IS "OPEN" ALWAYS BETTER? A MULTI-STAGE EXPLORATION OF ORGANIZATIONAL OPEN INNOVATION

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DECLARATION

I hereby declare that this thesis is my original work and it has been written by me in its entirety. I have duly acknowledged all the sources of information which have been used in the thesis.

This thesis has also not been submitted for any degree in any university previously.

CUI Tingru

26 December 2013

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SUMMARY

The advance in information technologies (IT) has made organizational boundaries so porous that innovations can be easily transferred between organizations internally and externally. There is an increasing trend towards leveraging on external knowledge for innovation, which is termed *open innovation*. Firms can obtain complementary knowledge from external partners, which encourages creativity and novel solutions, and results in the creation of new technologies or new market possibilities. Despite the potential benefits, organizations have been encountering challenges preventing them from benefitting from open innovation initiatives. Despite the growing popularity of open innovation, the strategies that organizations can apply to conduct open innovation have not been clearly examined. Although IT creates the necessity for the implementation of open innovation, prior literature provides a limited examination of the role of ITs in facilitating the open innovation process thus affecting effective open innovation performance.

To meet this research void, this thesis is structured in two essays to uncover the effective managerial strategies and technological mechanisms for managing open innovation. Study One (Chapter 2) explores the process of open search. The multiple case studies approach is used as the research method. Through interviews, this research identifies three different organizational open search patterns, i.e., centralized open search, differentiated open search and decentralized open search. Furthermore, drawing on the perspectives of the upper echelon theory and organic/mechanistic organizational forms, we developed a theoretical exposition of open search work by evaluating the impact of each open search pattern on efficient search outcomes and the appropriate IT mechanisms for each identified pattern. In addition, we unveiled the relationships of three open search patterns by considering the uncertainty as a unique trait of open innovation. As a result, a middle range theory of open search is built.

Study two (Chapter 3) focuses on the impact of open search outcomes on open innovation performance. This study examines the effect of openness in searching on inter-firm distance between open innovation partners. It then investigates how inter-firm distance influence open innovation project process and outcome product performance and different influential roles of three IT-enabled knowledge capabilities, i.e., IT-enabled exploratory learning, IT-enabled exploitative learning, and IT-enabled social integration. To seek answers to these questions, a two-staged research approach was adopted. In the first stage, we conducted an exploratory qualitative multiple case study approach to explore the concept of project openness in searching for and identifying the IT applications that are critical during the open innovation projects. In the second stage, drawing on the absorptive capacity theory, the findings from qualitative study were refined and a research model was proposed. Then we used a large scale field survey to collect data and further tested the research model.

Generally, Study One develops a better understanding of the organizational work arrangement for achieving open search efficiency and maximizing its impact, while Study Two reveals the impact of open search outcomes on both open innovation process performance and outcome performance. Contributions and implications of the studies are summarized and directions for future work are also discussed (Chapter 4).

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CHAPTER 1.

INTRODUCTION

1.1 The Emergence of Open Innovation

Traditionally, for most firms, the innovation process was located in the research and development (R&D) department, where dedicated specialists developed solutions in a more or less closed environment (Chandler 1990). However, over the past few decades, the mobility of knowledge workers, velocity of technological change and globalization of markets have shifted the way in which innovations are created. Many firms discovered that important innovations were increasingly being done by small and mid-size entrepreneurial firms. Individuals were eager to license and sell their IP. University and government labs had become more interested in forming industry partnerships, and they were hungry for ways to monetize their research.

With the proliferation of interconnectivity and interactivity through ITs, firms now frequently engage in innovations with customers, suppliers, universities, research institutions and other sources of knowledge (Enkel et al. 2009). This emerging networking style of innovation can bring significant benefits to the firms. Firms can obtain complementary knowledge from collaborative partners, which encourages creativity and novel solutions, and results in the genesis of new technologies or new market possibilities.

As a result, opening up the innovation process has become increasingly popular in industries. Several pioneering firms, such as Procter and Gamble, Cisco Systems, Genzyme, General Electric, IBM and Siemens, have obtained benefits from external knowledge resources. For example, Philips has a well-established open

R&D environment sharing their expertise and technical abilities with universities, institutes, and other firms. This is true of Siemens as well. Every year Siemens enters into over 1,000 cooperative projects in an effort to strengthen its portfolio of innovations for the long term. IT firms such as SAP and Microsoft have started to build decentralized research labs on university campuses to accelerate their innovation processes. Even Apple, with its strong position and high level of acceptance within its brand community, had to open up its proprietary technology to its addicted high-tech users.

More and more firms have realized the importance of moving from a centralized approach to a globally networked model. The results of an industrial innovation survey showed that the firms integrated external innovative sources in 35% of all their R&D projects (Enkel and Gassmann 2010). It must be noted that the number differs considerably across the various industries. In the rapidly evolving industries, especially within the electrical, electronic, IT, and other high-tech industries, the number of joint R&D projects comprises almost 50% of all R&D projects within a firm. In industries that evolve more slowly, the number of joint projects is 20% or less, especially in the leather, wood, and printing industries. Overall, the trend is still growing.

1.2 Definition of Open Innovation

Before introducing the definition of open innovation, we need to discuss the general concept of organizational innovation. Organizational innovation encompasses the generation, development, and implementation of new ideas or behaviors. An innovation outcome can be a new production process technology, new product or service (Damanpour and Evan 1984). Firms used to develop new technologies internally, and then transfer them to their own products and services, in a practice known as *closed innovation.*

Nowadays, the increasing trend towards connectivity and collaboration is more in line with *open innovation*, a term coined by Chesbrough (2003) to contrast with traditional *closed innovation* strategies. It is defined as:

> *"The use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively."* (Chesbrough et al. 2006, p. 1).

