledge (Cohen and Levinthal, 1990). Various researchers have used the ACAP to explain organizational phenomena, particularly in organizational learning and innovation. For instance, Mowery and Oxley (1995) found that national innovation and productivity are greater for countries that invest in building their ACAP. The synergy between investment in ACAP and investment in new knowledge is argued as the driver for innovation (Liu and White, 1997). However, the various usages of ACAP in the literature have displayed ambiguity in its definition and measurement (Zahra and George, 2002). Based on a thoughtful review, Zahra and George (2002) redefined ACAP as a set of organizational routines and processes by which firms acquire, assimilate,

[8] Note that the likelihood of pioneering innovations with regard to the four stages of foreign competition intensity, as illustrated in Figure 1, are very likely to overlap each other and should not be interpreted as mutually exclusive.

transform and exploit knowledge to produce a dynamic organizational capability. In this chapter, we follow Zahra and George (2002)'s definition and interpretation of ACAP on which we develop our argumentation.

Figure 4: The U-shaped Relationship between Foreign Competition and Pioneering Innovation



Proactive innovation I: Organizational slack; identify and satisfy latent customer need with new technology

Reactive innovation I: acquisition, imitation, adaptation

Reactive innovation II: outperform competitors by finding an equivalent resource or a superior

Proactive innovation II: Problemistic motivation; identify and satisfy latent customer need with new technology; using pioneering innovation to escape the competition

Under foreign competition in the domestic market, it is critical for firms to be able to search, acquire and assimilate market information. If foreign competition provides firms with incentives to undertake pioneering innovation, then ACAP is a crucial capability, with which a firm may be able to undertake pioneering innovation. Firms with a low level of ACAP will probably misinterpret the information over the competitive market and trap themselves in a continuous process of improving operational efficiency and reducing costs, and in turn, miss the opportunities to outperform its competitors by innovation (Ahuja and Lampert, 2001). Two antecedents of ACAP are identified as critical for acquiring and assimilating external knowledge (Zahra and George, 2002). The first is the *diverse and complementary knowledge sources,* and the second is the *past experience*. Firms with diverse and complementary knowledge sources and extensive experience tend to have greater ACAP than otherwise.

Diverse and complementary knowledge sources. A firm’s exposure to knowledge within its competitive environment will influence its decision making (March and Simon, 1993). Firms with broad exposure to diverse external knowledge sources may positively influence a firm’s propensity to explore new and related knowledge (Lin *et al*., 2007). Firms and industries differ among each other with regards to R&D, production efficiency, input and output of innovation, technological capabilities and so forth (Dosi, 1988). Difference in knowledge is a crucial condition for learning and innovation to produce Schumpeterian 'novel combination' (Nelson and Winter, 1982). Pioneering innovations, which create growth opportunities for the firm by combining new technologies with new markets, are more likely to emerge when a firm has access to broad and diverse external knowledge.

However, exposure to diverse knowledge does not necessarily lead to greater ACAP if these knowledge sources have low complementarity with the firm’s knowledge base (Zahra and George, 2002). Goerzen and Beamish (2005) found that the diversity of an MNE's alliance network has a negative impact on its economic performance due to the challenge of managing an increasingly complex alliance network would overwhelm the marginal benefits. The diversification literature argues that firms learn most from the alliance partners with related knowledge and skills (Tanriverdi and Venkatraman, 2005). As diverse knowledge sources provide potential for novelty, these knowledge sources should be related in a way that positively leverages the value of each source of knowledge. Diverse knowledge sources can be complementary to a firm’s knowledge base in different ways. For instance, firms that closely cooperate with their customers and suppliers keep close track on the knowledge along the value chain. In this way, a firm can quickly integrate the technological expertise from suppliers and the market needs from customers into its own knowledge base. This integration of knowledge, in turn, will lead to greater ACAP. The role of lead users in facilitating innovations has become well-established and has been adopted by many pioneering companies (Von Hippel *et al.,* 1999). Im & Workman (2004) argued that integrating customer needs and emphasizing customer-focused intelligence provide sources for creativity, which is crucial for successful innovations. Many firms also realize that supplier involvement in new product development is critical to provide firms with innovative knowledge which can facilitate radical innovations (Frazeir *et al.,* 1988; Handfield *et al*., 1999). Therefore, we argue that firms with exposure to diverse and complementary knowledge sources will benefit from greater ACAP, which eventually facilitate more innovations.

Pioneering innovations require unique capabilities to acquire and assimilate new technological and product-market knowledge. Given the level of foreign competition, firms with diverse and complementary knowledge are more likely to acquire and assimilate critical information on the latest technological development and find unique opportunities to combine it with emerging customer needs. Accordingly, we hypothesize accordingly, *H2: Diverse and complementary knowledge source is positively related to the likelihood of pioneering innovation.*

Past experience in pioneering innovations. Innovating firms differ also in their experiences in generating pioneering innovations. Firstly, firms with more successful experience in pioneering innovation will receive positive feedback from previous innovative practices and gain incentives to undertake innovation again. In this way, firms build up positive *organizational memory* with respect to pioneering innovation to cope with foreign competition (Walsh and Ungson, 1991). Secondly, past experience defines the locus of a firm's knowledge search (Rosenkopf and Nerkar, 2001). Firms with successful experience in competing with foreign competitiors by undertaking pioneering innovation are more likely to accumulate knowledge on how to interact with suppliers, customers and develop new routines (Nelson and Winter, 1982). ACAP is a path-dependent capability, which is influenced by a firm's past experience embedded in its organizational memory (Zahra and George, 2002).

Firms' path-dependence in developing new knowledge could trap themselves for various reasons. Ahuja and Lampert (2001) argued that firms under the pressure of avoiding uncertainty and improving efficiency tend to search for familiar, mature and proximate technologies. In this way, firms may fall into three types of learning traps, i.e., familiarity trap, maturity trap and propinquity trap. The familiarity trap results from overemphasizing refinement and improvement on a firm's existing knowledge base and operation. The maturity trap results from risk-averse decision making, which favors reliable and mature technology. The propinquity trap reflects the search for familiar, current and proximate knowledge. Past experience in pioneering innovations can positively help firms to escape these traps. Firstly, when a firm faces little foreign competition, it is very likely for a firm to be confined to the maturity and propinquity traps because the existing practice brings positive economic rent for the firm and the returns from pioneering efforts are less certain and more risky. However, under the same circumstance, firms with successful experience in pioneering innovation understand that such a kind of organizational slack is by no means sustainable. To sustain competitive advantage, firms with extensive experience learn how to make the best use of the current resource slack to explore new opportunities for the future. Secondly, when foreign competition intensifies, it is very likely for a firm to be confined by the familiarity trap and focus on improving efficiency and reduce costs. They choose neck-and-neck competition strategy to fight with foreign competitors and overlook the opportunity to explore. However, all else equal, firms with successful experience in pioneering innovation realize that the only way to "escape" the competition is to undertake pioneering innovation. They purposefully explore new technologies and create new market opportunities in response to the intensified foreign competition. Therefore, we expect that successful past experience in pioneering innovations brings positive feedback to the innovating firm and improves the management of these innovations over time, which, in turn, increases the chance for a firm to undertake pioneering innovations. Accordingly, we hypothesize, *H3: Past experience is positively related to the likelihood of pioneering innovation.*

Nevertheless, the combined effect of foreign competition and ACAP on pioneering innovation also deserves our research attention. Several studies have found that ACAP has a positive moderating role for firms' innovation performance. For instance, Veugelers (1997) found that external sourcing of knowledge will stimulate internal R&D investment only if a firm sustains a sufficient level of ACAP. In another study, Liu and White (1997) used the number of R&D personnel as a proxy of a firm's ACAP. They found that the interaction between a firm's technology imports and R&D personnel leads to positive synergies and higher new product sales.

The positive moderating role of ACAP could also be explained through the lens of the R-A theory. If we consider past experience and knowledge as two sources of intangible resource of firms, we could expect that firms that are rich in resource will be more likely to explore new opportunities than those firms that are poor in resource under certain level of competition. Given the level of foreign competition, it is reasonable to expect that -rich firms that are rich in past experience and exposed to diverse and complementary knowledge will be more likely to take a proactive innovation strategy to outperform their competitors than those firms with a low level of ACAP. This, in turn, leads to higher possibility to generate pioneering innovation. To summarize, we expect these advantages that stem from a high level of diverse and complementary knowledge will positively moderate the relationship between foreign competition and pioneering innovation. In other words, the U-shaped curve for the relationship between foreign competition and pioneering innovation will shift up and make the slope of the curve steeper (see Figure 5)[9]. We hypothesize accordingly.

H4: Diverse and complementary knowledge source positively moderates the U-shaped relationship between foreign competition and pioneering innovation.

H5: Past experience in generating pioneering innovations positively moderates the U-shaped relationship between foreign competition and pioneering innovation.

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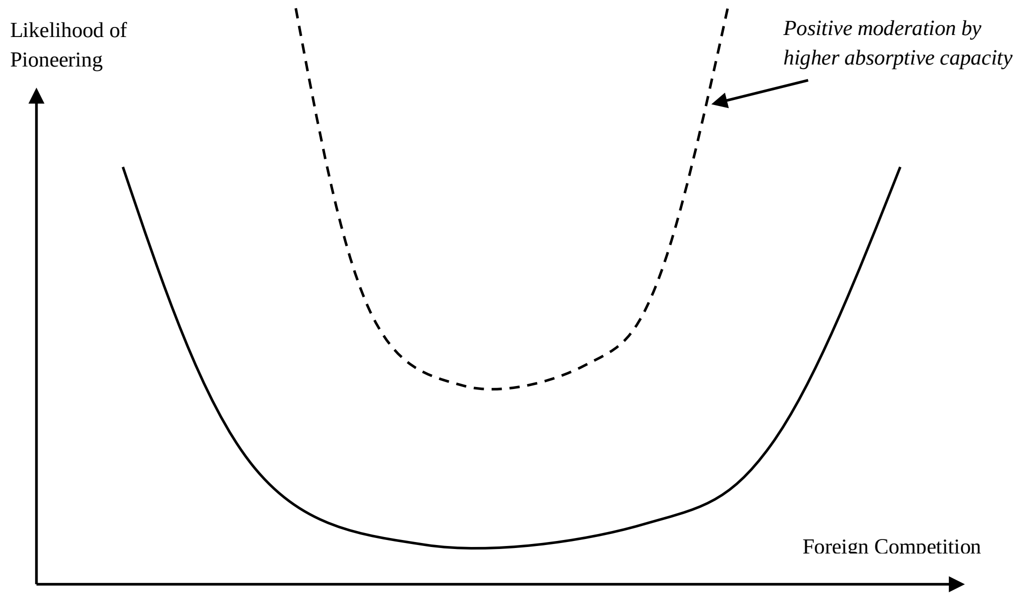
[9] From a mathematical point of view, the U-shaped curve will shift upwards for the following reason. Assume the U-shaped curve for the relationship between foreign competition and pioneering innovation can be represented by a quadratic function, i.e., $f(x)=ax^2+bx+c$, ($a\neq0$). The vertex of the parabola will be: $\left(-\frac{b}{2a}, -\frac{\Delta}{4a}\right)$ where $\Delta=b^2-4ac$. Suppose f(x') represents a positive linear relationship between ACAP and pioneering innovation as we argued, then the interaction between f(x) and f(x') will change the vertex of the parabola to be: $\left(-\frac{b}{2a}, -\frac{\Delta}{4a} f(x')\right)$. In this way, the U-shaped curve will shift upwards but not move towards left or right.

The reason why the slopes of the curve will be steeper is because in a quadratic function, $f(x)=ax^2+bx+c$, ($a\neq0$), the value of "*a*" determines the slopes of the parabola. Suppose f(x') represents a positive linear relationship between ACAP and pioneering innovation as we argued, then the interaction between f(x) and f(x') will change the value "*a*" to be "*a*f(x')*", which is a positive increase. In this way, the slopes of the parabola will be steeper.

Figure 5: Positive moderation of absorptive capacity



4.3 Variables and method

The dataset used for this study is the Canadian Data. The Canadian Data covers the most significant innovations in terms of technological novelty. In other words, the innovations covered in the Canadian data were all significant technological advancements that depart from previous practices at the industry level. Furthermore, innovations were also categorized according to their novelty in market introduction. Respondents to the questionnaire were asked if their company was the first to market this innovative product in Canada or not. If so, a further question asks whether the same or similar product had been marketed or used outside Canada before. We label those innovations that were introduced in Canada first and had no similar products/services introduced outside Canada before as *pioneering innovations* (new-to-the-world). The remaining innovations are not pioneering. Our definition of pioneering innovation combines the novelty criteria along both the technological and the market dimensions. In this way, our definition of pioneering innovation differs from other measurements of innovation based on patent citation data, which only represents the technological dimension of novelty of innovations and overlooks the market side of innovations (Li *et al*., 2008).

We eliminated those innovations where the information with respect to the type of innovations was unreliable. We used two criteria to select a sample from the Canadian data. Firstly, we excluded the innovations for which the respondents failed to indicate whether an innovation is *new-to-world, new-to-*

Canada or *new-to-firm-only*. Secondly, we also eliminated the innovations for which the answers to the questions with respect to the novelty of market introduction were illogical. This selection finally results in a sample of 1421 usable observations.

4.3.1 Dependent variable

The dependent variable is a binary variable which indicates whether an innovation is pioneering or not. Pioneering innovations, by definition, are not only novel in terms of technology, but the innovating firm also explores new market opportunities and introduces the product/service into the market for the first time in the world. Innovations are labeled according to their novelty into three categories: new-to-world, new-to-Canada, and new-to-firm only. The new to world innovation is not only technologically new for the industry, but also introduced a completely new market for the first time worldwide. The new-to-firm-only innovations are technologically new to the industry, but similar products had been introduced by others in Canada. The new-to-Canada innovations usually represent the early adoption of advanced technologies, which in most cases are developed in U.S. Therefore, we define those innovations that were first introduced in Canada and had no similar products/services introduced outside Canada before as the pioneering innovations. All other innovations are not pioneering innovations.

4.3.2 Independent variables

Foreign competition. The concept of competition usually cannot be directly measured. Various researchers measure competition in many different indirect ways, such as market concentration, market share (Greenhalgh and Rogers, 2006), profit persistence (Roberts, 1999), and conditions of entry (Baldwin and Scott, 1987). Similarly, Wiersema and Bowen (2008) measures foreign competition in terms of the ratio of imports to total domestic consumption in the industry in which the firm is active. It has been argued that these indirect measurements of competition, if other firm-level and industry-level variables are controlled, present artificial influence of competition, so that alternative measures of competition are needed to better understand the effect of competition and innovation (Tang, 2006).

Following Tang (2006), we use the perception of competitive environment to measure foreign competition. Tang (2006) explained why using the perception of competition can bring a better understanding for the relationship between competition and innovation. Firstly, it is the managers' perception of competition that eventually counts for the decision making in whether a firm will invest in innovations. Even under the same level of competition, managers at different firms with different decision-making propensity and personality may interpret the competitive environment differently. Thus, competition, as a possible motivation for innovation, must be understood as a subjective reflection based on limited information and bounded rationality over the objective competitive environment. Secondly, the perception-based measure captures firm-specific competition. Traditional industrial-level measures of competition may not distinguish firm-specific factors. Finally, managers' perception of competition not only provides information on domestic competitors but also on foreign competitors in the domestic market.

For the Canadian Dataset, the questionnaire asked the respondents to specify the companies (and their nationalities) that produce or market an identical or similar product that performs the same function for the same clients in Canada, including both domestic and foreign companies. The respondents filled in the specified information according to their firm-specific perception of competition environment. In this way, even if the manager's perception of competition is biased by limited market information, the bias would be naturally translated into the firm's decision-making in innovation. Thus, it's a much more genuine representation than traditional industrial-level measures of competition on how competitive environment can provide incentives for pioneering innovations. The design of the original survey question ensures that the respondents do not discriminate foreign imported goods against the affiliates of foreign-owned companies in Canada. For instance, if an American company is indicated as one of the competitors for focal firm X, this American company could possibly only export goods to Canada or it has subsidiary that is operating in Canada. The critical point is that we get information on all the *de facto* foreign competitors or the perceived foreign competitors in the domestic market regardless how they compete. We operationalize the value of the variable "foreign competition" as the count number of foreign competitors for a particular innovation.

Diverse and complementary knowledge. Measures for diversity or proximity in technology and knowledge have been well established. The literature on technological innovations usually use patent citation data to measure the distance of knowledge base between firms (e.g., Rosenkopf and Nerkar 2001; Benner and Tushman, 2002; Katila, 2002). However, a parallel patent dataset is not available for the period from the 1940s to 1980s. The only consistent information that may approximate the diverse and complementary knowledge exposure that we can get from the original Canadian Innovation Survey is the SIC code of the innovating firms, and those of their suppliers and customers. We believe that firms that are active in a particular industry make continuous investment and dedication of commitment to improve their technological capabilities. Because of the organizational inertia (path dependence) and limited resources, firms in a particular industry accumulate similar knowledge, which is specific to the industry. In this way, firms active in one industry inevitably distinguish their knowledge-base from firms in other industries. Following Keil *et al*. (2008), which has demonstrated that the SIC code is a satisfactory proxy for knowledge relatedness between firms, we use the information provided by the SIC code to construct a measure for the diverse and complementary knowledge base of the focal firms.

The Canadian Dataset used a unique 3-digit hierarchical classification to indicate the industries to which the firms belong. Each innovating firm has a primary industry in which it is active. It is also common for an innovating firm to have several secondary industries in which it is active. A firm can be categorized into maximum four secondary industries next to its primary industry. Further, the primary industry of the suppliers and customers of the innovation are also available in the Canadian dataset. Given the information on the SIC codes of the innovating firms and their suppliers and customers, we operationalize a measurement for diverse knowledge exposure and a measurement for knowledge complementarity. Finally, we multiply the values of these two measurements because we need a variable that counts for both diverse and complementary knowledge.