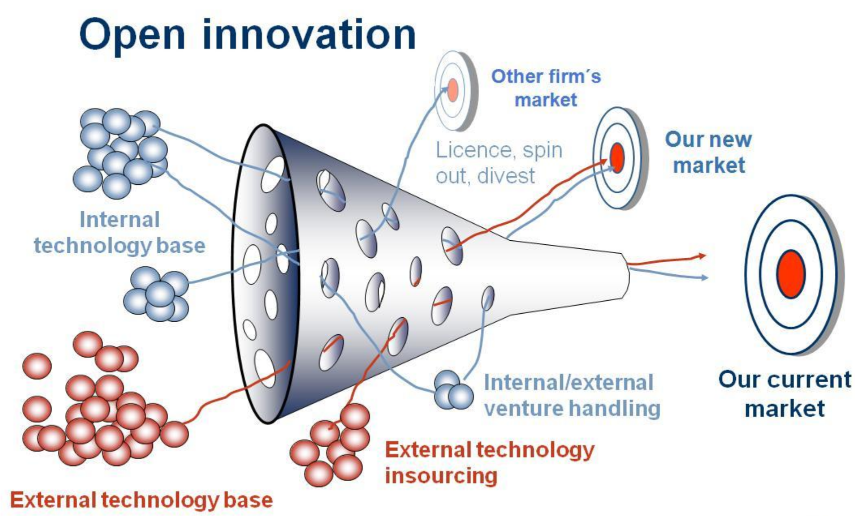

Figure 1.1 Open Innovation (Adopted from Chesbrough et al. 2006)

Open innovation assumes that useful knowledge is widely distributed, and even the most capable R&D firms must identify, connect to, and leverage external knowledge sources as a core process in innovation (Chesbrough 2004). In open innovation, R&D projects can be launched from either internal or external technology sources, and new technology can be incorporated into the process at various stages. In addition, projects can go to market in many ways, such as out-licensing or a spin-off venture firm, in addition to going to market through the firm's own marketing and sales channels. This process redefines the boundary between the firm and its surrounding environment, making the firm more porous and embedded in loosely coupled networks of different actors, collectively working towards commercializing new knowledge.

1.2.1 Types of Open Innovation

As suggested by previous research, open innovation is a broad concept encompassing different types (Chesbrough 2004). In order to clarify the concept of open innovation, we classify these various types of open innovation as follows: 1) differences in external sources; 2) differences in knowledge flow directions; 3) differences in implementation modes. By differentiating it according to these categories, it is possible to achieve a more comprehensive definition of the concept of open innovation.

Different External Sources

Considering the important postion of external knowledge, open innovation can be classified by differences in the external sources. Potentially game-changing innovations are everywhere. A survey with 144 firms revealed that external knowledge was gained mostly through clients (78%), suppliers (61%), and competitors (49%), as well as public and commercial research institutions (21%). Consultancies are used to a lesser degree. A surprisingly large body of other sources was used (65%), namely non-customers, non-suppliers, and partners from other industries (Enkel et al. 2009).

Current literature on open innovation focuses on different external sources, for example, employees and customers (Hienerth 2006), partners from other industries (Enkel et al. 2009), lead users (Franke and Piller 2004), peer production through communities (Jeppesen and Lakhani 2010), and in projects at universities and research institutes (Perkmann and Walsh 2007). It is possible to tap these sources by opening organizational boundaries and exchanging ideas with external partners.

Different Knowledge Flow Directions

As mentioned earlier, some studies distinguish between purposive outflows and inflows of knowledge, which serve to accelerate internal innovation processes and allow the firm to better benefit from innovative efforts, respectively (e.g., Chesbrough and Crowther 2006; Chesbrough et al. 2006; Gassmann and Enkel 2004). Based on knowledge flow directions, there are three core processes in opening up the innovation process: outside-in, inside-out and coupled (Gassmann and Enkel 2004).

- The outside-in process (or inbound open innovation) is the practice of enriching a firm’s own knowledge base through an integrated process of external knowledge sourcing that includes suppliers and customers. It is referred to as technology exploration, which refers to innovation activities aimed at capturing information and benefiting from external sources of knowledge to enhance current technological developments.

- The inside-out process (or outbound open innovation) is the practice of earning profits by bringing ideas to market, selling IP and multiplying technology by transferring ideas to the external environment. The process is known as technology exploitation, and focuses on establishing relationships with external firms with the purpose of commercially exploiting technological knowledge. Through the inside-out process, firms can bring ideas to market faster than they could through internal development.

- The coupled process involves integrating external knowledge and competencies while externalizing the firm’s knowledge and competencies. In order to do this, firms which utilize the coupled process innovate using a co-creative process involving (mainly) complementary partners through alliances, cooperation, and joint ventures, during which cooperation is crucial for success.

Sometimes, these processes complement one another, although academic studies point towards the dominance of the outside-in and coupled processes. Statistics show that 43% of the sample firms have an in-licensing policy in place, while only 36% use an out-licensing policy to externally commercialize their technologies (Enkel et al. 2009).

Different Implementation Modes

Based on different objectives of open innovation, firms may choose different organizational modes to enter a relationship with partners. For instance, they may use licensing agreements, non-equity alliances, purchases and supply technical and scientific services.

As a result of the existence of different implementation modes, there are studies in open innovation literature that discuss the choice of open innovation implementation modes available (Wang and Zajac 2007). A larger number of studies choose one specific implementation mode and discuss the issues involved. For example, some studies focus on the creation of strategic alliances (Srivastava and Gnyawali 2011) while others pay attention to the R&D collaboration/co-development process (Faems et al. 2010).

1.2.2 The Focus of this Thesis

There are various types of open innovation, but the central idea of the open innovation model is the incorporation of external knowledge to benefit innovating organizations with better innovation outcomes. The actor conducting open innovation is the innovating firm and the area of interest for this study is how the firm searches for external knowledge and implements it into their innovation processes. Through this process, innovating organizations may make use of different external sources, different knowledge flow directions and implementation modes according to their innovation strategies. Hence, this thesis includes all of these as aspects of open innovation. Besides the abovementioned types of open innovation, there are some specialized areas attracting attention both from academic researchers and practioners, such as crowdsourcing (e.g., Leimeister et al. 2009) and open source software (e.g., Von Hippel and Von Krogh 2003). This thesis does not specifically focus on these areas, but treats them as the methods organizations can employ to conduct open innovation activities.

In sum, this thesis uses the firm as the unit of analysis, focusing on organizational behavior and managerial mechanisms in implementing open innovation activities.

1.3 Organizational Open Innovation

1.3.1 Characteristics of Open Innovation

Open innovation has some unique characteristics that differentiate it from closed innovation. Firms incorporating open innovation strategies need to deal with the openness of the organizational innovation process, and many employ similar practices in coping with the issues involved in this.

Open innovation requires the firm to focus on the openness of the organizational innovation process. Openness is in part defined by various relationships with external actors and is thus closely coupled to a broader debate about the boundaries of the firm. With the proliferation of interconnectivity and interactivity through ITs nowadays, firms are able to use tools such as social media to actively search for potentially useful technology and collaborators, and use business analytics to process a large amount of data. The advancement of IT also provides firms with the ability to engage in new product development in a virtual space, with other firms located in a geographically distant place.

In addition, the importance given to external knowledge and internal knowledge is changed. In closed innovation, external knowledge plays a useful but supplemental role in prior theorizing about innovation. The firm is the locus of innovation, and the internal activities of the firm are the central object of study (Chandler 1990). In open innovation, external knowledge plays a more important role than internal knowledge.

Compared to closed innovation, open innovation firms lose control of their R&D processes and intellectual property (IP), as they have to give it out to distributed innovators. A new pro-active role for IP management is required. Prior theories of innovation treated IP as a by-product of innovation, and its use was primarily defensive. In open innovation, IP becomes a critical element of innovation, since IP flows in and out of the firm on a regular basis, and can facilitate the use of markets to exchange valuable knowledge.

A central part of the open innovation process concerns the way in which firms go about organizing the search for new ideas with commercial potential. The open innovation model has forced many innovative firms to change the way they search for new ideas. They have to adopt open search strategies that involve the use of a wide range of external actors and sources to help them achieve and sustain innovation.

In addition, prior concepts are accorded little or no recognition in purposive outbound flows of knowledge and technology. In the open innovation paradigm, when firms enable the outward flow of technologies, the technologies that lack a clear path to market internally have the potential to be channelled to market via an external route. These external channels, in turn, can provide important evidence of emerging or neglected technical or market opportunities.

Open innovation focuses on the importance of distributed external knowledge and open search strategies. This leads to an increase in cross-industry innovation potential. For instance, BMW’s iDrive system was transferred from the game industry, while Nike’s shock absorbers were adapted from Formula One racing technology. Thus, firms need to deal with partners with different knowledge bases. It may lead to some new challenges.

The open innovation approach also requires new and different metrics for assessing the firm’s innovation capability and performance. Metrics for closed innovation include the percentage of sales spent on R&D, the number of new products developed in the past year, the percentage of sales from new products, and the number of patents produced per dollar of R&D. Open innovation may incur increased coordination costs, so firms may not be able to achieve financial profits in the short term (Chesbrough et al. 2006). Thus new evaluation metrics are required. For instance, questions about how much R&D is being conducted within the firm’s supply chain (rather than R&D occuring simply within the firm itself) become more important. What percentage of innovation activities originated outside of the firm - and how this compares to the industry in which the firm operates - may be another. The time it takes for ideas to get from the lab to the market, and how that varies depending on the channel it takes to get to market (internal, outlicense, spin-off, etc) will be different.

In sum, open innovation has some new characteristics, and brought new situations that firms need to face. While open innovation literature draws extensively from an earlier body of academic studies, it offers a number of distinctive perspectives and interpretations of that prior literature of organizational innovation does not have.

1.3.2 Benefits of Open Innovation

Many firms started to incorporate open innovation as a necessary organizational adaptation to changes in the environment (Chesbrough 2003). A further exploration of motives was discussed in open innovation literature. Firms may implement an open innovation model to 1) acquire missing knowledge, complementary resources or finances; 2) to increase the speed of R&D, 3) to spread risks, 4) to enlarge its social networks, or 5) to reduce costs and meet customer demand (Chesbrough and Crowther 2006; van de Vrande et al. 2009).

Some firms indeed benefit extensively from an open innovation strategy. For instance, through their "Connect and Develop" program with external innovators, Procter and Gamble announced that they were able to increase their product success rate by 50 percent and the efficiency of their R&D by 60 percent (Huston and Sakkab 2006b). Strategic modes of open innovation have also become beneficial in the pharmaceutical industry. Examples of these include Bayer with its Creative Center, Eli Lilly and its Innocentive Initiative, and Pfizer with the in-licensed drug Lipitor. Lipitor became the first pharmaceutical product to top US$10 billion in annual sales (Gassmann et al. 2010).

1.3.3 Managerial Challenges of Open Innovation

Despite the promising benefits, firms investing in open innovation activities face risks and barriers that may hinder them from profiting from their initiatives (Cassiman and Veugelers 2006; Huston and Sakkab 2006a). According to a survey of 107 European SMEs and large enterprises undertaken in 2008, risks such as the loss of knowledge (48%), higher coordination costs (48%), loss of control and higher complexity (both 41%) are mentioned as frequent risks connected to open innovation activities. In addition, there are significant internal barriers, such as having difficulties in finding the right partner (43%), imbalances between open innovation activities and daily business (36%), and having insufficient time and financial resources for open innovation activities (Enkel et al. 2009).

The successful implementation of open innovation initiatives is dependent on effective management of inter-organizational relationships. Effective inter-organizational networks are critical for leveraging open innovation (Vanhaverbeke and Cloodt 2006).

Second, cultural change to accommodate a more "open" attitude among employees is also important. Due to this, the not-invented-here (NIH) syndrome and lack of internal commitment can be major factors hampering open innovation. The NIH syndrome has been previously found to be a prominent barrier for external knowledge acquisition (e.g., Katz and Allen 1982). In executive education programs, researchers have observed that CTOs with closed innovation models and strong internal R&D are under increasing pressure to justify their refusal to cooperate with the outside world and exploit the open innovation wave (Enkel et al. 2009). NIH focuses on the external acquisition of knowledge. Similarly, for the inside-out process, it leads to the "only-used-here" (OUH) syndrome (Lichtenthaler and Ernst 2006). R&D employees are also not motivated to commercially exploit technological knowledge by transferring ideas to the outside environment.

When collaborating with other firms, organizational concerns may also arise due to issues such as knowledge leakage, free-riding behavior, and problems with contracts, conflict management, information asymmetry, opportunistic behavior and bad coordination when implementing open innovation initiatives (Gulati and Singh 1998; Kale et al. 2000). In implementing the inside-out process, firms also consider that the outbound licensing of IP and patent pooling may give away their technology to their rivals.

Open innovation focuses on the importance of distributed external knowledge, which leads to an increase in cross-industry innovation potential. However, firms encounter challenges in collaborating with external partners from different technological domains and with distinct organizational backgrounds (Chesbrough et al. 2006). It may deter inter-firm knowledge transfer and learning. Potential problems may arise due to insufficient knowledge, clashing cultures or modes of the firms, or bureaucratic conflicts.

Even if external innovations are identified, that does not mean they will be incorporated into the firm's product strategies. To benefit from external innovations, firms need to maintain the absorptive capacity to understand them, and be able to combine such spillovers with firm-specific internal innovations to produce a product tailored to the firm's specific needs.

Another challenge faced by firms is that of finding a balance between open innovation and closed innovation. Today's business reality is not based on pure open innovation but on firms that invest simultaneously in closed as well as open innovation activities. Too much openness can negatively impact firms' long-term innovation success, because it could lead to a loss of control in core competencies. Yet, a closed innovation approach does not serve the increasing demands of shorter innovation cycles and reduced time to get the products to market. The future lies in an appropriate balance between the open innovation approach, where the firm or the institution uses every available tool to create successful products and services faster than their competitor, and the closed innovation approach, which fosters the building of core competencies and protects their IP.