Firstly, firms that are active in several industries are more likely to be exposed to diverse knowledge sources than those are active in only one primary industry. Moreover, for those innovating companies that are active in several industries, we assume that the more different these industries are the more diverse knowledge source the firms may get access to. To calculate the diversity of knowledge sources a firm may get access to, depending on the degree of difference between two SIC codes, we assign weights for different secondary industries. A difference between two SIC codes at the first digit indicates the largest difference. If two SIC codes are the same for the first digit and differ at the second digit, then we assume that the difference has an intermediate value. If the SIC codes only differ at the third digit, we assume that these two industries to which the firms belong are very similar. Finally, the same SIC codes indicate the same industry and are assumed to have a common knowledge-base. We assign weights of 4, 3, 2 and 1 for the four levels of difference between two SIC codes (with value of "1" if two SIC codes are identical), meaning the larger figures represent larger distances. The measure of diverse knowledge exposure is the ratio of the *weighted* value of total number of industries of a firm to the total number of industries of a firm. To illustrate, suppose an innovating firm is active in industries "378", "375" and "162", of which "378" is its primary industry. The diverse knowledge exposure value for this firm will be, (1*1+2*1+4*1)/3=2,33. According to this formula, if a firm is active in only one primary industry, the value for diverse knowledge exposure for this firm is "1", which is the lowest possible value for this measure.

Second, for the complementarity measurement, we argue that firms positioned at the different stages of the value chain of an industry enjoy complementary or related knowledge that provides them with a certain degree of common knowledge despite sufficient difference in their specialties. We define that a firm has complementary knowledge sources to its own if any of the secondary industries in which it is active happens to be similar to the industry of its main suppliers or customers. We further define that two industries are "similar" if the first two digits of the SIC code are the same. The measure, thus, is the count number of secondary industries of the innovating firm, which are similar to the industries of its main suppliers or customers. Finally, we multiply the diversity measurement and the complementarity measurement so that the product of these two measurements is the value for the variable of *diverse and complementary knowledge exposure*.

Past experience. We define *past experience* in undertaking pioneering innovations at the present year as a ratio of the number of pioneering innovations to the total number of innovations for the past 10 years[10] for a firm.

4.3.3 Control variables

1. Firm size. Firms in different sizes innovate differently. In the classical Schumpeterian argument, innovation performance of companies increases more than proportionally with firm size does so because large firms simply have more resources. They are most likely to be more effective in innovation than small firms and will therefore dominate the market. Small companies may be more likely to explore new technological areas by innovating in less crowded areas (Almeida and Kogut, 1997). Further, firm size is also related to the capacity to cooperate, which is crucial for inter-organizational learning and absorptive capacity (e.g., Shan, 1990; Powell and Brantley, 1992). Since firm size has been shown to influence firms' innovation performance, it is important to control for this variable. We measure firm size using the number of employees as prior research did (e.g., Goerzen and Beamish, 2005). We use an ordinal scale to measure the size of a firm, which is derived directly from the questionnaire of the Canadian survey (*size=1* for 0-19 employees, *size=2* for 20-199 employees, *size=3* for 200-499 employees, *size=4* for 500-999 employees, and *size=5* for more than 1000 employees).

2. SIC category of innovating firms. Innovating firms exist in different industries. Earlier studies found that firms in different industries vary in their appropriability regime, which is the degree to which firms are able to capture the rents generated by their innovations (Anand and Khanna, 1997). The appropriation concern constrains firms' motivation to bring out innovations, depending on whether the appropriability regime of industry is loose or tight (Teece, 1986). For these reasons, we control for the industry to which the innovating firms belong. We use nine dummy variables (the default is the industry with the first digit of SIC code as zero[11]) to measure whether an innovating firm is active in a broad category of industry[12]. The SIC code is an approximation of the industry in which a firm is active.

3. Time. The Canadian dataset contains innovations from 1945 till 1980. Time may have an effect on the likelihood of pioneering innovation as well. On the one hand, one could argue that firms benefit more advanced technology in the 1970s compared to the 1940s because of the increasing prominence of science and technology in creating a competitive advantage. Hence, we can expect that the chance of introducing pioneering innovation might be higher at the end of the observation period. On the other hand, it is also

[10] Alternatively, we also tried the same formula of past experience for the past 5 years. The empirical results shown no significant difference compared to the 10-year time span.

[11] The SIC code starting with zero at the first digit indicates a wide range of mining industries, including mining of gold, uranium, iron, base metal, coal, asbestos, etc.

[12] For instance, if the SIC codes of two innovating firms are 351 and 472, respectively, a dummy variable representing "300" industry category will take value as "1" for the former and "0" for the latter. A dummy variable representing ""400" industry category will take value as "0" for the former and "1" for the latter.

possible that in the late years, it is more difficult to introduce pioneering innovations because the market and technology are far better developed than the early years so that there are fewer opportunities to introduce pioneering innovations. We use three alternative measures to control for the effect of *time*. Firstly, we introduce four dummy variables (default is the 1940s) to represent any decade-specific effects on the dependent variable that are not captured by the independent variables. Secondly, instead of using dummy variables for the four decades, we used dummy variables to control for the consecutive five-year periods. Finally, we also tried a trend variable for each consecutive year.

4.3.4 Method

The dependent variable has no skewed distribution (with 44% of the sample valued at 1, and 56% percent at 0). We use a binary logistic regression model to test our hypotheses, given the binary nature of the dependent variable. Binary logistic regression is used to predict a dichotomous variable from a set of predictor variables, which are a mix of continuous and categorical variables regardless how these predictor variables are distributed. The predicted dependent variable is a function of the probability that a particular subject will be in one of the categories. In our case, the binary logistic regression predicts the probability that an innovation will be a pioneering innovation, given the value of a set of predictor variables that measures some attributes at the industry level (e.g., foreign competition) or at the firm level (e.g., firm size, firms' past experience, and firms' diverse and complementary knowledge).

4.4 Results and discussions

The descriptive statistics and correlations between the variables are presented in Table 5. Innovating firms in the Canadian data have more than one foreign competitor on average (with mean value 1.49). For the control variables, the average size of innovation firms is 3.10, which means a firm with slightly more than 500 employees. We found no high correlations between any pairs of variables, thus multicollinearity problem is not concerned for the main effect variables.

Table 5. Descriptive statistics

Correlations [a.]

Variables	Pioneering innovation	Foreign competition	Past experience	Diverse and complementary knowledge	Firm Size
Pioneering innovation	1				
Foreign competition	-,029	1			
Past experience	,136	,010	1		
Diverse and complementary knowledge	-,026	-,022	,003	1	
Firm Size	-,116	-,048	,154	,074	1
Mean	,440	1,490	0,240	0,125	3,100
s.d.	,497	1,669	0,355	0,697	1,543

N=1421,

[a.] Dummy variables *Decade* (D50, D60, D70 and D80) and *Industry category* (SIC00, 01, 02 through 09) as control variables are not listed in the table.

Table 6 presents the results of binary logistic regression to test our hypotheses[13]. All models meet the Hosmer-Lemeshow test, indicating that the data fit the models well[14]. We started with a base-line model with only control variables included in the regression (model 1), and then introduced the main effect variables, i.e., foreign competition, past experience, diverse and complementary knowledge, into the model (model 2). Furthermore, we introduced the quadratic terms of foreign competition (model 3), and the interaction terms into the models step by step (model 4, 5 and 6). Compared to the base-line model (model 1), the likelihood ratio test shows that other models have stronger explanatory power. The results demonstrate support for some of our hypotheses. Firstly, the coefficients of foreign competition have a negative sign and are statistically significant in models 3, 4, 5 and 6 (respectively, β= -0,298, $p<0.01$; β= -0,310, $p<0.01$; β= -0,277, $p<0.05$; β= -0,290, $p<0.05$). Secondly, the coefficients of the quadratic term of foreign competition have a positive sign and are statistically significant (in model 3, 4, 5 and 6, respectively, β= 0,058, $p<0.05$; β= 0,057, $p<0.05$; β= 0,050, $p<0.05$; β= 0.050, $p<0.05$). It suggested that there is a U-shaped relationship between foreign competition and the likelihood of pioneering innovation. Thus, hypothesis 1 is supported.

[13] Instead of using the four separate dummy variables for four *Decades*, we also used two different ways to control the effect of time. First, we introduce a *trend* variable with a continuous measure of year; second, we used dummy variables to control for the consecutive five year periods. The results show that the model fit and significance of effects for each main variable are similar to the models using four separate dummy variables for four decades. Therefore, hereby we only report the results by using four separate dummy variables for decades.

[14] The Hosmer-Lemeshow test tests the null hypothesis that there is a linear relationship between the predictor variables and the log odds of the criterion variable. A chi-square statistics is computed comparing the observed frequencies with those expected under linear model. A non-significant chi-square indicates that the data fit the model well (Hosmer and Lemeshow 1989).

Moreover, to have a more careful examination of the U-shaped relationship between foreign competition and the likelihood of pioneering innovation, we followed a procedure similar to Hitt and Middlemist (1978) and Hitt *et al*. (1997). We split the sample into two subgroups based on the value of foreign competition. The cases in the first group have a low to moderate level of foreign competition, and the cases in the second group have a moderate to high level of foreign competition. We conducted the procedure twice with two different cutoff values of foreign competition. When the cutoff value of foreign competition is set at "2", the first subgroup is composed of 1035 cases with the value of foreign competition from '0' to '2'; the second subgroup is composed of 386 cases, with the value of foreign competition from '3' to '5'. When the cutoff value of foreign competition is set at "3", the first subgroup contains 1197 cases with the value of foreign competition from '0' to '3'; the second subgroup is composed of 224 cases, with the value of foreign competition from '4' to '5' (see Table 3). In both cases, the coefficients of foreign competition are negative for the first subgroup (β= -0,140, p>0.1; β= -0,109, p<0.1; respectively). For the second subgroup, coefficients of foreign competition are positive (respectively, β= 0,203, non-significant; β= 0,940, p<0.01). This subgroup analysis further confirms that the relationship between foreign competition and the likelihood of pioneering innovation is U-shaped with a negative slope at the low and moderate levels of foreign competition but a positive slope at the high levels of foreign competition (see Table 7).

Next, we found that the coefficients of diverse and complementary knowledge have a negative sign and are not statistically significant in all related models (table 6, model 2, 4 and 6). Thus, hypothesis 2 is not supported. To have a more careful look at this result, we tried to find some insights from the subgroup analysis as well. In Table 6, we found that diverse and complementary knowledge is positively related to the likelihood of pioneering innovation only if the foreign competition is high (β= 0,402, p<0.1 for cutoff value = "2"; β= 0,502, p<0.1 for cutoff value= "3"). This result suggests that perhaps a firm's diverse and complementary knowledge is useful for pioneering innovation only when foreign competition is extremely high. Only then, firms start realizing that the value of their diverse and complementary knowledge can be a crucial resource for generating pioneering innovation, by which they might be able to escape the severe foreign competition.

Furthermore, we found that the coefficients of past experience have a positive sign and are statistically significant in all related models (Table 6, model 2, 5 and 6; β= 0,835, p<0.01; β= 0,781, p<0.01; β= 0,781, p<0.01; respectively). Thus, hypothesis 3 is supported. The subgroup analysis also shows that past experience is positively related to the likelihood of pioneering innovation, regardless of the level of foreign competition (see Table 7).

Table 6: Binary logistic regression—Effects of Foreign competition and absorptive capacity on the possibility of generating pioneering innovations [a]:

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Constant	-0,202 (0,492)	-0,118 (0,506)	-0,001 (0,499)	-0,006 (0,508)	0,421 (1,317)	0,062 (0,514)
Firm size	-0,191 (0,038)***	-0,222 (0,039)***	-0,193 (0,038)***	-0,184 (0,039)***	-0,228 (0,039)***	-0,219 (0,040)***
Past Experience		0,835 (0,165)***			0,781 (0,198)***	0,781 (0,201)***
Diverse and Complementary knowledge		-0,054 (0,084)		-0,218 (0,111)		-0,220 (0,110)
Foreign Competition		-0,041 (0,034)	-0,298 (0,109)***	-0,310 (0,111)***	-0,277 (0,110)**	-0,290 (0,112)**
Foreign Competition^2			0,058 (0,023)**	0,057 (0,024)**	0,050 (0,024)**	0,050 (0,025)**
Foreign Competition^2* Past Experience					0,008 (0,019)	0,007 (0,019)
Foreign Competition^2* Diverse and Complementary knowledge				0,045 (0,018)**		0,046 (0,018)**
Likelihood ratio test (relative to model X)	-	81,032*** (model 1)	7,751** (model 1)	61,071*** (model 3)	28,967*** (model 3)	26,767*** (model 4) 58,871*** (model 5)
Cox & Snell R^2	0,047	0,065	0,052	0,058	0,070	0,075

N=1421

* *p*< 0.1; ***p*< 0.05; ****p*< 0.01

[a]. Coefficients for dummy variables *Decade* (D50, D60, D70) and *Industry category* (SIC00, 01, 02 through 09) as control variables are included in all models, but not listed in the table.

Table 7: Subgroup analysis of the effects of foreign competition on the possibility of generating pioneering innovations [a]:

Variables	**Option 1 (cutoff value=2)**		**Option 2 (cutoff value=3)**	
	Subgroup 1 (**'Foreign competition'=0-2, *N=1035*)**	**Subgroup 2** (**'Foreign competition'=3-5, *N=386*)**	**Subgroup 1** (**'Foreign competition'=0-3, *N=1197*)**	**Subgroup 2** (**'Foreign competition'=4-5, *N=224)***
Constant	0,019 (0,546)	-0,757 (1,578)	-0,056 (0,514)	-4,267 (1,615)**
Firm size	-0,201 (0,046)***	-0,284 (0,082)***	-0,207 (0,043)***	-0,311 (0,110) ***
Past Experience	0,719 (0,199)***	1,022 (0,319)***	0,733 (0,185)***	1,342 (0,420)***
Diverse and Complementary knowledge	-0,164(0,102)	0,402 (0,219)*	-0,134 (0,095)	0,502 (0,293)*
Foreign Competition	-0,140(0,089)	0,203 (0,133)	-0,109 (0,059)*	0,940 (0,330)***
Cox & Snell R^2	0,064	0,123	0,066	0,161
-2Loglikelihood	1316,242	461,114	1509,809	266, 124

* $p < 0.1$; **$p < 0.05$; ***$p < 0.01$

[a]. Coefficients for dummy variables *Decade* (D50, D60, D70) and *Industry category* (SIC00, 01, 02 through 09) as control variables are included in all models, but not listed in the table.

Model 4 and 5, respectively, test the moderating roles of diverse and complementary knowledge and past experience with regard to the relationship between foreign competition and the chance that firms generate pioneering innovations. Since we hypothesized that foreign competition has a U-shaped effect on the likelihood of generating pioneering innovations, we follow an approach that has been used in Hitt *et al*. (1997), in which the moderating roles of diverse and complementary knowledge and past experience are examined through the interaction terms of the quadratic term of foreign competition and these two moderators. In model 4, the coefficient of the interaction term between diverse and complementary knowledge and the quadratic term of foreign competition has a positive sign and is statistically significant (model 4, β= 0,045, p>0.05). In model 5, we found that the coefficient of interaction term between past experience and the quadratic term of foreign competition has a positive sign but is not statistically significant (model 5, β= 0,008, p>0.1). In the full model (model 6), we included all the independent variables, the quadratic term of foreign competition, and the related interaction terms into the full model. We found that the coefficient of the interaction term between diverse and complementary knowledge and the quadratic term of foreign competition has a positive sign and is statistically significant (model 6, β= 0,046, p<0.05) and the coefficient of interaction term between past experience and the quadratic term of foreign competition has a positive sign but is still not statistically significant (model 6, β= 0,007, p>0.1). Thus, hypothesis 4 is supported but hypothesis 5 is only partially supported.

To have a more detailed examination on the moderating effects, we followed a procedure similar to Wiersema and Bowen (2008) to make an analysis on the total marginal effect of a change in the square term of foreign competition at a low, mean, and high value of each moderator variables, i.e., *past experience* and *diverse and complementary knowledge* (see Table 8). As shown, the total marginal effect of an increase in the square term of foreign competition on the likelihood of pioneering innovation is positive and significant at the low, mean, and high value of diverse and complementary knowledge. And the effect of an increase in the squared term of foreign competition is greater the higher the level of diverse and complementary knowledge is (the coefficients of the squared term of foreign competition increase with the increase of the level of diverse and complementary knowledge). This finding confirms the support to hypothesis 4, which suggests that diverse and complementary knowledge positively moderates the U-shaped relationship between foreign competition and pioneering innovation. However, this is not the case with regard to the total marginal effect of an increase in the square term of foreign competition on the likelihood of pioneering innovation at the low, mean, and high value of past experience (the coefficients of the squared term of foreign competition vary in its own way with increase of the level of past experience). This finding confirms that hypothesis 5 is not supported.

Table 8: Analysis on the total marginal effect of a change in the square term of foreign competition at a low, mean, and high value of each moderator variables

Moderator Variables	Level of moderator	Value of moderator [a]	Total marginal effect [b] Foreign competition^2
Past Experience	Low	0,000 [c]	0,243
	Mean	0,240	0,919
	High	0,595	0,832*
Diverse and Complementary knowledge	Low	0,000 [c]	0,055**
	Mean	0,125	0,538**
	High	0,822	0,817**

* $p< 0.1$; **$p< 0.05$; ***$p< 0.01$

[a]. For each moderator, its low (high) value is its value one standard deviation below (above) its sample mean as suggested by Jaccard, Turrisi and Wan (1990).

[b]. The total marginal effect is calculated as the effect of a one standard deviation increase in the squared term of foreign competition on the likelihood of pioneering innovation at the given value of the moderator variable.

[c]. The computed value is negative, but is indicated here as zero value.