1.4 Limitations of Current Research

Since the new characteristics of open innovation are not usually found in traditional industries, opening up the innovation process requires organizational adaptations and change, and brings new managerial challenges. Despite broad interest and a vast body of literature, our understanding of open innovation remains relatively undeveloped. Based on the new characteristics of open innovation, we identified the limitations of current research in three aspects: the open search process system in the external environment, the impact of an open search on innovation performance, and the supporting role of IT in the open innovation process.

1.4.1 Open Search Process in External Environment

External search has played a very critical role in the innovation process, especially in the R&D settings (e.g., Berchicci 2012; Li et al. 2010). Past studies have shown that firms must acquire and exploit new scientific knowledge and technological developments from the external environment in order to innovate and remain competitive (Cohen and Levinthal 1990; Escribano et al. 2009).

Table 1.1 summarizes the extant literature on external search by depicting the conventional pattern of open search work and their early evolution. Searching external knowledge is originally conducted for closed innovation projects whereby commercialized products and services are internally developed. External knowledge plays a supplemental role in closed innovations, mainly to inspire ideas at the beginning stages of the innovation process (Chandler 1990). In such a setting, ordinary R&D employees are not directly connected with external sources of knowledge but through a small group of people termed “boundary spanners” because of the underlying assumption that external information sources are scarce and difficult to access (Allen 1977; Subramani 2004). Hence, the sourcing and assimilation of these limited resources could only be performed by these key individual technologists who have strong connections with internal colleagues and to external sources of information and who possess the ability to link the acquired knowledge to the appropriate insiders (e.g., Allen 1977; Jeppesen and Lakhani 2010; Tushman 1977).

Table 1.1 Summary of Literature on External Search				
Source	**Research Context**	**Research Method**	**Major Findings on Search**	**Phase in Innovation Process**
Knight (1967)	Closed innovation	Theoretical	• The search process of firms differs in their recognition of the needs for search (i.e., perceived successfulness) and in their search patterns (i.e., external or internal sourcing and innovativeness of technology or idea sourced) to find a satisfactory solution. • The search process of individuals begins with recognition of a problem. Then they use their memory, develop their search strategy, and evolve criteria to identify a satisfactory solution.	Idea generation
Tushman (1977)	Closed innovation	Empirical: Survey	• There are several boundary-spanning roles. The laboratory and the organizational liaisons span intra-organizational boundaries for internal communication, while the gatekeepers span the extra-organizational boundary for external communication. • Projects with more complex information-processing requirements have more boundary roles than projects with less complex information processing requirements.	Idea generation
Choudhury and Sampler (1997)	Environmental analysis and information acquisition	Theoretical	• Decision makers will personally acquire information that is high in knowledge specificity in acquisition. • Decision makers will delegate the task of acquiring information with medium specificity in acquisition to subordinates. • For information that is low in knowledge specificity in acquisition, managers will delegate the task of acquiring	Idea generation

			information to (a) a central environmental scanning unit if the knowledge specificity in use of the information is low and (b) to a subordinate if the knowledge specificity in use of the information is high.	
Harada (2003)	Organizational innovation	Empirical: Case study	• Gatekeepers perform a three-step flow of communication of external information sourcing: 1) information gathering and 2) information transforming, and 3) information transmitting. • External communication stars with short the organizational tenure bring new outside information directly to knowledge transformers; • Knowledge transformers with longer the organizational tenure transform this information into firm specific knowledge consistent with the routines and coding schemes; • Knowledge is transmitted to other firm members via knowledge transformers.	Not specified
Grimpe and Sofka (2009)	Organizational open innovation	Empirical: Survey	• Firms in low-technology industries benefit more with market knowledge sourcing from customers and competitors. • Firms in high-technology industries benefit more with technology knowledge sourcing from universities and suppliers.	Idea generation
Whelan et al. (2010)	Organizational open innovation	Empirical: Social network analysis and case study	• Gatekeeper role is not performed by a single individual. • It requires the combination of internal communication specialists within firm boundary and external communication specialists across organizational boundary. • Internal communication specialists assimilate the information sourced by external communication specialists.	Not specified

Figure 1.2 depicts the conventional pattern of external search. As shown in the left diagram, boundary spanners in this setting tend to occupy managerial positions in the R&D department (LaValle et al. 2011; Levina and Vaast 2005; Sarker et al. 2012). They are both external and internal stars as well as the decision makers. Internally, they are more likely to have longer organizational tenure to develop one's communication network within the firm. Externally, they exploit their personal network and social networking abilities to source for external knowledge (Conboy and Morgan 2011). Oral contacts, rather than written materials, are the primary means used by gatekeepers to discuss and transfer technical information and knowledge (Allen, 1977). This communication is typically expensive and costly, especially in the field of technical communication. Hence, the boundary of the conventional sourcing work focuses mainly on local areas, which depends very much on adjacent industries/networks such as their familiar customers, suppliers or universities (Stuart and Podolny 1996; Tushman 1977). In this conventional work pattern, R&D employees work as the passive users and executors of external knowledge from boundary spanning managers.

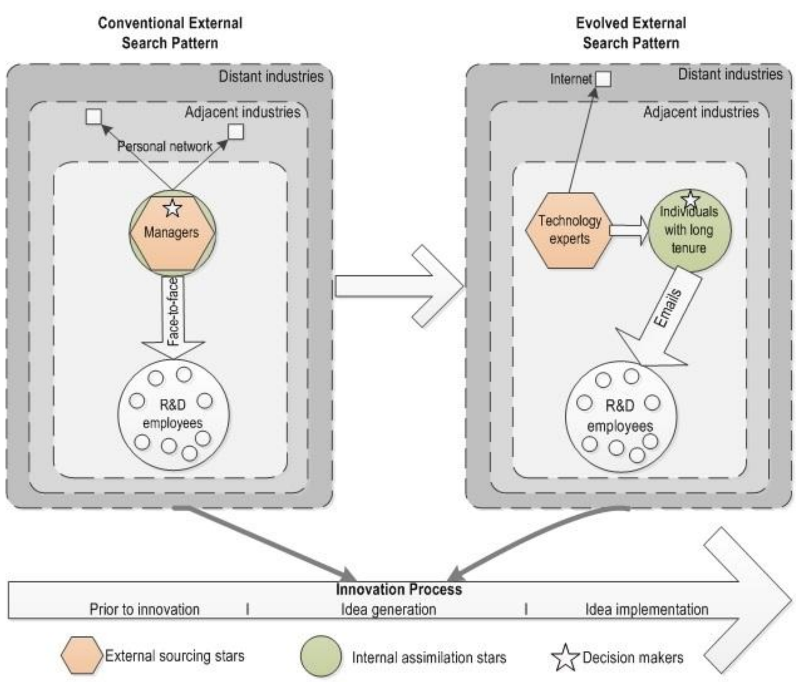

Figure 1.2 External Search Patterns in the Literature

With the advent of Internet technologies, boundary spanners who originally perform both external sourcing and internal assimilation have to adapt to a new work pattern. With large amount of information available on the Internet, distilling the valuable information becomes a complex and time-consuming process. Hence, a separation of boundary spanners' external sourcing responsibilities and internal assimilation work occurs. As shown in the right diagram in Figure 1.2, employees who are specialized in a deep and narrow knowledge domain such as those holding a PhD degree are inducted as external sourcing stars (Harada 2003; Whelan et al. 2010). Those with longer organizational tenure are recognized as internal assimilation stars and less likely to communicate with outside (Harada 2003).

While prior literature provides valuable insights on conventional work of external search, there are some gaps limiting our understanding on how external search can be conducted efficiently. First, external search in an open innovation is no longer limited to the beginning stage, but can occur at any stage of the innovation process. Such a change may exact different requirements on the open search work but this has not been recognized in the prior literature. Second, the employment of ITs in prior literature is limited to the Internet as the major external sourcing channel and the email as the main channel for internal knowledge assimilation (Whelan et al. 2010). A variety of IT applications and their impact on open search work are also not captured in the literature. Third, understanding how the work of key stakeholders such as managers and R&D employees has changed in open search is under-scrutinized in the literature despite its importance to the firms. Decision making, which is an important responsibility to control the knowledge flow into the firm, has been overlooked by prior external search literature because this role is traditionally being performed by internal communication stars. In the context of IT-enabled open search, how decisions are being made in the R&D department may have been changed too. Further investigation along these lines is thus required.

In this thesis, the external search in the open innovation context is termed as *open search process*, which we define as the work of sourcing external knowledge (i.e., technology or collaborator) and disseminating them to innovating teams.

1.4.2 Impact of Open Search on Innovation Performance

Besides than pointing to the process of organizational behavior in an open search for innovation opportunities, prior studies also suggest that innovation performance differences between organizations can be ascribed to outcomes of open search.

Early studies focus on the effect of distant search on organizational innovation performance and compares it with the limitations of local search. For instance, Rosenkopf and Nerkar (2001) explore the role of boundary-spanning searches for both organizational and technological boundaries and find that search processes that do not cross organizational boundaries generate less effects on subsequent technological evolution, indicating that the impact of explorative search is greatest when the search spans both orgnaizational and technological boundaries. Powell, Koput, and Smith-Doerr (1996) investigated inter-firm collaboration in biotechnology and assessed its contribution to learning and performance. They found that firms embedded in benefit-rich networks are likely to perform better, in terms of innovativeness. In sum, all these studies point to the positive impact of open search systems on organizational innovation performance.

Further literature investigates how firms search externally to achieve better innovation performance. For instance, Laursen and Salter (2006) examined how different strategies for using exernal sources of knowledge influence innovation performance. They focused on the number of search channels, such as suppliers, users, and universities, that firms use in their search for innovative opportunities (i.e. breadth) and the extent to which firms draw intensively from these different search channels (i.e. depth). They found that seaching widely and deeply has a curvilinear (an inverted U-shape) relation to performance. Besides, Lahiri (2010) examined the impact of the geographic distribution of R&D activity on innovation quality. Sidhu et al. (2007) examined the influence of supply, demand, and spatial search on organizational innovativeness.

Although prior studies highlighted the link between open search behavior and organizational innovation performance, there are some research gaps. Firstly, prior studies focused on innovation outcomes at the organizational level, such as the number of new product introductions, patents in a given year, or sales growth. Despite their importance, the project level innovation outcomes are largely ignored. Besides the innovation outcomes, the impact of open search systems on innovation process performance is neglected. We have not achieved a clear understanding of open innovation process performance yet. Moreover, in the context of open innovation, one critical characteristic of organizational open search behavior is the openness of the search in external environment. How does the openness of their open search behavior influence the firms' ability to innovate and appropriate the benefits of innovation? These questions lie at the heart of recent research on innovation (Chesbrough 2003; Helfat and Quinn 2006; Laursen and Salter 2006). Their answers require a conceptual frame that defines and classifies the different dimensions of openness. In spite of rising interest in using the open construct, systematic studies of the open search system remain cumbersome because of conceptual ambiguity.

Hence, this thesis is motivated by a desire to clarify the definition of "openness" as currently used in the literature on open innovation, and to investigate its impact on both innovation outcome performance and innovation process performance in an open innovation project.

1.4.3 IT and Open Innovation

Notably, as an important organizational resource, ITs could play a prominent role in creating the demand for open innovation strategy and cultivating the area of its deployment (Cui et al. 2012; Dodgson et al. 2006). Effective IT may help reduce the cost of searching for knowledge and facilitate knowledge sharing (Chi et al. 2010; Joshi et al. 2010) and impact the implementation of open innovation in firms. Prior literature has emphasized that IT creates the necessity for the implementation of open innovation (Dodgson et al. 2006). More specifically, the rise of the Internet has played an important role in enabling searches for external innovation, by facilitating technology intelligence (Veugelers et al. 2010), online communities (Dahlander and Gann 2010; Füller et al. 2008), crowdsourcing or broadcast search (Ebner et al. 2009; Jeppesen and Lakhani 2010), and Internet platforms such as blogs and virtual worlds (Droge et al. 2010; Kohler et al. 2011). In addition, organizations can rely on social media tools to actively search for customer preferences (Di Gangi and Wasko 2009), business analytics to process external data for knowledge (LaValle et al. 2011), and third-party platforms to identify promising innovations (Jeppesen and Lakhani 2010).

As for the implementation of external knowledge in the innovation process, IT is also imperative and IT tools are widely used in any open innovation project. Firms increasingly collaborate with geographically dispersed partners. IT facilitates communication with open innovation partners, to leverage complementary assets and combine existing applied knowledge (Kane and Alavi 2007). For instance, CAD/CAM systems help to digitize a new product's design and make it available among partners in the innovation development process. IT applications such as visualization, simulation tools, knowledge discovery tools, and business intelligence tools (Chi et al. 2007; Subramani 2004) are also important in supporting the implementation of knowledge in the innovation process.

Despite the importance of IT in facilitating the open innovation process, specific features of IT that organizations should develop to support open innovation are not well-understood. The role of IT in driving firms to be more open and interactive with their external environment, and facilitating the open search process, has been ignored in previous literature. In addition, how to use different IT tools during each stage of the open innovation process and how these tools influence the open innovation project performance should be examined.

In the following two studies, we will analyze the above-mentioned issues and aim to achieve an increased understanding of the phenomenon of open innovation.