To summarize, we found that, firstly, there is a U-shaped relationship between foreign competition and the likelihood of pioneering innovation. In other words, there is a negative relationship at low and moderate levels of foreign competition but it turns into a positive relationship when at high levels of foreign competition; secondly, diverse and complementary knowledge positively moderates the U-shaped relationship between foreign competition and the likelihood of pioneering innovation but has not direct effect on the likelihood of pioneering innovation; thirdly, past experience has a direct positive effect on the likelihood of pioneering innovation but does not positively moderate the U-shaped relationship between foreign competition and the likelihood of pioneering innovation. The reason why the result does not fully support hypothesis 5, which argues that past experience may positively moderate the U-shaped relationship between foreign competition and pioneering innovation, must be explained in combination with the direct effect of past experience. The direct and positive effect of past experience on the likelihood of pioneering innovation implies that firms with successful experiences in generating pioneering innovations perhaps learn how to deviate from their existing knowledge base and feel more comfortable to explore new opportunities. This implication is different than some viewpoints in the existing literature on exploitation and exploration (e.g., March, 1991; Audia and Goncalo, 2007), which argues that successful exploration leads to exploitation and eventually drives out further exploration. We argue that in the short run, to maximize the benefit of radical innovation, the following-up of exploitation right after exploration is inevitable. However, in a long run, firms with successful experience in making pioneering innovations benefit from higher return, which provides them a strong incentive to explore recurrently new sources of profits. With their successful experience, firms are more likely to know how to escape their own knowledge traps and ensure survival in the long run. Therefore, when a firm has extensive experience in pioneering innovation, the change in exogenous factors, such as foreign competition, may not effectively affect its decision making. In other words, the change in foreign competition does not provide effective incentives for the experienced firms because their organizational memory downplays the importance of competitive environment. They understand that no matter foreign competition is weak or fierce, the only sustainable way to outperform the competitors is to undertake pioneering innovation.

We also found that the coefficients of *firm size* have a negative sign and are all statistically significant in all models (model 1 through 6, respectively, β=-0,1910, p<0.01; β=-0,222, p<0.01; β=-0,193, p<0.01; β=-0,184, p<0.01; β=-0,228, p<0.01; β=-0,219, p<0.01). It implies that during the period of the 1940s till 1980s the small Canadian firms are more likely to generate pioneering innovations while the large firms are usually trapped with what they are good at although they might have greater resources than the small firms. This finding is in line with some arguments in the existing literatures, e.g., the notion of disruptive technology by Christensen (1998).

4.5 Conclusions

This study investigates the likelihood that firms generate pioneering innovations under different levels of foreign competition in domestic market, meanwhile taking the effects of absorptive capacity into account. We argue that the relationship between competition and innovation should be considered with specific types of competition and specific types of innovation activities. We investigate the role of absorptive capacity through two antecedents of absorptive capacity: the diverse and complementary knowledge exposure and the past experience. We argue that the relationship between foreign competition and pioneering innovation depicts a U-shaped curve. On the one hand, when foreign competition is low, firms may seek new technological and market opportunities based on organizational slack. When foreign competition intensifies, domestic firms will immediately be engaged in the competition by reducing the cost, improving efficiency or quickly adapt latest practices in the industry in reaction to the foreign competition, which will distract firms' incentive to bring about pioneering innovation. On the other hand, when foreign competition is too fierce, firms have to undertake pioneering innovation to "escape the competition". In this case, the possibility of undertaking pioneering innovation may again increase. We also argue that absorptive capacity may have positive direct effect on or positively moderate the relationship between foreign competition and pioneering innovation. The results of the empirical analysis support the alleged U-shaped relationship between foreign competition and pioneering innovation. Furthermore, the results show that diverse and complementary knowledge positively moderates the relationship between foreign competition and pioneering innovation, while past experience has a direct positive impact on pioneering innovation.

This chapter contributes to the existing literature in several ways. Firstly, the relationship between competition and innovation has found inconsistent support based on the seemingly contradictory theories of

Schumpeterian competition (1934) and Arrow's competition (1962). It seems that there is no unambiguous evidence of a generally valid relationship between competition and innovation. The relationship between competition and innovation is argued to be relative and meaningful when the competition context and the type of innovation activities are specified (Baldwin and Scott, 1987; Tang, 2006). Our study is one of the few empirical investigations on the specific relationship between foreign competition and pioneering innovations. Secondly, our measurement of foreign competition is based on the perceptions of the managers rather than any industrial parameters because we believe that the perceptions on competition better presents the real competitive condition under which managers make decisions about innovation activities. Finally, we operationalized the absorptive capacity into two factors that determine the capability of a firm to acquire and assimilate external knowledge. We found that diverse and complementary knowledge and past experience play different roles with regard to the relationship between foreign competition and pioneering innovation. The diverse and complementary knowledge exposure reflects the notion of cognitive distance (Nooteboom, 2000) and knowledge proximity (Knoben and Oerlemans, 2006) which has been extensively discussed in the literature. Diverse and complementary knowledge exposure does not directly increase the likelihood of pioneering innovation, but it positively moderates the effect of foreign competition. This implies that firms that are exposed to diverse and complementary knowledge will more rapidly find their way to create new pioneering innovations when foreign competition increases from moderated to high levels. On the contrary, past experience has a direct positive effect on the likelihood of pioneering innovation.

Our findings also provide several important implications for innovation management. Firstly, when more and more foreign competitors rush into the domestic market, domestic firms need to learn how to compete by exploring new technological and market opportunities rather than only focusing on improving efficiency and exploiting the existing technological competence (March 1991). Secondly, to enhance the likelihood of generating pioneering innovations, firms need to explore various resources outside of the organizational boundary. The investment in facilitating organizational absorptive capacity is important, which may enhance the innovation performance of firms under severe competitive conditions. Firms should consciously and actively search for new knowledge that is different and complementary to their existing knowledge base. Next, firms should accumulate innovation experience and embed it into their organizational memory. Positive experience in undertaking pioneering innovations encourages firms to generate more innovations alike in the future.

This chapter also has several limitations. Firstly, the data was collected for a period from the 1940s till 1980s, when the competitive landscape was different than the current one. One can reasonably expect that the competitive landscape might be much more intensive with the globalization of world economy in the 21st century. Thus, it is an open question whether the U-shaped relationship between foreign competition and pioneering innovation still holds nowadays. We expect that, in the 21st century, the left side of the U-shaped relationship (the downward slope) might not so obvious, while the right side of the U-shaped relationship (the upward slope) might be steeper than in the observation period in this study because the foreign competition is extremely intensified in most of the industrialized countries. Secondly, the innovating firms in our dataset are all Canadian firms. As a result, the generalizability of findings of this study is limited. We argued that each country holds its unique endowment for innovation. Studies using data of innovating firms from other countries are required to test if our findings can be generalized. For instance, we would expect that in developing countries, firms may have little experience in pioneering innovation and limited exposure to diverse and complementary knowledge; meanwhile foreign competitors are crowded in the market. In this situation, how firms in developing countries react to the competitive condition will be an interesting question to investigate. Finally, our measure for diverse and complementary knowledge exposure is based on the SIC-code, which is just a raw proxy for a firm's knowledge base. Constrained by the original design of the Canadian survey, we could not develop a more precise measure. Future research that uses other measures may deliver a better understanding of the role of diverse and complementary knowledge. Patent data might be helpful in that respect.

This chapter has shed some new insights on the important relationship between competition and innovation. Furthermore, it has also differentiated the roles of two antecedents of absorptive capacity, i.e., diverse and complementary knowledge and past experience, on the likelihood of pioneering innovation. In general, we hope our study can help guiding future research on the relationship between specific types of competition and innovation and bring thoughtful insights research on the different aspects of absorptive capacity.

Chapter 5

The dual role of external corporate venturing in technological exploration

5.1 Introduction

The role of gaining external knowledge source for a firm to explore new technological and market opportunities has been long recognized in the studies in innovation management, strategic alliances and corporate venturing (e.g., Rosenkopf and Nerkar, 2001; Lavie and Rosenkopf, 2006; Schildt *et al*., 2005; Keil *et al*., 2008). Companies are increasingly using external corporate venturing to learn from knowledge sources beyond the boundary of the firm (Rosenkopf and Nerkar, 2001). External corporate venturing, including corporate venture capital (CVC) investments (Dushnitsky and Lenox, 2005; Keil *et al*., 2008), alliances (Gulati, 1998), and mergers and acquisitions (M&A) (Ahuja and Katila, 2001; Puranam and Srikanth, 2007) has been found positively related to the innovation performance of firms and has become a noteworthy vehicle for exploration (Schildt *et al*., 2005; Lavie and Rosenkopf, 2006; Lin *et al*., 2007). Exploration refers to the variation-seeking, risk-taking and experimentation-oriented learning of unfamiliar knowledge (March, 1991). It has been suggested in the existent literature that by forming external venturing relationship with other firms, an innovating firm can tap into novel knowledge sources and explore new technological opportunities from venturing partners (Chesbrough, 2003; Rosenkopf and Nerkar, 2001; Schildt *et al*., 2005; Keil *et al.*, 2008).

We have also noticed that an innovating firm could not only explore new technologies from its corporate venturing partners, but also explore new technologies from the organizations to which the innovating firm has had no prior venturing relationships. When an innovating firm explores beyond the corporate venturing partnerships, the existing corporate venturing partnerships may have impact on the exploratory learning of the innovation firm by acting, for instance, as an information pipe, a reputation reference, or a complementary knowledge source (Podolny, 2001; Gulati, 1998). Although prior studies have greatly contributed to our understanding of the relationship between external corporate venturing and exploration, they mostly focus on a firm's exploratory learning *from* its venturing partners (hereinafter "exploration from partners" or "EFP"). There has been little insight on how external corporate venturing may affect the exploratory learning *beyond* the venturing partnerships (hereinafter "exploration beyond partners" or "EBP"). In other words, the existent literature has analyzed in detail the role of partners with regard to external sources of knowledge, but we know little about how external venturing partnerships could play their roles for an innovating firm to explore technological knowledge embedded in other organizations with which it has *no* venturing relationships. We also have little insight on how external venturing partnerships could affect on EFP and

EBP *differently*. We believe it is important to investigate the role of a firm's external corporate venturing on explorative *from* partners as well as on exploration *beyond* partners for several reasons. Firstly, since firms are socially embedded with various social connections in a more and more open innovation context, non-venturing-partner firms should be an equally important external source for exploration as those venturing partners. Secondly, a firm's external corporate venturing is highly relevant to its exploration beyond partners because the venturing partnerships can serve for the innovating firm as a radar to allocate the new technological opportunities, as a prism to identify the relevance and complementarity of new technologies, and as a reputation mechanism to justify the exploration beyond partners. Finally, the quantity and quality of a firm's existing venturing relationships might alter the incentive and constrain the resource for exploration beyond partners.

The purpose of this paper is to investigate the effect of external corporate venturing, including corporate venture capital (CVC), alliances and mergers and acquisitions (M&A), on both types of explorative learning – exploration from partners and exploration beyond partners. We focus on corporate venturing relationships that are aimed at exploring new *technological* opportunities.

This paper makes several contributions to the corporate venturing and inter-organizational learning literature. Firstly, to our knowledge, this paper, for the first time in the literature, conceptually distinguishes exploration *from* partners and exploration *beyond* partners. Secondly, it empirically investigates the different effect of external venturing on a firm's exploration from partners and exploration beyond partners. The results of the test extend our understanding on corporate venturing and innovation. Third, it also theoretically explores and empirically tests the relationship between the level of integration in the venturing governance modes and the exploration from partners and exploration beyond partners. Finally, we also take into account the possible influence of technological distance (Nooteboom, 2000) on exploratory learning in combination with the effects of external corporate venturing. We hope our exploratory attempt may provide a new insight for the literature on inter-organizational learning in general and for the prevailing research topic on exploration in particular.

This paper is organized as following. Firstly, we introduce the concept of exploration and exploitation and explain the difference between exploration from partners and exploration beyond partners. We also illustrate how most of the prior literature limited their focus only on the inter-organizational learning *between* venturing partners. Secondly, we provide the theoretical background for corporate venturing and develop hypotheses on the relationships between corporation venturing and exploration from partners and exploration from partners. Next, we present the data and estimation methods to test the hypotheses. Finally, we discuss the results and draw some conclusions for our research.

5.2 Theory and hypotheses

5.2.1 The dual role of external corporate venturing partnerships in technological exploration

The notion of exploration and exploitation has been widely used in studies on organizational learning, strategic renewal and technological innovation. March (1991) introduced the two concepts as follows: 'exploration includes things captured by terms such as search, variation, risk taking, experimentation, flexibility, discovery, and innovation. Exploitation refers to such things as refinement, choice, production, efficiency, selection, implementation, and execution (March, 1991, pp 71). Exploration is variation-seeking, risk-taking and experimentation oriented. Exploitation is variety-reducing and efficiency oriented (March, 1991). In this paper, we focus on the *exploration* between firms. Moreover, we explicitly distinguish two types of exploration with regard to the external corporate venturing relationships between firms.

Exploration is usually recognized as activities that search for unfamiliar, distant and remote knowledge (Ahuja & Lampert, 2001; Rosenkopf & Nerkar, 2001; Benner & Tushman, 2002; Katila &Ahuja, 2002; Nerkar, 2003). There have been many different ways of definition of exploration in the existent literature (Li *et al.*, 2008), One of the basic factors that differentiate exploration from exploitation is whether the learning of new knowledge crosses the organizational boundary (Rosenkopf & Nerkar, 2001; Sidhu *et al*., 2004). In other words, a firm's reuse of internal knowledge source is exploitation, while learning new knowledge outside of the firm is regarded as exploration (Katila and Ahuja, 2002; Rosenkopt and Nerkar 2001). Knowledge source from other firms is crucial for exploration because any innovation is considered as the result of a recombination of component elements (Schumpeter, 1934; Henderson and Clark, 1990; Kogut and Zander, 1992). Firms can find for new technological knowledge from other companies because firms differ among each other in many ways, such as R&D, production efficiency, input and output of innovation, technological capabilities and so forth (Dosi, 1988). Difference in knowledge is a crucial condition for learning and innovation to produce Schumpeterian 'novel combination' (Nelson and Winter, 1982). Therefore, several studies on corporate venturing and strategic alliances have interpreted exploitation as to reuse and refine a firm's existing knowledge base, while exploration as to learn new technology from venturing partners (Benner and Tushman, 2002; Schildt *et al*., 2005; Lavie and Rosenkopf, 2006; Yin *et al*., 2007). These venturing partnerships may vary from corporate venture capital investment, strategic alliances, joint ventures, and mergers and acquisitions. However, the existent literature, which defines exploration whether a firm's learning of new knowledge crosses the organizational boundary, only investigates the innovating focal firm's exploratory learning *from* its partners and overlooked the possibility that a firm may utilize the external corporate venturing relationships to explore new technologies *beyond* the existing venturing partnerships.

We draw on the existent literature on technological innovations to define the two types of exploration—exploration from partners (EFP) and exploration beyond partners (EBP). The distinction between EFP and

EBP allows us to test some hypotheses with regard to the possibly different effects of external venturing partnerships on both types of exploration. To explain the our distinction between EFP and EBP, Figure 6 illustrates the rationale on how to distinguish different types of learning by tracking the patent citations of an innovation firm. Firstly, if firms innovate, they usually build on prior developed technologies of their own or from other organizations (Nelson and Winter, 1982; Katila, 2002). When companies build on prior technological knowledge, the new patents must cite existing patents on which it builds. Hence, patent citations provide us with a unique and reliable method to define different types of learning.

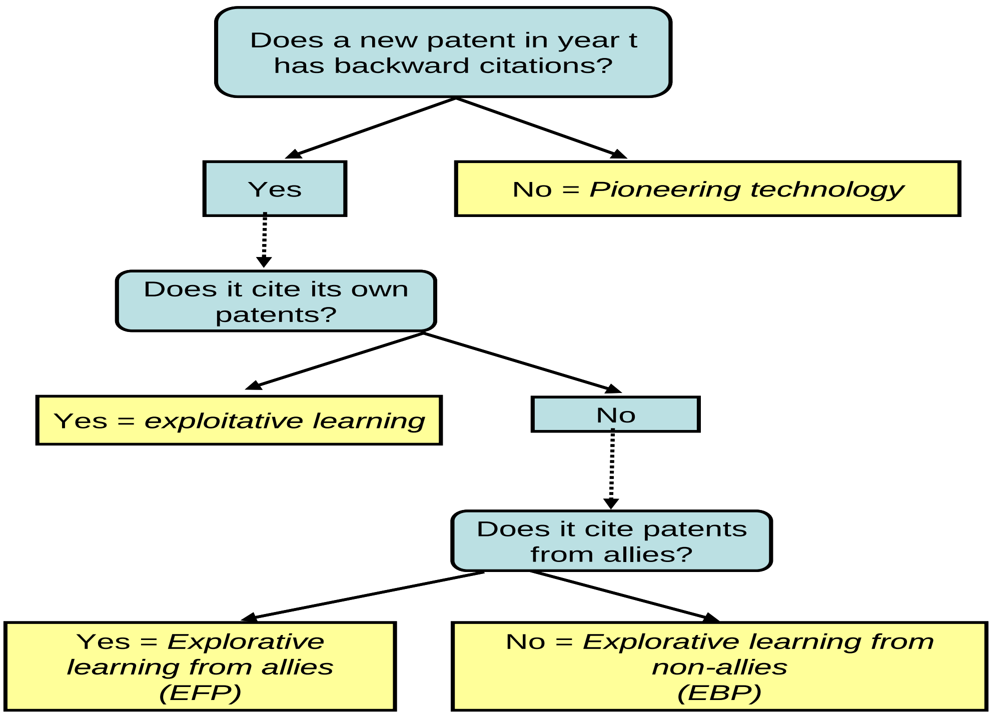


Figure 6. How to distinguish between the two types of explorative learning

In some cases where firms invent completely new technologies, the new patents do not cite any prior patents. These so called pioneering technologies have no technological antecedents and they represent the technologies that do not build on any existing technologies (Ahuja and Lampert, 2001). Pioneering technologies are interesting as they may have a disruptive effect on existing technologies, but they fall outside the scope of this paper (Van de Vrande *et al.*, 2006; Kleinschmidt and Cooper, 1991). We can further distinguish two different cases when a firm's new patents do cites prior patents. On the *exploitative* one hand, the new patent can cite some of the firm's own patents, which implies that the firm's new patents are build on the firm's prior expertise and experience. This type of self-citation is usually regarded as learning in the literature (Benner and Tushman, 2002; Rosenkopf and Nerkar, 2001; Schildt *et al.*, 2005). By exploitation, firms deepen and refine their current technical capabilities that are most likely important competencies underlying the current businesses of these firms. Exploitative learning also goes beyond the scope of this paper. In other cases, a firm can also successfully file new patents that do not necessarily cite the firm's own prior technology. When an innovating firm's new patents have no backward self-citations, the firm explores some new technological areas and broadens its own technological capabilities, building on the knowledge from other organizations. Patents with no self-citations can be associated with novel technologies, i.e., technologies that are new to the organization, even though they may have been in existence earlier on in other organizations (Ahuja and Lampert 2001). They are more explorative than patents with self-citations and are an important mechanism to avoid the problems related to a strong dependence on local search.