1.5 Research Questions

This thesis explores two important aspects of open innovation. Study One specifically focuses on the open search process and the role of IT in this process, and Study Two focuses on the impact of the "openness" of an open search on project innovation performance and the supporting IT. By identifying what is lacking in the current literature, this thesis investigates how to successfully implement open innovation activities to create value for organizations.

1.5.1 Study One: Exploring the Open Search Process through a Multiple Case Study

External searches have played a very critical role in a firm's innovation process. Conventional external search work is characterized by employing a small number of individuals, often taking managerial positions, to act as boundary spanners by sourcing through personal networks. The advancement in ITs, a cornerstone of the success of open innovations, has altered external search processes. Employees at different organizational levels can source external knowledge and share them with other employees with consummate ease and speed. However, extant literature has paid scant attention to capture such a change. Study One fills the gap by investigating:

- *How do ITs change the work processes of an open search?*
- *How should firms re-design their work arrangement in order to achieve open search efficiency and maximize its impact?*

Study One employed two-stage multiple case studies to unveil the changing work process of "open search", which consists of sourcing external knowledge (i.e., technology or collaborators) and assimilating their acquired knowledge into the firms' internal R&D employees' work. In the first stage, we observed three patterns of open search - centralized, differentiated, and decentralized - and explored the evolutionary processes of how IT changes the patterns of open search (e.g. the function of IT as an amplifier and a catalyst). In the second stage, drawing on the perspectives of upper echelon theory and organic/mechanistic organizational forms, we developed a theoretical exposition of open search work by 1) evaluating the impact of each open search pattern on efficient search outcomes; 2) understanding appropriate IT mechanisms for each identified pattern; and 3) unveiling the relationships between the three open search patterns by considering the uncertainty as a unique trait of open innovation.

1.5.2 Study Two: Exploring the Impact of Openness on Open Innovation Performance

While open innovation can help organizations obtain complementary knowledge from collaborators, it is likely to present inherent challenges in knowledge absorption. The differences in inter-organizational knowledge can seriously inhibit the ability of the focal firm to innovate via external knowledge. While the concept of open innovation has attracted significant attention, there remains a paucity of research on how information technology (IT) can address the challenges of knowledge absorption. Therefore, Study Two examined:

- *How does the degree of openness vary among collaborative innovation projects? How does the degree of openness influence open innovation performance?*
- *What are the IT tools used during each phase of the open innovation process?*
- *How does IT usage facilitate the open innovation process?*

To investigate these questions, Study Two adopted a two-stage research approach. In the first stage, we used an exploratory qualitative multiple case study approach to explore the underlying factors that influence the open innovation project performance, as well as the important IT tools used during the open innovation project. In the second phase, drawing on absorptive capacity theory, we proposed our research model and conducted a quantitative survey study to further explore the findings from the qualitative study. The dual-phase approach, which has been used to good effect in previous research (Kaplan and Duchon 1988), allowed us to triangulate from multiple data sources and establish a strategy for improving reliability and validity (Yin 1994).

1.6 Potential Contribution

This thesis seeks to benefit and contribute to both academic and practitioner arenas by investigating the open search process and the impact of open search on open innovation project performance. Specifically, by addressing the research gaps proposed in the previous sections, the two studies in this thesis are expected to make the following contributions.

- It contributes to building a middle-range theory of open search by shedding light on the different patterns of open search and their varying impact on search outcomes.

- It provides useful insights to firms' managers to design their innovation units effectively to achieve optimal open sarch results.

- It defines the degree of openness required for collaborative innovation projects by focusing on the openness in searching for collaborators, and the openness demonstrated during the process of collaboration.

- It extends inter-firm diversity literature by adding to the organizational learning perspective and provides a clear understanding of this issue in the context of open innovation.

- It adds much-needed perspective on open innovation literature by unveiling various IT tools and the differentiated roles that IT-enabled knowledge capabilities can play.

- It provides managers with the conceptual clarity to use open search patterns appropriately, and enable them to mindfully select appropriate work arrangement so as to achieve desirable open search outcomes.

1.7 Thesis Structure

The opening chapter has provided an overview of the study context and general motivations based on the current research gaps. It highlights the importance of open innovation, and raises the research questions that will be addressed in the studies as well as the potential contributions. The subsequent chapters of the thesis are organized as follows.

Chapter 2 describes Study One in detail. It first reviews the literature on the external search process for innovation technology or ideas and identifies specific gaps in the literature. A description of the 2-stage multiple case study research methodology used is provided. Next, we describe the first stage case study and its findings, followed by the second stage case study. We conclude with a discussion of the implications of the results for future research and practice.

Chapter 3 describes Study Two in detail. It first reviews the literature on current open innovation research and identifies the research gaps requiring further investigation. It then presents the two-staged research approach used. It follows a first stage exploratory qualitative multiple case study. Next, we describe the quantitative survey study to further explore the findings from the qualitative study. Discussions and implications are then reported.

Chapter 4 concludes this thesis by summarizing the findings and implications of the two studies, followed by a projection of possible future research directions.

CHAPTER 2.

STUDY 1: EXPLORING THE OPEN SEARCH PROCESS: MULTIPLE CASE STUDIES OF CHINESE FIRMS

2.1 Introduction

External search has played a very critical role in the innovation process, especially in the R&D settings (e.g., Berchicci 2012; Li et al. 2010). Past studies have shown that firms must acquire and exploit new scientific knowledge and technological developments from the external environment in order to innovate and remain competitive (Cohen and Levinthal 1990; Escribano et al. 2009). This external environment includes sources such as customers, suppliers, universities, research institutions, industry consortia, and even rival firms (Chesbrough 2003). It is noteworthy that conventional external search work is characterized by the use of a small number of individuals taking managerial positions in the R&D department to act as the firm's boundary spanners to scan the outside world through personal networks for knowledge, and process and disseminate them to the R&D employees (e.g., Allen 1977; Jeppesen and Lakhani 2010).

However, the advancement in ITs has dramatically changed the work pattern of external search in the R&D department. ITs such as search engines, electronic communication tools and intra and inter-firm systems have empowered R&D employees of different organizational levels to source for external knowledge and share them with other employees with consummate ease and speed (Melville et al. 2004). In addition, the utilization of some newly developed IT tools (e.g., data and text mining techniques) in external search have changed the face of the conventional external search team by requiring boundary spanners with high IT literacy and efficacy. Meanwhile, other developments in ITs such as open innovation and crowd sourcing platforms have also broadened the scope and the distance of external search. As a consequence of the expanded number of boundary spanners and broadened search domains, ITs have precipitated external search to be more open and hence the advent of open innovation (Chesbrough 2003).