So far, we have only been summarizing some of the existing definitions of technological exploitation and exploration in the literature. A major contribution of this paper to the literature consists of a further segmentation of the explorative patents into two subcategories. On the one hand, innovating firms may avoid local search by learning from their venturing partners. These venturing partners are connected to the innovating firm by various venturing relationships, including corporate venture capital, strategic alliances, joint ventures or mergers and acquisitions. For the sake of simplicity, we call this 'exploration from partners (EFP)'. As a result, a patent is regarded as a proxy of the learning process and categorized as EFP when some backward citations of an innovating firm refer to those organizations that have venturing relationships with the innovating firm (Benner and Tushman, 2002; Schildt, *et al.*, 2005).

On the other hand, companies can avoid local search by exploring further from organizations with which they have had no prior external corporate venturing relationships. We call it 'exploration beyond partners (EBP)'. The existent literature has noticed the importance of this type of learning (Beckman *et al*., 2004; Lavie and Rosenkopf, 2006), but overlooked the relationships between the external corporate venturing and EBP (Schildt, *et al.*, 2005; Keil *et al*. 2008). As the system of innovation and its network become more open and more associated with different levels of collaborations between various social and economic actors, it is possible for a firm to explore new technology from other firms, with whom it has no corporate venturing relationships. For example, one of the important non-corporate venturing external sources of innovation comes from customers and suppliers. Some studies have suggested that market orientation yields superior innovation and greater new product success (Kohli & Jaworski, 1990; Narver & Slater, 1994). The role of lead users in facilitating innovations became well-established as well (Von Hippel, 1986; Von Hippel *et al*., 1999). Many firms increasingly realize that supplier involvement in new product development is critical to provide innovative technologies that can facilitate radical innovations (Håkansson, 1982; von Hippel, 1988). Another way to get access to external new knowledge is via the technology intermediaries. The intermediaries in innovation and technology have their roots in the 'middlemen' in the agricultural and textile industries in the 16th. Nowadays, in every OECD country, the intermediaries, including Technology Transfer Office, industry technology associations and private technology brokers, play a crucial role in facilitating innovations (Howells, 2006). An innovative firm may not necessarily form venturing relationships to explore new technologies because the intermediaries can connect the technology-seeker and technology-provider (van der Meulen and Rip, 1998). An innovating firm could also explore new technological knowledge beyond its existing external corporate venturing relationships by attending industrial exhibitions, referring to public science (McMillan *et al*., 2000), benchmarking with competitors (Wiersema and Bowen, 2008; Hunt and Morgan, 1997), etc.

Although EBP is important for a firm's innovation, the existent literature seems to overlook the relevance between a firm's external corporate venturing relationships and EBP. For instance, Schildt *et al*. (2005) intentionally excluded the patents that do not make reference to patents of a venture partner but to other organizations because they are not considered as constituting *interorganizational learning*. As Gulati (1998) has pointed out, prior research has primarily focused on the implications of the network of existing corporate venturing relationship, yet the role of the multiplicity of social and economic contexts in which firms are embedded remains underdeveloped. We argue that there are many reasons to believe that it is important to link a firm's existing external corporate venturing relationships and its exploration *beyond* these venturing partners. Firstly, the innovating firm is embedded in a social network of firms with which the innovating firm is directly or indirectly connected via the venturing partnerships (Granovetter, 1985). The social embeddedness of firms provides an innovating firm not only with access to the knowledge base of its venturing partners to which it's directly connected, but also the possibility to reach the knowledge base of other firms to which are connected to the focal firm's venturing partners (Davis, 1991). The external corporate venturing relationships may not only serve as a conduit for knowledge flow between the venturing partners and the focal innovating firm, but also provide the innovating firm with the access to the knowledge base of other firms that are not directly connected with the innovating firm (Burt, 1992). In other words, the external venturing partnerships may increase the likelihood of knowledge spillover from other firms to the focal innovating firm (Meyer, 2004; Chang and Xu, 2008). The external corporate venturing relationships can be regarded as the channels to reach beyond the boundary of an innovating firm's direct network to a larger network of other firms and a broader knowledge pool (Gulati, 1998; Beckman *et al*., 2004; Lin *et al*., 2007). Secondly, due to the unique knowledge base of the partner firms, the external corporate venturing partners may help the innovating firm to find where the novel technologies are. When the novel technologies is allocated, the external corporate venturing partners may further act as a knowledge reference to identify the relevance and complementarity of the knowledge with regard to the existing knowledge base of the innovating firm (Burt, 1992; Nooteboom, 2000a). In other words, raised to a metaphorical abstraction, the external corporate venturing partnerships may act as radars to allocate the new knowledge beyond the boundary of the network of direct venturing partners, and as a controller to check the usefulness of the new knowledge for the innovating firm. Last but not least, the relationships between the innovating firm and its external venturing partners affects third party's perceptions of the relative trustworthiness, organizational capabilities and performance of the innovating firms (Podolny, 2001). For instance, if the innovating firm has an external corporate venturing relationship with a firm having superior reputation and performance, other firms with complementary technologies will perceive the innovating firm as with great capability, competence and trustworthiness (Gulati, 1995; Nooteboom, 2000b). Thus, in turn, this may create potentials for the innovating firm to form new cooperation and explore new technological opportunities with other firms with which it has not had venturing relationships before. In other words, the external corporate venturing partnerships may act as a reputation reference for other firms to evaluate the value of the innovating firm, which, in turn, affects the choice and success for the innovating firm to explore beyond the external corporate venturing relationships (Burt, 1992).

This categorization of explorative patents with regard to a firm's external corporate venturing partnerships into EFP and EBP creates the possibility to distinguish *two roles* for a firm's technology venturing partnerships in conceiving and applying for exploratory patents. When an innovating firm is not relying on the technological capabilities of its partners to explore new technologies, the venturing partners may still have a role to play in helping or facilitating exploratory learning of the focal firm as we mentioned above. inter-firm networks are collections of firms joined by various types of ties. One can define different networks of the same collection of social actors by the nature of the relationships, such as friendship network, reporting network, investment network, supplier-customer network, corporate venturing, etc (Scott, 2000). For those studies that are interested in the effects of firms social embeddedness on exploration, they mostly focused only on one single type of network based on a particular nature of inter-firm relationship (e.g. Ahuja, 2000; Rowley et al., 2004; Rowley et al., 2005; Vanhaverbeke and Noorderhaven, 2001; Lin, *et al*., 2007). We know little about how a firm's exploratory learning from its venture partners may influence the similar kind of learning from other social actors with whom the firm has other types of relationships or no relationships. Hence, the main purpose of this study is to investigate the possibly different effects of external corporate venturing partnerships on the *exploration from partners* and the *exploration beyond partners* of the focal firm.

5.2.2 Corporate venturing and exploratory learning

Corporate venturing has been recognized as a main source for firms to get access to external technology. Firms have choices for different forms of corporate venturing with respect to the level of integration for the venturing relationship, which defines the governance mode of a particular corporate venturing (Schildt *et al*., 2005). These venturing forms include corporate venture capital, non-equity alliances, equity alliances (including joint ventures), and mergers and acquisitions. Companies are increasingly using corporate venturing to gain technological knowledge beyond the boundary of the firm.

Corporate venturing investments are usually flexible investments of a firm to get access to the knowledge of the start-ups (Dushnitsky and Lenox, 2005). Investments in innovative start-ups may provide the corporation with and ensure a stake in novel technological opportunities. Non-equity alliances, which include licensing, second-sourcing, distribution agreement and technology exchange agreements, refer to those that do not involve an equity investment in the partner firm. The alliances scope and cooperation are largely based on flexible contractual agreement. Equity alliances are those alliances that require either shared ownership, independent administrative, operational and incentive system (joint ventures), or one or more partners take equities in other partners' ownership (minority holdings) (Gulati and Singh, 1998). Both non-equity and equity alliances are found positively related to firms' innovation performance because firms can learn from their allied partners through various level of cooperation (Stuart, 2000; Hagedoorn & Duysters 2002). Those alliances that are established in order to search for new technology from partners usually result in positive exploratory performance (Rothaermel, 2001; Rothaermel & Deeds, 2004). Finally, merger and acquisition allows the acquiring firm completely to absorb the knowledge from the acquired firms through the ownership control. Prior research also found positive relationship between M&A and innovative performance (Ahuja and Katila, 2001; Keil, *et al.*, 2008).

On the one hand, the existent literature has found that the external venturing partnerships are positively related to the exploratory learning of firms (Schildt *et al*., 2005; Keil, *et al.*, 2008; Van de Vrande *et al*., 2007). On the other hand, there are several reasons why we believe the external venturing partnerships are also positively related to the exploration beyond partners (EBP). Firstly, inter-firm networks are considered a potential source of learning (Levitt and March, 1988; Powell, 1990). Networks enable forums for discussion, direct attention to new practices, and facilitate the transmission of information (Beckman and Haunschild, 2002). With venturing relationships, a company can get connected to a much larger inter-firm network by directly or indirectly connected with the contacts of its venturing partners. The enlarged inter-firm network serves as conduits for technological information, which in turn lead to new technological capabilities (Davis, 1991). Thus, the possibilities of exploration beyond partners increase when a firm has large number of venturing relationships. Moreover, firms are usually engaged in many different types of networks at the same time, such as venturing network, supplier and customer network, and distribution network, etc. A firm's resource in one type of network may be transferable to other types of inter-firm network. The *transferability* of network resources entails that a network resource is transferable to some extent if it is valuable outside the network in which it embedded and therefore can provide firms with advantages in multiple networks (Jensen, 2003). In this case, firms with rich network resource in the external corporate venturing network are more likely to transfer their exploratory knowledge and capability to other types of social network and explore elsewhere. The experience in exploration from venturing partners may teach the innovating firm how to build up an effective exploratory learning routine from external source, which can be applied to and benefit the exploration from sources other than venturing partners. Secondly, the external corporate venturing partners may help the innovating firm to find where the novel technologies are and identify the relevance and complementarity of the knowledge with regard to the existing knowledge base of the innovating firm (Burt, 1992; Nooteboom, 2000a). It is also likely that EFP demand more complementary technologies from non-venturing-partner firms, without which the value of EFP remains worthless. Last but not least, a firm with many external venturing partnerships could be deemed as having a high position in a status hierarchy to control over resources with strong innovation capabilities and financial performance (Ibarra, 1993; Lin *et al*., 2007). The external corporate venturing partnerships may act as a reference for other firms to evaluate the reputation and capability of the innovating firm, which, in turn, affects the choice and success for the innovating firm to explore beyond the external corporate venturing relationships (Burt, 1992). Therefore, we expect that firms that are rich in external corporate venturing partnerships will be more likely to undertake exploration from partners (EFP) and exploration beyond partners (EBP) than those firms with few corporate venturing partnerships. Accordingly, we hypothesize

Hypothesis 1a: The number of corporate venturing, including CVC, non-equity alliances, equity alliances, and M&A, are positively associated with a firm's exploration from partners (EFP) and exploration beyond partners (EBP).

Although we would expect a positive relationship between the external corporate venturing of an innovating firm and its exploratory learning, there are also many concerns with regard to the significance of this positive effect. Firstly, external corporate venturing partnerships provide the innovating firm with direct connections with its partners. The exchange of knowledge between the innovating firm and its partners, i.e., EFP, is based on certain level of reciprocity (Kachra and White, 2008) and regulated by certain level of contractual agreement (Gulati, 1998). However, the external corporate venturing partnerships only provide the innovating firm with some possibilities to get *indirect* connection with other firms. Even if the innovating focal firm explore beyond the venturing partners via the connections of its venturing partners, the knowledge exchange between the innovating focal firm and other non-venturing-partner firms is not based on and governed by the reciprocity and contractual agreement of external corporate venturing partnerships. Secondly, although a great number of external corporate venturing partners may raise the chance that the novel and complementary technological knowledge beyond the venturing partnerships will be identified and effectively utilized for the innovating focal firm, this might not always the case because it is dependent on the network resources and technological capabilities of the venturing partners (Eisenhardt and Schoonhoven, 1996). A firm's corporate venturing partners vary in terms of their size, age, competitive position, product diversity, financial resources, etc. (Shan, 1990; Burgers *et al*., 1993). Thus, their capabilities to facilitate the innovating focal firm to undertake EBP may differ as well. Moreover, an innovating firm with many external venturing partnerships may be conceived by other firms as competitive in many industries and markets. Thus, other firms, which have no venturing relationships with the innovating firm, may consider the innovating firm as a potential competitor and prevent their technologies from spilling over to the innovating focal firm (Schrader, 1991; Chang and Xu, 2008). Due to these concerns, we expect the positive effects of the external corporate venturing on EFP and EBP to be different. Accordingly, we hypothesize,

Hypothesis 1b: The positive impact of the number of corporate venturing (including CVC, non-equity alliances, equity alliances, and M&A) on EFP is more evident than the impact of the number of corporate venturing on EBP.

5.2.3 Governance modes of corporate venturing and exploratory learning

External corporate ventures differ in their governances modes with respect to the level of hierarchical control and the intensity of integration. Prior research on contract choices in corporate venturing has been influenced primarily by transaction cost economy (Gulati, 1998). Two key dimensions of transaction cost economy are *assets specificity* and *uncertainty* (Williamson 1975, 1985). Assets specificity refers to the assets that are invested in a particular transaction and cannot be easily redeployed to another transaction. Uncertainty is the fact that relevant contingencies of an exchange are too unpredictable to be specified *ex ante* a transaction (environmental uncertainty) or the performance of a transaction is not easily be verified *ex post* (behavioral uncertainty). Under uncertainty, as specific assets invested, one with bounded rationality has to safeguard his transaction against partners' potential opportunistic behavior (Williamson 1985, 1991, 1996). In addition to safeguarding transaction hazards, relational risks such as *holds-up risks* and *spill-over risks* (Nooteboom 2004a, 2004b) exist in various alliances relationships. The holds-up risks (lock-in/out) results from the interdependence of organizations and relational-specific investments. The spill-over risks (i.e. learning races) emerge due to the asymmetry of inter-organizational learning between firms whose relationship are never exclusively cooperative or competitive (Nooteboom 2004a, 2004b, Gulati *et al.* 2000). The interactive nature of innovation and organizational learning requires appropriate governance to realize the potential of inter-organizational relationships and control the relational risks.

The governance modes we introduced in this paper (CVC, equity and non-equity alliances and M&A) differ in the degree of integration between the partners. CVC is the most arms-length relationships among all these governance modes, while M&A requires the closest integration between partners (Schildt *et al*., 2005). Standing in between is the alliances relationships. For non-equity alliances, coordination among partners is based on contract. Members of the partners work jointly on behave of their own organization. Day-to-day activities are limited in time and frequency. Equity alliance (usually joint ventures) is a separate entity created by alliance partners. It requires not only specific equity investment, but also tight coordination between alliance partners because a separate administrative, operational and incentive system needs to be established (Gulati and Singh, 1998). Researchers have found that governance modes that appropriately aligned with transaction dimensions leads to enhanced performance (Geyskens *et al*., 2006). Prior research has suggested that due to the uncertain nature of exploration and the unknown strategic importance and operational relatedness of ventures toward exploratory learning, less integrated governance modes are more likely to be appropriate for exploration (Schilt *et al*., 2005; Van der Vrande and Duijsters, 2007; Gilsing and Nooteboom 2006). However, the relationship between the integration level of governance modes in external venturing and a firm's *exploration beyond partners* (EBP) has received little attention in the literature.

On the one hand, the existent literature has argued that higher levels of integration in the governance modes of external corporate venturing are less likely to lead to *exploration from partners* (EFP) because of the uncertain nature of the returns to EFP and the unknown strategic importance and operational relatedness of the ventures (Schildt, *et al*., 2005; Van de Vrande, *et al*., 2006). In this case, innovating firms tends to form venturing partnerships with low integration levels of governance to remain flexible. On the other hand, we argue that there are also reasons to believe that higher levels of integration in the governance modes of external corporate venturing may lead to less *exploration beyond partners* (EBP). High levels of integration in governance modes entail more specific investment in the venturing relationships. Holds-up risks are much higher in high levels of integration in governance modes (Gilsing and Nooteboom, 2006). The innovating firms are more likely to *exploit* the best out of these specific investments as much as possible in high levels of integration modes. Thus, it is less likely to see EBP happening. In other words, from a resource-based point of view, when the innovating firm forms venturing partnerships with low integration level of governance modes, it does not commit much specific assets and thus might have more resource to explore beyond the venturing partnerships. Therefore, we expect that a firm having a corporate venturing portfolio with high levels of integration will undertake little effort to explore beyond partners. Accordingly, we hypothesize

Hypothesis 2a: All else equal, lower levels of integration in the governance modes of external corporate venturing have a stronger impact on EFP and EBP.

However, contrary to the arguments above, the traditional theory of transaction cost economy (TCE) argues that exchange relationships between firms with high uncertainty are subject to highly integrated governance modes to control the transaction hazards and the risks of spillover (Williamson 1975, 1991). Since exploratory learning between firms are highly uncertain in terms of returns and unknown with regard to the strategic importance and operational relatedness of the ventures, traditional TCE predicts that exploration from partners requires hierarchical governance modes (Pisano, 1989, Van de Vrande, *et al*., 2006). There are also reasons to expect that not only *exploration from partners* (EFP) but also *exploration beyond partners* (EBP) may be subject to high levels of integration in the governance modes of venturing partnerships. On the one hand, prior research has long recognized that firms not only cooperate with their partner firms but also take competition with their partners into account when making strategic choices (Lado *et al*., 1997). The learning opportunities created by venturing relationships and the learning racing between venturing partners may lead to greater innovative performance than either cooperation or competition (Quintana-Garcia and Benavides-Velasco, 2004). On the other hand, knowledge spillovers are most of times inevitable in inter-firm relationships. The returns of EBP may not only benefit the focal firm (private benefit) but also benefit the partner firms to any extent (common benefit) (Khanna *et al*., 1998). When the levels of integration in governance modes with the venturing partners are *low*, for instance, in a CVC relationship, the returns of an innovating firm's EBP that spill over to the venturing partners will be a serious concern of competition if the knowledge is relevant to the scope of the venturing partnership. When the levels of integration in governance modes with the venturing partners are *high*, for instance, in a M&A relationship, even if the returns of an innovating firm's EBP spill over to the venturing partners, it is usually not a concern of competition at all because the acquired enterprise is an integrated part of the innovating firm. If a firm foresees the EBP may bring great private benefit for itself, it will not consider enter into many venturing relationships with low levels of integration *ex ante*. For these reasons, accordingly, we propose a counter hypothesis against hypothesis 2a,

Hypothesis 2b: All else equal, higher levels of integration in the governance modes of external corporate venturing have a stronger impact on EFP and EBP.

5.2.4 Technological distance

Another important factor that might affect the relationships between the corporate venturing partnerships and the exploration *from* or *beyond* the partners (EFP or EBP) is the *technological distance* between the focal firm and its venturing partners (Ahuja and Lampert, 2001; Nerkar and Roberts, 2004; Phene *et al*., 2006). Due to different experiences, technologies, markets and organizational histories, organizations have different foci, which yields the cognitive distance between organizations (Nooteboom, 1999, 2000, 2004b). Technological distance reflects the technical dimension of the cognitive distance among firms. Technological distance provides firms with possibilities to explore novel combinations of technological elements. Firms with large technological distance are more likely to get access to complementary information, resources and knowledge, which in turn will result in more exploration. However, as novelty is a source for innovation, firms also need sufficient organizational capabilities to digest novel knowledge and to develop it into marketable products or process. At the organizational level, this critical organizational capability has been recognized as absorptive capacity (Cohen and Levinthal, 1990). Absorptive capacity includes organizational capabilities to assimilate externally developed information, to internally distribute it, and implement knowledge in various activities. On the one hand, learning takes place where there are differences in knowledge. On the other hand, too large cognitive distance makes basic mutual understanding unachievable (Gilsing and Duysters, 2008). Many studies have found that though difference in knowledge is a crucial condition leading to novelty in innovation (Nelson and Winter, 1982), it also has a negative effect on absorptive capacity because it creates learning problems resulting from the lack of basic mutual understanding between each other. For instance, Stuart (1998) argues that the most valuable alliances are those with similar knowledge foci and/or operating in similar markets, whereas distant firms are inhibited from cooperating effectively. Similarly, the diversification literature argues that firms learn most from alliance partners with related knowledge and skills (Tanriverdi and Venkatraman, 2005). These studies have revealed the importance of cooperation between firms with a minimum degree of similarity in their knowledge base in order to maintain sufficient absorptive capacity.

Given the possible positive effect of knowledge difference on novelty and the possible negative effect on firms' absorptive capacity, the combined effect of cognitive distance on innovation is expected to be a curvilinear function of innovation performance (see figure 3 in Chapter 3, adapted from Nooteboom, 1999).

One can expect that for the sake of exploration from partners, innovating firms should hold a moderate level technological distance with their external corporate venturing partners because too small technological distance provides little novelty for learning and too large technological distance endangers the exploratory learning by diminishing the absorptive capacity of firms. Accordingly, we hypothesize

Hypothesis 3: The technological distance between the focal innovating firm and its external corporate venturing partners has a curvilinear effect (inverted U-shape) on EFP.

Nevertheless, the effect of technological distance between the innovating focal firm and its external corporate venturing partners on exploration *beyond* partners (EBP) could be different to the one on exploration *from* partners (EFP). From a resource-based view, resource allocation is a strategic choice when the available resource is limited for a firm. Resource allocation process usually needs budgeting, which inevitably involve explicit rankings and comparisons. The process is an internal selection, through which programs and projects are compared (Burgelman, 1996). Some are deemed more important than others and are awarded a larger share of available funds and management attention (Simons, 2006). When the technological distance between the focal innovating firm and its venturing partners is very small, there is barely anything to explore from the venturing partners. The top management of the innovating focal firm may have strong incentives to exploration *beyond* its venturing partners and explicitly or implicitly downplay the importance of exploration *from* partners. When the technological distance between the focal innovating firm and its venturing partners increases, it gets more difficult for the venturing partner firms to help the focal firm to identify the location, relevance and complementarity of other external technology sources. Therefore, we expect that the innovating firms will more likely to explore beyond the venturing partnerships when the technological distance between the focal firm and its partners is at low level, but less likely to do so when the technological distance is at high level. Accordingly, we hypothesize

Hypothesis 4: The technological distance between the focal innovating firm and its external corporate venturing partners has negative effect on EBP.

5.3 Data, variables and method

5.3.1 Data and sample

To test our hypotheses, we use a sample consisting of 153 firms that were active in the pharmaceutical industry between 1990 and 2000. The dataset was constructed in the following way. For each year of the observation period, the 200 companies with the largest cumulative number of patents in the industry were collected. The pharmaceutical industry consists of mainly two types of firms: generic drug companies and innovators. To distinguish between those, the sample was selected based on the firms' prior patents in the industry. Selection was based on patents filed in the following patent classes, defined by the USPTO

(Rothaermel and Hess, 2007; Rothaermel and Thursby, 2007): 424, 435, 436, 514, 530, 536, 800, and 930[15]. Firms with a large number of patents in the industry are typically also large firms in terms of revenues. Moreover, large firms are more likely to engage in external technology sourcing activities and are more likely to report them publicly (Keil *et al*., 2008). Prior research on alliances and acquisitions has for that reason also focused on the largest companies in the industry (Ahuja, 2000; Gulati, 1995; Gulati and Garguilo, 1999; Hitt *et al*., 1991, 1996; Keil *et al*., 2008). The sample was selected based on companies' prior patents in the industry. 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, which were then aggregated on parent company level. After checking for duplicates, this leads to 153 independent companies to be included in the sample. We will refer to these independent companies as "focal firms", to distinguish them from their partners.

Next, we have gathered for these firms all the venture capital investments, technology alliances, minority holdings, joint ventures, and merger and acquisition activities during the period of 1985-2000, which allows us to calculate some of the independent variables using a five-year time lag. Furthermore, we collected 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. Because both the collected alliances and corporate venture capital investments have a strong technology component, we also included only technological M&As in our sample, following the method by Ahuja and Katila (2001)[16].

Patent information 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, we consolidated the patents on parent company level for each observation year, using *Who Owns Whom* by Dun & Bradstreet. In addition to that, we gathered financial data using Worldscope, including sales, research and development expenses and the number of employees. Because financial information was not available for all firms in our sample, and because some firms in our sample did

15 Description of the patent classes is as follows: 424: drug, bio-affecting and body treating compositions; 435: chemistry: molecular biology and microbiology; 436: chemistry: analytical and immunological testing; 514: drug, bio-affecting and body treating compositions; 530: chemistry: natural resins or derivatives; peptides or proteins; lignins or reaction products thereof; 536: organic compounds; 800: multicellular living organisms and unmodified parts thereof and related processes; 930: peptide or protein sequence.

16 The method employed in this paper is slightly different from the method by Ahuja and Katila (2001). Ahuja and Katila (2001) included also deals for which they found press releases indicating technology as a specific motivation for undertaking the M&A. Since we had no access to these press releases, we could only include deals in which the partner has applied for at least one patent in the 5 years prior to the acquisition.

not have any pioneering technologies, these firms were dropped from the sample. The final sample consists of 105 focal firms.

5.3.2 Variables

Dependent variables:

In this study, we distinguish between two types of dependent variables: exploration from partners (EFP) and exploration beyond partners (EBP). Both variables are count variables, indicating the number of new patent applications that fulfill certain requirements. *Exploration from partners* is calculated as the sum of patents successfully applied for per year by the focal firm which have at least one citation to its partner's prior patents, but no citations to its own prior patents. *Exploration beyond partners*, on the other hand, is calculated as the number of patents successfully applied for per year by the focal firm which neither cites its own prior patents, nor its partners' prior patents. Table 9 below shows the difference between the two variables:

		Citation to partners' prior patents	
		Yes	No
Citation to own prior patents	Yes	Local search within venturing network (exploitative)	Local search within the firm (exploitative)
	No	Exploration from partners	Exploration beyond partners

Table 9. Definition of Exploration From Partner (EFP) and Exploration Beyond Partners (EBP)

In our sample, there are 171,532 patents in total, of which 101,228 are exploitative patents and 70,304 are exploratory patents. 15% of the exploratory patents cite partners' prior patents (EFP).

Independent variables

The hypotheses 1a, 1b, 2a and 2b predict a direct relationship between CVC investments, non-equity alliances, equity alliances, M&As and EFP and EBP. 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*). A five year moving window is appropriate, since technological knowledge loses most of its value within the first five years.

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 $1 - T_{ij}$.

Control variables

1. *Firm size*. Firms of different sizes innovate differently. In the classical Schumpeterian argument, companies' innovation performance increases more than proportionally with firm size due to large firms simply having more resources. Large firms usually have more external corporate venturing partnerships and more centrally positioned in their venturing networks than small firms. Large firms also have greater capacity to cooperate in multiple tasks, which is crucial for inter-organizational learning and absorptive capacity (e.g., Shan, 1990; Powell and Brantley, 1992). Prior research has found that more likely than the small firms to undertake exploratory learning *from* or *beyond* their existing venturing partners, which leads to better innovative performance (Lin *et al*., 2007). Large firms are more capable to achieve EFP and EBP because it is much easier for large systems to allocate different activities at different units at various levels within an organization (Gutpa *et al*., 2006). small companies may be more likely to explore new technological areas with focused strategy in less crowded areas (Lin *et al*., 2007; Almeida and Kogut, 1997). *Firm size* is measured as the natural logarithm of sales of the focal innovating firms.

2. *R&D intensity*. Prior research has indicated a strong relationship between R&D inputs and innovation, and regarded R&D expenditure as a means to maintain 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. The control variables *size* and *R&D intensity* are lagged by one year.

3. *Technological age*. Technological age is a firm-level control variable. To measure it, we first need to measure the technological newness. Technological newness is operationalized by two steps. Firstly, we determine the age of all patent classes. This is calculated as the median of the age of all patents in a patent class in a particular year. The age of the patent is the time elapsed between the application year and the year of observation. To overcome outlier bias, we use the median age rather than the average to calculate the age. Secondly, to calculate the average technological age of a firm, we multiply the share of patent applications by the technology age for each patent class. The reason why to control for the technological age of firms is as follows: If a firm has a relevantly young portfolio of patents, it implies that the firm holds some technologies in their early phase of the life cycle, which may entail high technological uncertainty. Under different degrees of technological uncertainty, firms might employ different strategies to explore knowledge from external sources (Lambe and Spekman, 1997; Steensma and Fairbank, 1999).

4. *Dummy variables of geographic regions*. The focal innovating firms are either American firms, or European firms, or Japanese firms. Companies on different continents may innovate differently due to the differences with respect to the culture, institute, and natural endeavor of resources. Thus, we use two dummy variables to control for the geographic location of the focal firms (The US firms are set as default).

5. *Dummy variable for industries*. Because the sample consists of firms in both pharmaceutical and chemical industries, we use one dummy variable to control for the two different industries.

6. *Year dummy variables*. Finally, we used dummy variables to control for the unobserved effects of time in each consecutive year.

5.3.3 Method

The dependent variables, i.e., EFP and EBP are count variables. A Poisson regression approach provides a natural baseline model for such data (Hausman *et al*., 1984; Henderson and Cockburn, 1996; and Freese, 2003). However, Poisson regressions assume that the mean and variance of the event count are equal. This assumption is likely to be violated since overdispersion usually occurs in patents. 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). For this reason, some studies that used patent counts as a dependent variable have used a negative binomial model to test their hypotheses (e.g., Hausman *et al*., 1984; Stuart, 2000). The negative binomial model for panel data is estimated using the XTNBREG command in STATA.

To determine whether a random- or fixed-effects model is more appropriate approach for the analysis, we further conducted a Hausman specification test (1978) upon the baseline model. The Hausman test was not significant, indicating that it is safe to use a random-effects model (see Appendix I). Since random-effects model do not control for time-invariant variables (i.e., variables that differ between cases but remain constant over time), we used dummy variables to control for unobserved effects of industry and geographic regions.

5.3.4 Results

The descriptive statistics and correlations between the variables for the 898 firm-year observations in the sample are presented in Table 10. The correlation between equity alliances and non-equity alliances is high (with a coefficient of 0.7145). The high correlation between equity alliances and non-equity alliances may cause the multicollinearity problem. For this reason, we could not use a full model that includes all the different governance modes along with all the control variables. Instead, we firstly used several separate models that only include each single governance mode to examine the effects of each type of governance mode alone. After that, we used two semi-full models to avoid the problem of multicollinearity. The first semi-full model only includes CVC, equity alliances and M&As, and the second semi-full model only includes CVC, non-equity alliances and M&As, besides the control variables (see Table 11, model 6, 7, 13 and 14; Table 12, model 20 and 21). In this way, equity alliance and non-equity alliances are avoided to be included in a single model.

Tables 11 represents the results of the regression analysis using random-effects negative binomial estimations of the two types of exploration. The dependent variable is *exploration from partners* (EFP) in Model 1 to 7 and *exploration beyond partners* (EBP) in Model 8 to 14. The baseline models (Model 1 and Model 8) include the linear effects of the control variables. The coefficients of firm size are positive and significant in all models for both EFP and EBP, which suggests that larger firms are more successful in exploration. This finding seems confirms the Schumpeterian argument, which prefers large firms with market power to be more innovative. Next, the coefficients of R&D intensity are positive and significant in all models for both EFP and EBP (expect model 7), which suggests that R&D investments positively facilitate firms' exploration. However, the coefficients of firm size and R&D intensity are larger for EFP than for EBP. That is probably because EBP is more risky and harder to manage than EFP even if a firm enjoys abundant resources and strong R&D investment.

Table 10. Descriptive statistics

Correlations [a.]

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13
1. EFP	1												
2. EBP	0.5205	1											
3. Firm size	0.2851	0.2685	1										
4. R&D intensity	-0.0421	-0.0968	-0.3448	1									
5. Technological age	0.0207	0.0384	0.0233	-0.2443	1								1
6. Dummy Europe	0.0238	0.1909	-0.1737	0.0082	0.1648	1							
7. Dummy Japan	0.1128	-0.0583	0.7589	-0.0456	-0.1615	-0.3356	1						
8. Dummy Industry	-0.2035	-0.1776	-0.0311	0.2820	-0.4182	0.1153	0.1423	1					
9. Technological distance	-0.0657	0.1216	-0.1090	-0.1061	0.2131	0.0614	-0.1884	-0.1906	1				
10. CVC	0.1085	0.1739	-0.0191	-0.0080	-0.0778	-0.0538	-0.1319	-0.0584	0.0785	1			
11. Non-equity alliances	0.6676	0.4754	0.1231	-0.0414	0.0138	0.1095	-0.1131	-0.1548	-0.0007	0.2749	1		
12. Equity alliances	0.6511	0.4858	0.1854	-0.0643	0.0403	0.0409	-0.0599	-0.2120	0.0059	0.2925	0.7145	1	
13. M&As	0.2148	0.3625	0.0107	-0.1404	0.2029	0.1915	-0.3121	-0.2259	0.1615	0.3739	0.3574	0.3650	1
Mean	11.8207	57.2861	9.7471	0.1738	10.2763	0.2984	0.2093	0.4788	0.7159	0.7438	6.6748	2.8596	2.9365
s.d.	51.5243	67.2342	2.1310	0.1738	1.9784	0.4578	0.4070	0.4998	0.1882	2.8199	12.8809	4.9199	3.7388

N=898,

☐ Dummy variables of year is included but not listed in the table.