The inclusion of more and different boundary spanners and broadened search domains pose new challenges to firms in managing their *open search process*, which we define as the work of sourcing external knowledge (i.e., technology or collaborator) and disseminating them to innovating teams. First, searching knowledge from a wide range of less known external sources may generate significant uncertainty and risk to the innovation project. “Settling” for less satisfied technologies or partners usually yields poorer resources and threatens the attainment of effective innovation outcomes. For instance, inappropriate external knowledge source was deemed as a main reason causing the failure of Boeing’s Dreamliner 787 project (Chesbrough 2011). A survey results show that 43% managers are concerned with the difficulty of finding the right partner in open innovations (Enkel et al. 2009). Second, without building sufficient knowledge in this new work arrangement and a suitable organizational design, firms can suffer from unnecessary organizational resources wastage on search, chaos in R&D employees’ open search, and delayed innovation time to market. These challenges therefore call for a more insightful understanding into how ITs change the work of open search process and how firms should then re-design its structure, process and decision-making components in order to achieve open search efficiency, defined as the favorable ratio of external search outputs (acquisition of satisfactory external technology or partner) to inputs (time and effort expended in the search process).

In this study, we attempt to address this under-studied phenomenon by conducting two-stage multiple case studies to build a deep understanding of the open search work. In the first stage, we observed three patterns of open search - centralized, differentiated, and decentralized and explored the evolution processes of how IT induces the emerging of the three work patterns of open search (e.g., IT as an amplifier and a catalyst) from the conventional search pattern. In the second stage, drawing on the perspectives of upper echelon theory (Hambrick 2007; Hambrick and Mason 1984) and organic/mechanistic organizational forms (Burns and Stalker 1961), we developed a theoretical exposition of open search work by 1) evaluating the impact of each open search pattern on efficient search outcomes; 2) understanding appropriate IT mechanisms for each identified pattern; and 3) unveiling the efficiency of the three open search patterns by considering the uncertainty of involving external knowledge along the innovation process. Through this study, we seek to contribute to building a middle-range theory of open search by shedding light on the different patterns of open search and their varying impact on search outcomes along the innovation process. Our findings can also provide useful insights to top management to design their innovation units effectively to achieve optimal results.

2.2 Stage 1 - Understanding the Evolution of Open Search Work

To fill the identified research gaps, we used inductive theory building approach (Eisenhardt 1989b) to identify IT-induced work change in open search. Two firms leading in open innovation were selected at this stage (see Table 2.1 for firms' details). Such a selection makes our findings more robust and generalizable than selecting single case (Eisenhardt and Graebner 2007). The qualitative data were collected through four sources: 1) interviews with key stakeholders, 2) onsite observations of innovation products and work places, 3) follow-up e-mails and phone calls to track the innovation processes and clarify details, 4) archives including media and corporate materials. Such triangulation bolsters confidence in the accuracy of the findings. In total, 11 onsite interviews were conducted from two leading firms in open innovation (see Table 2.1). Each interview last 45-60 minutes, and was taped and transcribed. The interview questions largely focused on the evolution of work in conducting open search. Sample interview questions included “How does your firm conduct open search? Who and how to source external knowledge? How can the sourced knowledge be assimilated internally? What factors drive the changes of open search work? What’s the role of ITs in open search?”

Table 2.1 Descriptions of Interviewed Firms in Stage 1

Firm*	**Business Description**	**Number of Employees**	**Number of Interviews**	**Interviewees’ Position**
Pluto	A global top American multinational consumer goods firm. Its products include pet foods, cleaning agents and personal care products.	7000 (China branch)	6	Senior technology manager, R&D director, R&D employee
Neptune	The largest and leading solar energy firm in China. Its products range from solar water heaters, solar collectors to solar lights and PV lighting products.	4000	5	Chief executive officer, senior technology manager, R&D employee

* To protect the confidentiality of participants' data, all firm names have been replaced with pseudonyms.

We addressed potential informant bias in several ways. First, we triangulated data from multiple sources and informants for a firm. At least two evidences were used to support each finding (Chiang and Hung 2010; Teigland and Wasko 2003). Second, we used “courtroom question” that focused on factual accounts of what informants knew (e.g., dates, meetings, participants) and avoided speculation (Grimpe and Sofka 2009). Third, we gave anonymity to our informants and their firms, which encourages candor. The transcribed field notes and interviews were coded by three researchers, who then met to discuss the codes to ensure the interpretation consistency. An initial set of coding themes was derived based on our objective to understand the open search work and its evolution. The findings were moved back and forth between empirical data and conceptual themes. This process ended when "theoretical saturation" was reached, where the incremental improvement on the research findings became minimum (Eisenhardt 1989b).

2.2.1 Case Pluto

Episode 1: Centralized Open Search

Operating in a competitive market, Pluto envisioned new ideas and new products as its lifeblood and continuously searched for innovative ideas. As a leading firm in the consumer goods market, R&D managers in Pluto paid huge attention to assimilating state-of-the-art technologies into its product lines. Similar to the conventional external search pattern identified in Figure 1.1, the responsibility of open search fall upon the manager, who selected appropriate external knowledge (technologies or collaborators) from personal networks or reach potential ones through mutual acquaintances in personal networks. These technologies and collaborators were used for achieving long-term goals and gaining competitive advantage. However, ITs played prominent roles along the two stages of the open search process (i.e., external sourcing and internal assimilation). Since decision making is also a critical work responsibility and the stakeholders to perform it has changed, we include the discussion of it in the open search process. For managers, ITs had facilitating roles of broadening their networks, facilitating the decision making, and easing the internal knowledge assimilation process.

External sourcing: The work of external sourcing in Pluto was conducted by R&D managers. Besides existing network, managers also employed IT tools such as Internet to source potential external knowledge. After identifying potential targets, the possibility of collaboration was first negotiated mainly in the offline setting such as site visits and conference attendance. For example, the senior technology manager stated the following strategy to establish the network:

"Some top researchers at Chinese Academy of Sciences were invited to seminars and visits at our firm a long time ago before our collaborative innovation projects started."

Once the network was initiated, communication technologies such as emails, video conferencing and chat applications were used by managers to strengthen the relationships with external parties and build shared structures of interactions, cognition, and trust.

Decision making: We learnt from our informants that electronic reports available on the Internet were used by Pluto's managers to evaluate the potential collaborators. To ensure that the chosen external knowledge fit the firm, they also used executive information systems to monitor customer demands and competitors' movements before making the final selection.

Internal assimilation: After selecting the external collaborator, decision and the collaborator' information were passed downward from managers to lower level R&D employees, mainly through emails. This is referred to as top-down assimilation. R&D employees then planned the collaboration details with external partner together. Besides face-to-face meetings, communication ITs (e.g., emails, electronic noticeboards, newsletters, phone, fax), were used to facilitate interactions between the cooperating parties.