Table 11: Random-effects negative binomial estimations for EFP and EBP (with the linear effects of control variables in the baseline model)

Models	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	EFP	EFP	EFP	EFP	EFP	EFP	EFP	EBP	EBP	EBP	EBP	EBP	EBP	EBP
Size	0.596 (0.101) ***	0.576 (0.101) ***	0.554 (0.100) ***	0.503 (0.103) ***	0.495 (0.104) ***	0.411 (0.103) ***	0.375 (0.102) ***	0.408 (0.040) ***	0.403 (0.040) ***	0.422 (0.042) ***	0.401 (0.041) ***	0.384 (0.040) ***	0.388 (0.043) ***	0.371 (0.041) ***
R&D	1.522 (0.623) **	1.517 (0.628) **	1.348 (0.613) **	1.227 (0.615) **	1.328 (0.625) **	1.031 (0.612) *	0.984 (0.604)	0.744 (0.229) ***	0.738 (0.229) ***	0.79 (0.232) ***	0.729 (0.230) ***	0.69 (0.226) ***	0.713 (0.231) ***	0.668 (0.227) ***
Europe	0.222 -0.242	0.267 -0.244	0.139 -0.237	0.275 -0.234	0.214 -0.238	0.061 -0.235	0.175 -0.229	0.077 -0.132	0.099 -0.133	0.081 -0.132	0.062 -0.131	0.025 -0.131	0.053 -0.133	-0.009 -0.133
Japan	-3.878 (0.569) ***	-3.728 (0.573) ***	-3.686 (0.561) ***	-3.579 (0.559) ***	-3.263 (0.589) ***	-2.905 (0.573) ***	-2.884 (0.559) ***	-1.764 (0.248) ***	-1.726 (0.249) ***	-1.813 (0.252) ***	-1.703 (0.248) ***	-1.706 (0.246) ***	-1.703 (0.251) ***	-1.608 (0.246) ***
Pharma. Ind.	-1.428 (0.228) ***	-1.402 (0.229) ***	-1.307 (0.231) ***	-1.284 (0.227) ***	-1.454 (0.229) ***	-1.272 (0.229) ***	-1.275 (0.224) ***	-0.143 -0.123	-0.143 -0.123	-0.166 -0.124	-0.111 -0.124	-0.112 -0.123	-0.127 -0.124	-0.072 -0.123
Tech. age	-0.077 (0.043) *	-0.06 -0.044	-0.075 (0.043) *	-0.054 -0.043	-0.069 -0.043	-0.062 -0.044	-0.038 -0.045	-0.031 (0.013) **	-0.028 (0.013) **	-0.031 (0.013) **	-0.025 (0.013) *	-0.033 (0.013) **	-0.03 (0.013) **	-0.025 (0.013) *
Tech. distance	-1.372 (0.423) ***	-1.422 (0.423) ***	-1.07 (0.448) **	-1.001 (0.443) **	-1.739 (0.439) ***	-1.351 (0.456) ***	-1.364 (0.457) ***	-0.225 (0.118) *	-0.232 (0.117) **	-0.245 (0.118) **	-0.203 (0.119) *	-0.275 (0.119) **	-0.285 (0.119) **	-0.256 (0.120) **
CVC		0.017 (0.009) *				0.001 -0.009	-0.01 -0.009		0.008 (0.004) **				0.006 -0.004	0.001 -0.004
Equity alliances			0.005 (0.002) **			0.008 (0.002) ***				-0.002 -0.001			-0.001 -0.001	
M&A				0.02 (0.006) ***		0.047 (0.010) ***	0.059 (0.010) ***				0.007 (0.003) ***		0.015 (0.005) ***	0.022 (0.005) ***
Non-equity alliances					0.038 (0.009) ***		0.032 (0.006) ***					0.018 (0.005) ***		0.01 (0.003) ***
Constant	-2.645 (1.055) **	-2.684 (1.058) **	-2.735 (1.039) ***	-2.594 (1.058) **	-1.562 -1.112	-1.534 -1.099	-1.416 -1.105	-0.793 (0.392) **	-0.793 (0.390) **	-0.86 (0.397) **	-0.846 (0.396) **	-0.533 -0.395	-0.588 -0.404	-0.57 -0.398

log lik	**-1427.57**	**-1425.87**	**-1425.32**	**-1422.07**	**-1419.57**	**-1413.57**	**-1406.95**	**-3761.79**	**-3760.04**	**-3761.02**	**-3758.73**	**-3755.57**	**-3754.62**	**-3749.39**
lr-test		**3.28***	**4.38****	**10.88*****	**15.88*****	**27.87*****	**41.41*****		**3.51***	**1.55**	**6.13****	**12.46*****	**14.36*****	**24.81*****

N=898

Dummy variables of year is included but not listed in the table

Standard errors in parentheses

- significant at 10%; ** significant at 5%; *** significant at 1%

Hypothesis 1a predicts that the number of corporate venturing, including CVC, non-equity alliances, equity alliances, and M&A, are positively associated with a firm's EFP and EBP. In Table 11, Models 2 through 5 show that all types of the governance modes are positively related to EFP (the coefficients are significant at various levels). Models 9 through 12 show that all types of the governance modes are significantly positively related to EBP, except for model 10. Thus, we found support for hypothesis 1a (except for the effect of equity alliances on EBP). This implies that an innovating firm can not only tap into its external venturing partners' – CVC, non-equity and equity alliances and acquisitions – technology sources but also benefit from its external venturing partnerships to explore new technologies from other firms with whom it has had no prior venturing relationship before. This finding supports our claim that innovation partners play a dual role in technological exploration.

Hypothesis 1b predicts that the positive effect of the number of corporate venturing relations on EFP is stronger than the effect of the number of corporate venturing relations on EBP. All the coefficients of each governance mode in the models for EFP are generally larger and more significant than the corresponding ones in the models for EBP. Hence,, we find empirical support for hypothesis 1b. This finding implies that the positive effect of external venturing partnerships on EBP is, comparing to the one on EFP, indirect and less effective because the exploratory learning from non-partner firms is beyond the scope of the venturing partners network and the risks involved with the EBP is also unlikely to be controlled by the governance modes of the venturing relationships.

Hypotheses 2a and 2b predict the relationship between the levels of integration in the governance modes of external corporate venturing and EFP/EBP from two seemingly conflicting perspectives. To test these two hypotheses, we included different types of governance modes into the semi-full models. In model 6 (for EFP) and 13 (for EBP), CVC, equity alliances and M&A are included, and in model 7 (for EFP) and 14 (for EBP), CVC, non-equity alliances and M&A are included. The results in model 6 and 7 show that more integrated governance modes have a stronger positive impact on EFP. The results in model 13 and 14 also confirm that more integrated the governance modes have a stronger positive effect on EBP (except for equity alliances in model 13, β= -0,001, *p*>0.1). However, this association is not as pronounced as the results in model 7 for EFP. In sum, based on the results in models 6, 7, 13 and 14, it is safe to conclude that M&As are more appropriate for EFP and EBP than alliances, and alliances are more appropriate for EFP and EBP than CVC. In other words, we found support in favor of the traditional governance perspective, which argues that the risky and uncertain nature of exploration requires more integrated governance modes. Innovating firms need some specific investment to develop mutual understanding, to cross cognitive distance (Nooteboom, 1999). Hypothesis 2b is supported.

Hypothesis 3 predicts that the technological distance between the focal innovating firm and its external corporate venturing partners has a curvilinear effect (inverted U-shape) on EFP. To test this hypothesis, we introduced a linear and a squared term of technological distance into the models. Table 12 represents the results of the regression analysis using random-effects negative binomial estimations of EFP. Firstly, model 15 includes all the control variables, technological distance and its squared term, without the governance modes variable. In Model 15 to 21, the coefficients of the squared term of technological distance are negative and significant ($p<0.01$). Consequently, hypothesis 3 is supported. This result confirms with some prior studies on the role of technological distance on innovation (Nooteboom *at el*., 2007; Van de Vrande, 2007). More interestingly, when the squared term of technological distance is added into the models for EFP in Table 12, the coefficients of governance modes in model 16 till 19 are positive and significant (except for equity alliances). Moreover, in model 20 and 21, when more than one governance mode variables are included, the results remain similar with the ones in the models without the squared term of technological distance in Table 11 (model 6 and 7). The results shown in Table 12 further confirm the support for hypothesis 1a, 1b and 2b.

Hypothesis 4 predicts that the technological distance between the focal innovating firm and its external corporate venturing partners has negative effect on EBP. In Table 11, the results in model 8 till 14 show that the coefficients of technological distance has a negative sign and they are significant at various levels, which means firms with large technological distance with its venturing partners are less likely to explore beyond the network of venturing partners. The results clearly support hypothesis 4.

To summarize, the results of our analysis found support for hypothesis 1a, 1b, 2b, 3 and 4. The empirical support for these hypotheses suggests that, firstly, corporate venturing, including CVC, non-equity alliances, equity alliances, and M&A, lead to more EFP and EBP activities of a firm; however, the positive effect of external venturing partnerships on EBP is less pronounced comparing to their effects on EFP. Secondly, the argument that the risky and uncertain nature of exploration requires integrated governance modes found support by the fact that M&As are more appropriate for EFP and EBP than alliances; alliances are more appropriate than CVCs for both EFP and EBP. Finally, technological distance between the focal innovating firm and its external corporate venturing partners is found having an inverted U-shaped relationship with EFP, but a negative relationship with EBP.

Table 12: Random-effects negative binomial estimations for EFP and EBP (with the squared term of 'technological distance' in the baseline model)

Models	15	16	17	18	19	20	21
	EFP	EFP	EFP	EFP	EFP	EFP	EFP
Size	0.573	0.553	0.558	0.506	0.467	0.404	0.379
	(0.101)***	(0.102)***	(0.103)***	(0.104)***	(0.105)***	(0.106)***	(0.104)***
R&D	1.336	1.334	1.281	1.156	1.105	0.916	0.927
	(0.604)**	(0.606)**	(0.608)**	(0.604)*	(0.608)*	-0.613	-0.598
Europe	0.21	0.267	0.184	0.251	0.196	0.119	0.161
	-0.241	-0.244	-0.241	-0.233	-0.239	-0.239	-0.231
Japan	-3.614	-3.454	-3.553	-3.344	-2.987	-2.726	-2.571
	(0.579)***	(0.583)***	(0.582)***	(0.573)***	(0.597)***	(0.592)***	(0.575)***
Pharma.Ind.	-1.506	-1.484	-1.459	-1.375	-1.561	-1.413	-1.378
	(0.227)***	(0.228)***	(0.237)***	(0.228)***	(0.230)***	(0.235)***	(0.226)***
Tech.age	-0.089	-0.072	-0.088	-0.065	-0.084	-0.072	-0.043
	(0.044)**	-0.044	(0.044)**	-0.045	(0.044)*	-0.045	-0.045
Tech.distance	11.229	11.375	10.833	10.905	11.807	10.784	11.434
	(2.976)***	(2.991)***	(3.036)***	(3.037)***	(2.984)***	(3.036)***	(3.058)***
Tech.distance2	-9.409	-9.554	-9.034	-8.936	-10.2	-9.227	-9.677
	(2.135)***	(2.144)***	(2.213)***	(2.187)***	(2.148)***	(2.212)***	(2.212)***
CVC		0.018				0.005	-0.006
		(0.008)**				-0.008	-0.008
Equity alliances			0.001			0.005	
			-0.002			(0.002)**	
M&A				0.015		0.047	0.061
				(0.006)***		(0.010)***	(0.010)***
Non-equity alliances					0.043		0.027
					(0.009)***		(0.006)***
Constant	-6.183	-6.302	-6.061	-6.097	-5.24	-4.877	-5.213
	(1.381)***	(1.392)***	(1.387)***	(1.416)***	(1.416)***	(1.427)***	(1.461)***
Log lik	-1415.17	-1413.18	-1414.98	-1411.73	-1405.06	-1402.64	-1394.99
lr-test		3.98**	0.39	6.88***	20.24***	25.06***	40.36***

N=898
Dummy variables of year is included but not listed in the table
Standard errors in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

5.4 Discussions and conclusions

This study investigates the dual role of external corporate venturing, including corporate venture capital (CVC), alliances and mergers and acquisitions (M&A), on two different types of exploratory learning – exploration from partners (EFP) and exploration beyond partners (EBP). EFP and EBP represent two different types of innovation strategies that tackle the problem of local search at two different levels. On the one hand, innovating firms may avoid local search by learning from their venturing partners. These venturing partners are connected to the innovating firm by various venturing relationships, including corporate venture capital, strategic alliances, joint ventures or mergers and acquisitions. On the other hand, companies can avoid local search by exploring further from organizations with which they have had no prior external corporate venturing relationships. The existent literature has studied the role of external venturing partnerships on EFP, but overlooked its role regarding EBP. We argued that although external corporate venturing partnerships do not provide direct technology source for and govern the relationships with other firms with which the focal firm has had no venturing relationships before, it might still impose influences on the exploratory learning from non-partner firms by functioning as information pipes, or reference systems to identify the location, usefulness, relevance and complementarity of other technology sources, or reputation leverages. The findings of this study suggest that external corporate venturing relationships lead to better performance with respect to both EFP and EBP, which confirms the dual role of external corporate venturing partnerships. However, the positive effect of external venturing partnerships on EBP is less evident than the one on EFP because the exploratory learning from non-partner firms is beyond the scope of the venturing partners network and the risks involved therewith is unlikely to be directly controlled by the governance mechanisms of the venturing relationships. The results of this study also found that the risky and uncertain nature of exploration requires highly integrated governance modes. In other words, M&As are more appropriate for EFP and EBP than alliances; alliances are more appropriate for EFP and EBP than CVC. Finally, the increase of technological distance between the focal innovating firm and its external corporate venturing partners from a low to moderate level will enhance EFP, while the increase from a moderate to excessively high level will on the contrary hinder EFP. Our finding also suggests that the increase of technological distance is associated with a decrease of EBP, which implies that specific investment in the venturing relationships and maintaining sufficient technological proximity are important to absorb other types of external knowledge sources.

This study contributes to the existing literature in several ways. Firstly, we define exploration based on whether a firm searches for external knowledge source and explicitly distinguish exploration *from* partners and exploration *beyond* partners. We argue that local search, which entails exploitation, occurs at two levels. To overcome the local search of exploiting its own internal knowledge, a firm needs to search for new knowledge source from its venturing partners; to overcome the local search of knowledge within a firm's venturing partner network, a firm needs to search for new knowledge sources beyond the venturing partner network, probably with the help of the venturing partners. Secondly, the findings from an empirical analysis indicate that the positive effects of external corporate venturing partners on EFP are more evident than the ones on EBP, suggesting that EBP is by nature more risky and uncertain in terms of return, and more difficult to govern *ex ante*. Thirdly, it also theoretically explores and empirically tests the relationship between the level of integration in the venturing governance modes and the exploration from partners and exploration beyond partners. Finally, we found the influence of technological distance (Nooteboom, 2000) on a firm's exploratory learning. The findings suggest that technological distance imposes very different impact on EFP and EBP.

This study provides innovation managers with some new insights on how to better manage external corporate venturing partnerships not only for exploring new technologies from the existing partners, but also for exploratory learning beyond the venturing relationships. Some of the EBP will evolve and enter into new external venturing partnerships, others may remain flexible under arms-length contractual relationship, e.g., licensing. The former will build up and strengthen the existing corporate venturing partner network, while the latter will still be of importance for an open model of innovation strategy to balance exploration and exploitation. How EFP and EBP evolve against each other will be an interesting challenge for future research. We hope our exploratory attempt in this study may provide a new insight for the literature on inter-organizational learning in general and for technological exploration in particular.

Chapter 6

Discussions and Conclusions

6.1 Discussions

Resource allocation between exploration of emerging technologies and exploitation of existing knowledge involves a delicate trade-off. This trade-off has been a central research topic for studies about adaptation and survival in general, and for the studies about innovation and organizational learning in particular. Exploration is variation-seeking, risk-taking, and experimentation-oriented. Exploitation is variety-reducing and efficiency-oriented (March, 1991). Compared to exploitation, returns from exploration are less certain, more remote and more risky. As firms learn from their experiences, the advantages of exploitation cumulate. However, in a competitive context, particularly for high-tech industries, Schumpeterian rents (Schumpeter, 1934) are likely to be diluted by both imitation and destructive innovations (Nelson and Winter, 1982). Therefore, the tendency towards exploitation leads to a sub-optimal equilibrium and the failure to survive in the long run. Consequently, exploration is critical for firms' adaptation and survival in a long-run.

Firms may explore new knowledge and practice in many different ways. This thesis focuses on the exploration of firms in technological innovation. Innovative firms are increasingly generating new knowledge in collaboration with partners. Studies on strategic management and innovation have recognized that innovation is an interactive, cumulative and cooperative phenomenon occurring between different organizational actors (Powell *et al*., 1996; Gulati, 1999; Nooteboom, 2000; Freel, 2003; Zaheer and Bell, 2005). This is because the novelty of innovations lies in the differences between the component elements of knowledge, or the novel ways in which these elements are recombined (Nooteboom, 2000a). The important role that external knowledge sources plays in respect of a firm's exploratory innovation performance has been widely discussed in the existing innovation literature (e.g., Jaffe and Trajtenberg, 2002; Rosenkopf and Nerkar, 2001; Ahuja and Lampert, 2001; Katila and Ahuja, 2002). However, the existent literature diverges with respect to whether exploration needs to be considered as features of the innovation process or the innovative outcome itself. Some researchers investigate exploration and exploitation in terms of the innovation process, which involves learning activities, behavior, investment and strategies (e.g. Nerkar, 2003; Nerkar and Roberts, 2004; He and Wong, 2004; Jayanthyi and Sinha, 1998; Phene *et al*., 2006; Sidhu, 2007; Van Looy *et al*., 2005). These researchers regard exploration and exploitation as different forms of the learning and creation process through which innovations come forth. Studies on technological innovation usually use patent data to measure to what extent search is distant or local. Patents, here, are considered as indicators of technology search rather than the outcome of innovation (e.g., Argyres, 1996; Nerkar and Roberts, 2004; Katila and Ahuja, 2002). Others relate exploration directly to innovative outcomes, which are the products or services (Greve, 2007; Jansen *et al.*, 2006; Dowell and Swaminathan, 2006). In such case, exploration and exploitation are usually used as synonymous with "radical innovation" and "incremental innovation", respectively (Jansen *et al.*, 2006; Benner and Tushman, 2003). In this thesis, to investigate firms' exploration in technologica innovation from external knowledge sources, I used patent data to distinguish exploration from partners (EFP) and exploration beyond partners (EBP) in chapter 5, which treats exploration has an innovative process; in chapter 3 and 4, exploration is rather treated as the innovative outcome, which is measured by means of the pioneering innovations.

The contribution of this thesis to the literature with regard to the interpretations and definitions of exploration can be understood as following. Firstly, I have distinguished three domains of knowledge along the value chain that are crucial in technological innovations, i.e., science, technology and product-market knowledge. Exploration and exploitation can also be defined according to the knowledge distance between the new knowledge and the existing knowledge along any of the cognitive, temporal and spatial dimensions of knowledge space. Search locally is exploitation and search distantly is exploration. To avoid being trapped in local search, firms need to search new knowledge externally. A challenge is how to combine more than one dimension of knowledge search with more than one domains of knowledge along the value chain. Chapter 3 interpreted exploration as the pioneering innovations that are technologically new at the industry level and introduced first to the world, which combines the technology and product-market domains of knowledge in one single construct. Moreover, we investigated how the knowledge search in the cognitive dimension (inter-industrial difference) and the spatial dimension (country difference) is related to pioneering innovations. Secondly, in chapter 5, I distinguished two different types of exploration of technological knowledge, i.e., exploration from partners (EFP) and exploration beyond partners (EBP). The definition of EFP and EBP can be understood as two different strategies to overcome *local search* of knowledge. Local search occurs, at the first place, when a firm only repeatedly uses its own knowledge, which can be overcomed by EFP. When a firm's relationships with venturing partners endure with the time being, local search (though at a higher level in a sense) may reoccur when a firm only searches for knowledge from partners with whom it has had corporate venturing relationships. This higher level of local search is subject to EBP to overcome. Thus, chapter 5 explicitly pointed out two different levels of local seasrch and investigated the two correspondent strategies to tackle them.

The three empirical chapters in this thesis try to tackle the central research question from different angles. Chapter 3 investigates the impact of knowledge difference between firms on the likelihood for a firm to generate pioneering innovations. It decomposes the knowledge differences into two dimensions: the industrial dimension and the geographic dimension in national context. The theory of organizational cognitive distance (Nooteboom, 1999, 2000a) is used to explain why that the inter-industry difference between the innovating firm and its suppliers has a curvilinear effect (inverted U-shape) on the likelihood of pioneering innovations. We argue that inter-industry difference may have a positive effect or a curvlinear effect based the argument of cognitive distance (Nooteboom 2000a). The impact of country difference was explained based on two different lines of argument. On the one hand, innovating firms may need to seek meta-national advantage by choose suppliers globally. On the other hand, due to the sticky knowledge inherent in pioneering innovations, large country difference may hinder the communication and coordination. The result shows that the country differences have a negative effect on the likelihood of generating pioneering innovations, which implies that the learning and communication concern may overwhelm the possible positive effect based on the technology specialization across nations. Chapter 3 contributes to the existing literature in several ways. Firstly, studies on the influence of knowledge difference usually use patent data to measure technological distance or geographical proximity, which inevitably overlook the distinctive industrial relationships between firms (such as Ahuja and Lampert, 2001; Nerkar and Roberts, 2004; Phene et al., 2006). Other studies that investigate the relationship between customer orientation, supplier involvement and innovation fail to explore the impact of external knowledge differences between firms in multiple dimensions (such as Johnsen et al., 2006). Chapter 3, thus, investigates the specific relationship between innovating firms and their suppliers.. It focuses on the influence of inter-industry and country difference between the innovating firms and their suppliers on a particular type of innovation—pioneering innovations. The findings of our analysis are not completely in line with the existing literature, which may suggest the importance of distinguishing certain types of inter-firm relationships when examining the role of knowledge differences between firms in respect of firms' innovation performance. Secondly, the findings of our analysis refute the thesis of 'death of geography', which claims diminishing differences between nation-states because of the growing role of multinationals and the increasing market globalization (Ohmae, 1990). We found that large country differences between innovating firms and their suppliers hinder the likelihood of creating pioneering innovations.

Chapter 4 investigates the likelihood that firms generate pioneering innovations under different levels of foreign competition in domestic market, meanwhile taking the effects of absorptive capacity into account. We argue that the relationship between competition and innovation should be considered with specific types of competition and specific types of innovation activities. We investigate the role of absorptive capacity through two antecedents of absorptive capacity: the diverse and complementary knowledge exposure and the past experience. We argue that the relationship between foreign competition and pioneering innovation is U-shaped. That is because, on the one hand, when foreign competition is low, firms may seek new technological and market opportunities based on organizational slack. When foreign competition intensifies, domestic firms will immediately be engaged in the competition by reducing the cost, improving efficiency or quickly adapt latest practices in the industry in reaction to the foreign competition, which will distract firms' incentive to bring about pioneering innovation. On the other hand, when foreign competition is too fierce, firms have to undertake pioneering innovation to "escape the competition". In this case, the possibility of undertaking pioneering innovation may again increase. We also argue that absorptive capacity may have positive direct effect on or positively moderate the relationship between foreign competition and pioneering innovation. The results of the empirical analysis support the alleged U-shaped relationship between foreign competition and pioneering innovation. Furthermore, the results show that diverse and complementary knowledge positively moderates the relationship between foreign competition and pioneering innovation, while past experience has a direct positive impact on pioneering innovation. Chapter 4 contributes to the existing literature in several ways. Firstly, the relationship between competition and innovation has found inconsistent support based on the seemingly contradictory theories of Schumpeterian competition (1934) and Arrow's competition (1962). Our study is one of the few empirical investigations on the specific relationship between foreign competition and pioneering innovations. Secondly, our measurement of foreign competition is based on the perceptions of the managers rather than any industrial parameters because we believe that the perceptions on competition better presents the real competitive condition under which managers make decisions about innovation activities. Finally, we operationalized the absorptive capacity into two factors that determine the capability of a firm to acquire and assimilate external knowledge. We found that diverse and complementary knowledge and past experience play different roles with regard to the relationship between foreign competition and pioneering innovation. The diverse and complementary knowledge exposure reflects the notion of cognitive distance (Nooteboom, 2000a) and knowledge proximity (Knoben and Oerlemans, 2006) which has been extensively discussed in the literature. Diverse and complementary knowledge exposure does not directly increase the likelihood of pioneering innovation, but it positively moderates the effect of foreign competition. This implies that firms that are exposed to diverse and complementary knowledge will more rapidly find their way to create new pioneering innovations when foreign competition increases from moderated to high levels. On the contrary, firms that are rich in past experience in generating pioneering innovations can benefit directly from their organizational memory.

Chapter 5 investigates the dual role of external corporate venturing, including corporate venture capital (CVC), alliances and mergers and acquisitions (M&A), on two different types of exploratory learning – exploration from partners (EFP) and exploration beyond partners (EBP). EFP and EBP represent two different types of innovation strategies that tackle the problem of local search at two different levels. On the one hand, innovating firms may avoid local search by learning from their venturing partners. These venturing partners are connected to the innovating firm by various venturing relationships, including corporate venture capital, strategic alliances, joint ventures or mergers and acquisitions. On the other hand, companies can avoid local search by exploring further from organizations with which they have had no prior external corporate venturing relationships. I argued that although external corporate venturing partnerships do not provide direct technology source for and govern the relationships with other firms with which the focal firm has had no venturing relationships before, it might still impose influences on the exploratory learning from non-partner firms by functioning as information pipes, or reference systems to identify the location, usefulness, relevance and complementarity of other technology sources, or reputation leverages. The findings of this study suggest that external corporate venturing relationships lead to better performance with respect to both EFP and EBP, which confirms the dual role of external corporate venturing partnerships. The results of this study also found that the risky and uncertain nature of exploration requires highly integrated governance modes. In other words, M&As are more appropriate for EFP and EBP than alliances; alliances are more appropriate for EFP and EBP than CVC. Finally, the increase of technological distance between the focal innovating firm and its external corporate venturing partners from a low to moderate level will enhance EFP, while the increase from a moderate to excessively high level will on the contrary hinder EFP. Our finding also suggests that the increase of technological distance is associated with a decrease of EBP, which implies that specific investment in the venturing relationships and maintaining sufficient technological proximity are important to absorb other types of external knowledge sources. Chapter 5 contributes to the existing literature in several ways. Firstly, it defines exploration based on whether a firm searches for external knowledge source and explicitly distinguish exploration *from* partners and exploration *beyond* partners. I argued that local search, which entails exploitation, occurs at two levels. To overcome the local search of exploiting its own internal knowledge, a firm needs to search for new knowledge source from its venturing partners; to overcome the local search of knowledge within a firm's venturing partner network, a firm needs to search for new knowledge sources beyond the venturing partner network, probably with the help of the venturing partners. Secondly, the findings suggest that EBP is by nature more risky and uncertain in terms of return, and more difficult to govern *ex ante*. Thirdly, it also theoretically explores and empirically tests the relationship between the level of integration in the venturing governance modes and the exploration from partners and exploration beyond partners. Finally, the findings also indicate the different influences of technological distance (Nooteboom, 2000) on a firm's EFP and EBP.

6.2 Managerial implications

This thesis also provides several important implications for innovation management. Firstly, to enhance the likelihood of generating pioneering innovations, firms need to explore various resources outside of the organizational boundary. Firms should actively search for new knowledge across industry boundaries and geographic locations. Secondly, firms should understand how to differentiate knowledge searching strategy accordingly in supplier relationships. On the one hand, it is beneficial to search for suppliers from distant industries due to the value of new knowledge elements and new ways of recombination. On the other hand, for the sake of communication, coordination and logistic cost, the innovating firms should choose suppliers from unfamiliar industries that are located in Canada or nearby countries. Firms should learn how to combine the effects of inter-industry differences and country differences in supplier relationships and maximize the likelihood to create pioneering innovations. Firms can develop a strategy to enhance innovations by seeking suppliers from unfamiliar industries but preferably in the domestic or neighbouring markets. Moreover, when more and more foreign competitors rush into the domestic market, domestic firms need to learn how to compete by exploring new technological and market opportunities rather than only focusing on improving efficiency and exploiting the existing technological competence. To enhance the likelihood of generating pioneering innovations, firms need to explore various resources outside of the organizational boundary. The investment in accessing diverse and complementary external knowledge sources and accumulating innovation experience is very important because it increase the level absorptive capacity, which may enhance the exploratory innovation performance of firms under severe competitive conditions. Finally, firms should accumulate innovation experience and embed it into their organizational memory. Positive experience in undertaking pioneering innovations encourages firms to generate more innovations alike in the future.

This study also provides innovation managers with some new insights on how to better manage external corporate venturing partnerships not only for exploring from the existing partners, but also for exploratory learning beyond the venturing relationships. Some of the EBP will evolve and enter into new external venturing partnerships, others may remain flexible under arms-length contractual relationship, e.g., licensing. The former will build up and strengthen the existing corporate venturing partner network, while the latter will still be of importance for an open model of innovation strategy to balance exploration and exploitation. The relationships represented in this thesis between external corporate venturing partnerships, the governance modes thereof, the technological distance and the exploration from and beyond partners may help managers to better use external corporate venturing partnerships to facilitate innovations.

6.3 Limitations

This study also has several limitations. Firstly, for chapter 3 and 5, the Canadian data is collected for the period of the 1940s till 1980s, when IT technology has not been well developed yet. One can reasonably expect that communication between firms is much easier than ever by means of IT technology in the 21 century. Thus, in chapter 3, the negative effect of country difference on absorptive capacity may be decreased if tacit knowledge is not a major concern. Whether country difference still plays the same role for stimulating innovation as we reveal in this chapter may be questionable in the new era. It will be interesting to test same hypotheses with more recent data. In chapter 5, it will be an open question whether the U-shaped relationship between foreign competition and pioneering innovation still holds nowadays. We expect that, in the 21st century, the left side of the U-shaped relationship (the downward slope) might not so obvious, while the right side of the U-shaped relationship (the upward slope) might be steeper than in the observation period in this study because the foreign competition is extremely intensified in most of the industrialized countries. Secondly, the innovating firms in our dataset are all Canadian firms. Thus it is an open question to what extent our findings can be generalized. We argued that each country holds its unique endowment for innovation (Nelson, 1991). Studies using data of innovating firms from other countries are required to test if our findings can be generalized. For instance, we would expect that in developing countries, firms may have little experience in pioneering innovation and limited exposure to diverse and complementary knowledge; meanwhile foreign competitors are crowded in the market. In this situation, how firms in developing countries react to the competitive condition will be an interesting question to investigate. Finally, we also noticed that the measure of inter-industry differences using SIC-code is only a raw proxy, which resulted in unsatisfactory results for testing the hypothesis in chapter 3 and 5. Constrained by the original design of the Canadian survey, we could not develop a more precise measure. Future research that uses other measures to indicate the cognitive dimension of knowledge difference may deliver a better understanding of the impact of knowledge difference between innovating firms and their suppliers. Patent data might be a help in that respect, which is the reason why patent data was used in chapter 4.

6.4 Conclusions

To my understanding, exploration in technological innovations requires firms to manage three domains of knowledge—scientific knowledge, technology and product-market knowledge. Scientific knowledge is increasingly important as the source of technological developments, which, in turn, opens opportunities to develop new products or services. Firms that want to develop exploratory innovations based on science-driven technologies have to understand two processes. On the one hand, they need to understand how new technology can be developed successfully from new scientific insights. On the other hand, they need to translate new technologies into new and profitable business models. The critical challenge is to manage the three functions as a whole in a coherent way. Exploration in science and exploration in product market knowledge have different drivers and should be managed differently. Exploration of new scientific disciplines to rejuvenate technological capabilities is a quite different task from the development of new business based on the current technology in the company. Technology itself should be continuously adapted in conjunction with new societal needs (demand pull) and scientific discoveries (technology push).

Although it will be very interesting to study the comprehensive interplays beween science, technology and market, it is somehow not feasible for a doctoral thesis within a limited time period. This thesis, thus, highlights the fundamental issue of utilizing diverse external knowledge as resources for exploratory technological innovations and focuses rather on the connection between technology and market with respect to exploratory technological innovations. The findings show that the value of external knowledge in collaboration with suppliers is affected by the inter-industry differences and by the geographical proximity between the innovating firms and their suppliers. Chapter 3, on the one hand, explains that the strategy to search for new external knowledge should be appropriate with the underlying industrial relationship; on the other hand, brings new insights for managing suppliers' involvement in respect of pioneering innovation by considering suppliers' industrial and national differences between the innovating firms and their suppliers. Chapter 4 has shed some new insights on the important relationship between competition and innovation. It has differentiated the roles of two antecedents of absorptive capacity, i.e., diverse and complementary knowledge and past experience, on the likelihood of pioneering innovation. Finally, chapter 5 points out that how EFP and EBP evolve against each other will be an interesting challenge for future research. We hope that our study not only provides researchers with new insights on inter-organizational learning in general and for technological exploration in particular, but also provides a common ground to encourage the necessary dialogue between academia and practitioners.

Appendix I

Research approach and selected literature for review

In order to have a systematic review of studies on exploration and exploitation in the literature on technological innovation, I conducted a systematic literature search. I focused on articles published in different academic journals since 1991, when March published his seminal work, till to date. I applied three basic selection criteria: first, the article must focus on the notion of exploration and exploitation; second, the theme of the article must be closely related to technological innovation; third, I excluded theoretical review papers[17]. A research approach similar to Knoben and Oerlemans (2006) has been used for this literature search. I used the WileyInterScience database, the EBSCOHost Research database and the Web of Science database to perform a literature search. Due to the difference among the search engines of these databases, I used slightly different search techniques for each of the three databases, though the underlying selection criteria remained the same. In the WileyInterScience database, the search is preliminary based on the keywords: (1) "Business" as journal discipline; (2) "March" in references, and (3) "Innovation, technology, exploration, exploitation" in full text or abstracts[18]. This search yielded 91 papers. In the EBSCOHost Research database, the search is preliminary based on the keywords: (1) "exploration, exploitation" in abstracts, and (2) "Innovation, technology" in full text[19]. This search yielded 37 papers. In the Web of Science database, the search is based on the keywords: "exploration", "exploitation" and "innovation" in the topic. This search yielded 46 papers. Thus, the first round of selection yielded 174 papers in total. To narrow this list of articles down, I carefully read the abstracts and full text for each paper, and eliminated those papers that only mentioned exploration and exploitation as a relevant theoretical background but did not specifically focus on them. I also eliminated those articles that were not relevant to technological innovation. This manual process reduced the number of articles further to 37. I also realized that such a search method has its disadvantage. Articles that are not listed in these three databases will not be found by this method. Therefore, I also employed a complementary source for the literature search. First, as I have been interested in this research topic for years, I have accumulated a list of papers from various journals that fall into our basic selection criteria. Second, I also consulted many researchers in this research field and asked them to recommend published papers. By carefully reading the abstract and full texts of the articles from this complementary source, I finally agreed to add 6 papers to the list of articles. Hence, the total number of articles under review for this study is 43. Table 1 alphabetically depicts the selected papers with their

[17] I focused on empirical papers to limit the review effort. From empirical papers, one can directly see how researchers interpret exploration and exploitation, while theoretical review papers usually present the reviewers subjective interpretation of other authors. I exclude theoretical papers in the literature review list, but still refer to them while analysis is necessary.

[18] I also used "innovation, technology, exploring, exploiting" or "innovation, technology, exploratory, exploitative" in full text or abstracts. The results are of no difference. The relationship between these keywords is "AND", which means there is no sequence for the keywords.

[19] I also used "exploring, exploiting" or "exploratory, exploitative" in abstracts. The results are of no difference. The relationship between these keywords is "AND", which means there is no sequence for the keywords.

interpretations of exploration and exploitation. Table 2 summarizes the selected literature according to their sources and the level of analysis.

Table 1: Alphabetic list (author name) of the selected literatures with the interpretations of exploration and exploitation

Article	Definition/Interpretation
1. Ahuja & Katila (2004)	Path-creating search is exploration. Thus, the more diversified the search is, the greater degree of exploration (measure search diversity). Knowledge search in science and across different markets dimensions.
2. Ahuja & Lampert (2001)	It defines exploration and exploitation based on knowledge distance, but it goes beyond local vs. distant search. It defines 3 levels for distant search. Novelty is categorized as "new to firm", "new to industry", and "new to world". It only discussed the knowledge search within the technology function along the technical dimension.
3. Argyres (1996)	Exploration as technological capability broadening; exploitation as technological capability deepening.
4. Audia & Goncalo (2007)	Exploration and exploitation as different types of creativity of individuals. It uses number. of new subclass and number of new citations of an inventor as indicators. It only discusses the technology knowledge.
5. Atuahene-Gima (2005)	Exploration is to invest resources to refine and extend its existing product innovation knowledge, skills and process. Exploitation is to invest resources to acquire entirely new knowledge, skills and process.
6. Benner & Tushman (2002)	Defines exploration and exploitation in terms of technology search activities. Local search is exploitation, distant search is exploration.
7. Bierly & Daly (2007)	Exploration is experiment with radical new ideas or ways of doing things. Exploitation involves refining and leveraging existing knowledge and focus on efficiency at current practices.
8. Cantwell & Mudambi (2005)	Competence-creating subsidiary as exploration, competence-exploiting subsidiary as exploitation. They have different nature and level of R&D.
9. Cesaroni, Minin & Piccaluga (2005)	Investing in a firm's main operations and establishing alliances to secure complementary assets are exploitation. Invest in R&D in new technology is exploration.
10. Danneels (2002)	Exploration and exploitation are defined by 2 dimensions of competence used in product innovation: technology & market. Exploration is to develop new technology to serve new customers, and exploitation is to strengthen existing technology to serve existing customers.
11. Danneels (2007)	Same as Danneels (2002)
12. Dittrich & Duysters (2007)	Exploration is non-equity alliances with new partners, who have different technologies. Exploitation is equity alliances with existing partners, who have similar technologies.
13. Dittrich, Duysters & de Man (2007)	Exploration is non-equity alliances with new partners, who have different technologies. Exploitation is equity alliances with existing partners, who have similar technologies.
14. Dowell & Swaminathan (2006)	Exploration is defined as a large variety of technology trajectories ever since a firm's initial choice of technology.
15. Faems, Van Looy & Debackere (2005)	Exploratory collaboration is to create new competences such as those with universities and research institute, while exploitative collaborations focus on complementarities between technologies and products, such as those with customers and suppliers.
16. Garcia *et al.,* (2003)	Exploration is to conduct research projects, and exploitation is to conduct product development projects.
17. Geiger & Makri (2006)	Exploration as science search, exploitation as technology search.

18. Gilsing & Nooteboom (2006)	Exploration is searching and recombining technology and science; exploitation is search market knowledge.
19. Greve (2007)	Searching new tech as exploration (explicit), searching new market as exploitation (implicit).
20. Hagedoorn & Duysters (2002)	Exploratory alliances are usually established in order to explore new technological opportunities. Exploitative alliances enable firms to commercialize the technology gained through exploration.
21. He & Wong (2004)	Technological innovation activities aimed at emerging new product-market is exploration, and those aimed at improving existing product-market is exploitation.
22. Holmqvist (2004)	It examines how exploration and exploitation build upon each other at firm-level. The key is dissatisfaction with performance. Firms search for proximate/distant knowledge or do extensive recombination under certain incentives, either from dissatisfaction or from slack.
23. Jansen, V.D. Bosch & Volberda (2006)	It defined exploration and exploitation with respect to search new or existing knowledge on the customers/markets.
24. Jayanthi & Sinha (1998)	exploration as the technology search that aims at meeting future market demand, while exploitation as the technology search that aims at meeting current market demand.
25. Katila & Ahuja (2002)	The degree of exploration is indicated by "search scope", which is how broad knowledge a firm searches. The degree of exploitation is indicated by "search depth", which describes how deeply a firm reuses its existing knowledge.
26. Lavie & Rosenkopf (2006)	It defines exploration and exploitation in alliances with respect to the “function domain”, “structure domain” and “attribute domain”. “Function domain” refers to the nature of value chain functions. “Structure domain” refers to whether to ally a new partner without prior ties. “Attribute domain” describes to what extent the new partner’s organizational attributes are different than those of prior partners.
27. Lee & Ryu (2002)	Investment in unknown technological opportunities is exploration, and investment in existing technology is exploitation.
28. Lin, Yang & Demirkan (2007)	Search new knowledge through new alliance partners as exploration, while consolidating a firm’s existing partner networks is exploitation.
29. McGrath (2001)	It uses a multi-item scale to measure exploration and exploitation. It emphasizes on the search of new knowledge in technology and market.
30. Mom, v.d.Bosch & Volberda (2007)	Managers’ exploration activities include searching for new possibilities with respect to product, service, process or markets, which require learning of new skills and knowledge. Managers’ exploitation activities include serving existing customers with existing products/services, which requires present knowledge and accumulation of experiences.
31. Nerkar (2003)	For technology search, “temporal recency” is exploitation, and “temporal spread” is exploration.
32. Nerkar & Roberts (2004)	It defines exploration and exploitation with respect to search technology and market. Distal experience in technology and market is exploration, and proximate experience in technology and market is exploitation.
33. Perretti & Negro (2007)	Recombining old, reuse existing, leverage prior knowledge is exploitation, and recombining old and new (hiring new employees) is exploration.
34. Phene *et al*. (2006)	It defines exploration and exploitation with respect to the combination of local or distant search in technical knowledge dimension and geographic/spatial dimension.
35. Rosenkopf & Nerkar (2001)	It defines exploration and exploitation with respect to the combination of search across the organization boundary (spatial) and the technological boundary (technical).
36. Rothaermel (2001)	The activities of exploitative alliances include manufacturing, marketing or supply agreements, which are typical product-market knowledge.

37. Rothaermel & Deeds (2004)	Motivation differs in alliances: R &D alliances is exploration (technology-side), commercialization alliances is exploitation (product-market knowledge).
38. Rothaermel, Hagedoorn & Roijakkers (2004)	Similar as Rothaermel & Deeds (2004)
39. Sidhu, Commandeur & Volberda (2007)	Three dimensions to define ex/ex: 1. technology dimension (supply-side), 2. market dimension (demand-side), 3. Spatial side. Supply side may involve both science & technology.
40. Sidhu, Volberda & Commandeur (2004)	It defines exploration in terms of the scope of external information acquisition (thus a search view). External information acquisition is examined through the supply-side, demand-side, and geographic side. It mixes up the value chain and knowledge dimensions.
41. Vanhaverbeke & Peeters (2005)	Exploration is interpreted as the corporate venturing/NBD, which is related to "structural ambidextrous" organization.
42. Van Looy, Martens & Debackere (2005)	Exploitation is to invest in the lucrative part of the technology life cycle, and exploration is to invest in various stages of the technology life cycle.
43. Vassolo, Anand, & Folta (2004)	The alliances set up by big pharmaceutical companies with biotech companies are exploratory alliances, mainly to explore technological advantage.

Table 2: List of selected literature and level of analysis

	Source			
Level of analysis	*WileyInterScience*	*EBSCOHost Research*	*Web of Science*	*Complementary sources*
Individual level		Audia & Goncalo (2007)	Mom, v.d.Bosch & Volberda (2007)	
Project/project team level	Perretti & Negro (2007)			McGrath (2001)
Firm level	Argyres (1996), Danneels (2002), Ahuja & Katila (2004), Dowell & Swaminathan (2006), Phene *et al*. (2006), Danneels (2007)	Jayanthi & Sinha (1998), Cesaroni, Minin & Piccaluga (2005), Geiger & Makri (2006), Sidhu, Commandeur & Volberda (2007), Jansen, Van Den Bosch & Volberda (2006), Van Looy, Martens & Debackere (2005)	Rosenkopf & Nerkar (2001), Greve (2007), Ahuja & Lampert (2001), Benner & Tushman (2002), He & Wong (2004), Katila & Ahuja (2002), Nerkar (2003), Nerkar & Roberts (2004), Garcia *et al.* (2003) Lee & Ryu (2002), Atuahene-Gima (2005), Bierly & Daly (2007)	Sidhu, Volberda & Commandeur (2004) Holmqvist (2004),
Corporate group level	Cantwell & Mudambi (2005)	Vanhaverbeke & Peeters (2005)		
Alliances level	Rothaermel (2001), Vassolo, Anand, & Folta (2004),		Rothaermel & Deeds (2004), Lavie & Rosenkopf (2006), Lin, Yang & Demirkan (2007), Dittrich, Duysters & de Man (2007), Dittrich & Duysters (2007)	Rothaermel, Hagedoorn & Roijakkers (2004), Hagedoorn & Duysters (2002), Faems, Van Looy & Debackere (2005)
Industry level		Gilsing & Nooteboom (2006)		

Appendix II

An Example of the Questionairre for the Canadian Dataset

Firm serial no. 122
Innovation serial no. C20119

THE INNOVATION CHECK LIST (1)

An innovation is a commercialized invention or improvement. An innovation is a new or improved product which has withstood the trial of the market for approximately three years in Canada. The period covered is 1945 to date.

1a. Innovation: name and description:

"Swing tail" air cargo at 1960's

1b. if this is not the correct description, please revise it:

2a. name of innovating firm (head office):

Canadair Ltd. PO Box 6087, Station A., Montreal, QUE, Canada

2b. innovating establishment (factory, mine or the operating entity that first produced the innovation or used the process):

St. Laurent, QUE

3. In which year was the innovation-product first produced and marketed in Canada?

1960

4. Were you the first to market this product in Canada?

□ Yes □ No □ Don't know

5. Had this or a very similar product been marketed or used outside Canada before?

□ Yes Country Date
1).
2).
3).
□ No
□ Don't know

6a. Who was (were) the principal client(s) for the innovation during the first three years?

(Multiple answers are allowed)

□ Cosumer and/or trading companies
□ The establishment within your company that first produced the product
□ Another establishment of your own company
□ Other non-trade establishments and companies

6b. Identify up to three establishments and/or companies

1). name: address: town: country: Industry or economic activity
2). name: address: town: country: Industry or economic activity
3). name: address: town: country: Industry or economic activity

7. Your product-innovation probably competes for markets with firms that produce and market an identical or similar product, or products performing the same function for the same clients. Name up to five of your main competitors in Canada or abroad:

	Name	Country
1).		
2).		
3).		
4).		
5).		

8a. Who developed the innovation?

□ The establishment within your company that first produced the product
□ Other establishment in the same company
□ Other establishments or company

8b. who supplied your firm with some of the key components contributing to this innovation? (scientific, technical, equipment, materials, etc.)

1). name: address: town: country: Industry or economic activity:
Rough descrition of contribution:

2). name: address: town: country: Industry or economic activity:
Rough descrition of contribution:

3). name: address: town: country: Industry or economic activity:
Rough descrition of contribution:

9. In what industries was your firm involved in at the time the innovation was first produced, marketed or used?

Industry main SIC code
Industry 2nd SIC code
Industry 3rd SIC code
Industry 4th SIC code
Industry 5th SIC code

10. How many employees did your firm have at the time the innovation was first produced, marketed or used?

□ 1-19
□ 20-199
□ 200-499
□ 500-999
□ Over 1000

11. CONFIDENTIALITY CLAUSE

Appendix III

Industries chosen for the random sample survey in the Canadian Data

SIC	Industry	SIC	Industry	SIC	Industry	SIC	Industry
051	Gold mines	188	Automobiel fabric asscessories	318	Office & store machinery & equipment	376	Soap & cleaning compounds manuf.
057	Uranium mines	239	Other knitting milles	321	Aircraft & aircraft parts	378	Industrial chemicals manuf.
058	Iron mines	243	Clothing industry	323	Motor vehicle manufacturers	379	Misc. chemical industry
059	Base metal & other metal mines	251	Sawmills, planing mills & shingle mills	324	Truck body & trailer manufacturers	391	Scientific & professional enquipment
061	Coal mines	256	Wooden box factories	325	Motor vehicle parts & accessory manuf.	501	Air transport
064	Petroleum & gas wells	264	Office furniture industries	326	Railroad rolling stock	503	Railway transport
071	Asbestos mines	271	Pulp & paper industry	327	Shipbuilding & repair	504	Water transport
079	Other non-metal mines	273	Paper box & bag manufacturing	328	Boat building & repair	572	Electrical power
101	Slaughtering & meat processing	289	Printing & publishing	329	Miscellaneous transportation equipment	574	Gas distribution
102	Fish products industry	291	Iron and steel mills	331	Small electrical appliance	576	Water & other utilities
104	Dairy factories	294	Iron foundries	332	Electrical & non-electrical major appliance	701	Banks & other deposit accepting estab.
108	Miscellaneous food industry	295	Smetling & refining	334	Radio & TV receivers	703	Other credit agencies
109	Beverage industry	296	Aluminum rolling & extracting	335	Communication equipment manuf.	821	Health services
162	Other rubber industries	297	Copper and Alloy Rolling	336	Electrical industrial equipment manuf.		
165	Plastic fabricators	302	Fabricated structural metal	338	Electrial wire & cable manuf.		
172	Leather tanneries	304	Metal stamp, press and coat	359	Misc. non-metallic mineral products		
174	Shoe factories	305	Wire & wire products manufacturing	365	Petroleum refineries		
181	Cotton yarn & cloth mills	308	Machine shops	373	Plasitc & synthetic resins		
182	Wool yarn & cloth mills	311	Agricultural implements	374	Pharmaceutical & medicines		
183	Man-made fibre, yarn & cloth mills	315	Miscellaneous manchinery & equipment	375	Paint & varnish manuf.		

Appendix IV

Coverage of firms in the population among different industries in the Canadian Data

Percentage	Less than 10%	10-15%	15-20%	20-30%	30-50%	50-90%	More than 90%
Industries	Plastic fabricators	Misc. chemicals	Rubber products	Sawmills	Small elec. Appliances	Drugs	Cotton yarn & cloth mills
	Wire and products	Metal stamping	Gas distribution	Aluminum	Fish products	Petroleum refineries	Wool yarn & cloth mills
	Beverages	Paper box & bag manu.	Coal mines	Leather tanneries	Non-metallic mineral	Major appliances	Automobile fabrics
		Meat processing	Boat building	Communication equip.	Industrial chemicals	Iron & steel	Asbestos mines
		Men's clothing	Railway transport	Agricultural implements	Office & store machinery	Smelting & refining	Iron mines
		Dairy factories	Machine shops	Misc. machinery	Soaps & detergents	Pulp and paper	Copper & alloy rolling
		Other non-metal mines		Gold mines	Base metal mines	Shipbuilding & repair	Water transport
		Truck body & trailer		Knitting mills	Man-made fibre	Electric power	Shoe factories
		Motor vehicle parts		Aircraft & parts			Radio & TV
		Misc. food industry		Plasitics & resins			Misc. transport equipment
		Office furniture		Iron foundries			Uranium mines
		Petroleum & gas wells					Railroad rolling stock
		Elec. Industrial equip.					

Appendix V

Summary of definition and operationalization of variables

Variable	**Description**	**Ch 3**	**Ch 4**	**Ch 5**
Pioneering innovations	A binary variable which indicates whether an innovation is pioneering or not. Product innovations that are technologically new at the industry level and introduced first to the world.	✓	✓	
Inter-industry difference	The difference of the SIC codes between the focal firm and its suppliers. A difference between two companies in the SIC's first digit indicates that these two companies have the largest possible difference. If firms' first digit SIC codes are the same, but differ in respect of the second, we assume that the difference has a medium value. If the SIC labels only differ regarding the third digit, we assume that the industries to which the firms belong are very similar. If an innovating firm has more than one supplier, we calculated the mean value for the inter-industry difference between the innovating firm and all its suppliers.	✓		
Country difference	We measure country difference in terms of language, institution and Hofstede's culture parameters[20]. A factor analysis is conducted to determine whether there is a common factor regarding country difference. The result indicates a single factor is sufficient to capture almost 88% of the variance in country difference. Thus, we used one variable to measure country differences. The factor score is the value of this variable.	✓		
Foreign competition	The number of *de facto* foreign competitors or the perceived foreign competitors in the domestic market regardless how they compete. We operationalize the value this variable as the count number of foreign competitors for a particular innovation.		✓	
Diverse and Complementary knowledge	This measure is based on the difference of the SIC codes between the firms. First, we assign weights of 4, 3, 2 and 1 for the four levels of difference between two SIC codes (with value of "1" if two SIC codes are identical), meaning the larger figures represent larger distances. The measure of diverse knowledge exposure is the ratio of the weighted value of total number of industries of a firm to the total number of industries of a firm. Second, We define that a firm has complementary knowledge sources to its own if any of the secondary industries in which it is active happens to be similar to the industry of its main suppliers or customers. We further define that two industries are "similar" if the first two digits of the SIC code are the same. The measure, thus, is the count number of secondary industries of the innovating firm, which are similar to the industries of its main suppliers or customers. Finally, we multiply the diversity measurement and the complementarity measurement so that the product of these two measurements is the value for this variable.		✓	
Firm size	We use an ordinal scale to measure the size of a firm, which is derived directly from the questionnaire of the Canadian survey (size=1 for 0-19 employees, size=2 for 20-199 employees, size=3 for 200-499 employees, size=4 for 500-999 employees, and size=5 for more than 1000 employees).	✓	✓	

[20] A detailed explanation of the scales for language difference, institutional difference and Hofstede's culture parameters is available upon request.

Prior Experience	The ratio of the number of new-to-world innovations to the total number of innovations for the past 10 years.	✓	✓	
SIC category of innovating firms	Dummy variables (the default is the industry that has a SIC code of which the first digit is a zero) to measure whether or not an innovating firm is active in a broad industry category.	✓	✓	
Time	We use three alternative measures to control for the effect of time. We first introduce three dummy variables (default is the 1940s) to represent any decade-specific effects on the dependent variable that are not captured by the independent variables. Secondly, instead of using dummy variables for the four decades, we used dummy variables to control for the consecutive five-year period. Finally, we also use a trend variable for years.	✓	✓	
Exploration from partners (EFP)	calculated as the sum of patent applications made by the focal firm that have at least one citation to its partner's prior patents, but no citations to its own prior patents.			✓
Exploration beyond partners (EBP)	calculated as the number of patent applications made by the focal firm that neither cites its own prior patents, nor its partners' prior patents.			✓
Technological age	Technological age is operationalized by two steps. Firstly, we determine the age of all patent classes. This is calculated as the median of the age of all patents in a patent class in a particular year. The age of the patent is the time elapsed between the application year and the year of observation. To overcome outlier bias, we use the median age rather than the average to calculate the age. Secondly, to calculate the average technological age of a firm, we multiply the share of patent applications by the technology age for each patent class.			✓
Technological distance	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).			✓

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