During this episode, Pluto had twelve innovation projects collaborating with two universities and one research institution. By sharing resources, leveraging ideas, and tapping the expertise, Pluto was able to create vibrant innovation ecosystems, multiply its efforts, and derive more strategic value for the firm.

Episode 2: Differentiated Open Search

To mark the completion of the first innovation episode, a specialized sourcing unit focusing on sourcing external knowledge was established in Pluto. We understood that the establishment of this unit was mainly due to two reasons. First, IT tools such as data mining applications, analytic techniques, and open innovation platforms significantly amplified the speed and intensity of external sourcing and selection capabilities. Under such circumstances, managers had limited ability and time to employ these IT tools. Second, the open mindset toward innovation has taken root in Pluto. Managers and R&D employees view external search not merely as a task also as a way of building useful knowledge sources for future innovation projects.

<u>External sourcing</u>: The sourcing unit initially consisted of 11 employees, who were both IT experts and PhD holders in the areas relevant to Pluto's products. These employees in the sourcing unit not only handled requests for searching external knowledge from R&D unit, but also proactively probed cutting-edge external knowledge, mapping these emerging technologies to products and monitoring the technological capabilities of competitors. Employees in the sourcing unit were good at filtering, interpreting and synthesizing information from vast amount of web pages, scientific literature and patent databases using data mining and retrieval technologies.

In addition, employees in the sourcing unit also utilized open innovation portals to identify innovative external knowledge. First, they built a portal to post their needs and look for solutions from people all over the world. Second, they also utilized existing portals such as InnoCentive, NineSigma, and Alibaba to source for potential technologies, partners and monitor the development of new technologies. For instance, the R&D director mentioned that, Alibaba, an online China manufacturer portal, *"linked our firm to various manufacturers, suppliers, exporters, importers and buyers. For one innovation project, we searched for an important technology for two years, but did not find any satisfactory technology provider. With Alibaba, our sourcing unit managed to find one small firm in China that met our requirements."*

Decision making and internal assimilation: After the new idea was identified by the employees in the sourcing unit, the knowledge was then assimilated throughout the R&D department. A down-top-down communication was used for knowledge assimilation. Managers of R&D department served as boundary spanners between the employees in the sourcing unit and R&D employees. As a supporting unit of the R&D department, the sourcing unit sourced external innovation solutions or potential technology or collaborators for the R&D department during their innovation projects. As we learnt from Pluto, R&D employees sent open search requests through managers of the R&D department to the employees in the sourcing unit. The acquired external knowledge was also transmitted through managers. Although R&D employees participated in the decision making process, R&D managers still possessed more decision making power of deciding whether and which of the sourced external knowledge will be assimilated among R&D employees. For sourcing unit's proactive open search, they also disseminated new and innovative technologies they thought useful for R&D employees through managers to R&D employees. As illustrated by the R&D director,

"We had a structured and organized communication way between the sourcing unit and the rest of the R&D employees. The communication was bridged by the managers."

Episode 3: Decentralized Open Search

As the benefits of external knowledge spread, more and more open search requests were requested by R&D employees. Only a small number of open search requests were handled by employees in the sourcing unit due to their limited capacities. Besides that, the communication and coordination costs involved in discussing open search requests and sourced knowledge with the sourcing unit were high. The R&D employees at Pluto started to search externally for their own innovation problems. They engaged in both external open search and traditional R&D work.

External sourcing: Compared to the sourced technology by the sourcing unit was potentially beneficial to the entire R&D department, the objective of open search by R&D employees was to find solution to solve more specific innovation problems they encountered during their work. One R&D employee in Pluto indicated,

> *"Once during our innovation process, our bottle sealing technology failed to develop the new product. Since this needed technology may only be applied in this particular innovation project. Rather than sending request to the sourcing unit, we took the responsibility of open search. Finally my colleagues and I found the satisfactory technology in an exhibition in Hong Kong."*

Since open search was only a part of and not the focus of R&D employees' work, the search was not conducted systematically, but focused on finding a feasible solution for immediate practical use. They tapped closed proprietary networks (e.g., suppliers, retailers, competitors, and development and trade partners) and prior collaborative networks of firms available to the firm. They also looked for ideas and solutions in exhibitions, industrial associations, and organizational yellow pages. Various IT tools were also implemented by R&D employees to source external knowledge. We learnt through interviews that RSS technologies helped R&D employees in Pluto synthesize and share information from multiple sources; wikis and blogs had opened up new opportunities to integrate knowledge and ideas, accelerating knowledge discovery and innovation. R&D employees also actively participated in external communities of practice and Internet-based technology forums, which facilitated interactive and timely tacit knowledge acquisition. Therefore, ITs provided the means by which R&D employees engaged in their sourcing tasks with flexibility and agility.

Decision making and internal assimilation: If the sourcing R&D employees were also users of the acquired external knowledge, they would then made decisions about whether and which of the acquired external knowledge will be used in the innovation projects. If the sourced external knowledge will be used by all of the innovation project team members, then the R&D managers also participated in the decision making process to select the right external knowledge. Since R&D employees knew very well who required the sourced external knowledge, they also took on the role of internal assimilator to disseminate the sourced the sourced external knowledge among the innovation project team members. Face-to-face meetings and discussions were used for internal assimilation. However, as a very large R&D department with around 550 R&D employees, the project team may involve a large number of members, with some members who are distributed around the world. IT significantly enhanced interactions among individuals for knowledge assimilation in Pluto. A senior technology manager of Pluto said,

> *"When some R&D employees identified the potential external knowledge, they uploaded it to a knowledge management system, called InnovationNet, and provided access to other innovation project team members to it. In addition, intranet and online communities also connect our R&D employees to facilitate their communication."*

Today, open innovation has permeated into each and every corner of Pluto's firm and all of its R&D employees actively search externally during the innovation process.

2.2.2 Case Neptune

Episode 1: Centralized Open Search

Neptune is the largest and leading solar energy firm in China. Its products range from solar water heaters, solar collectors to solar lights and PV lighting products. Neptune started its collaborative innovation journey as early as 2000. Similar to Pluto, in the early stage, the senior and R&D managers of Neptune undertook the work of open search through their personal networks.

External sourcing: Managers of Neptune, a Chinese firm, adopted a different approach from their Pluto counterparts by paying more attention to cultivate government ties in their social networks. Through attendance of association meetings and industrial development events, managers took opportunities to interact with government officers, which in turn brought them valuable connections to managers from other firms. The chief executive officer of Neptune recounted:

> *"I know some government officers who are in charge of the technological development park. Our collaborative innovation project with the Institute of Electrical Engineering was brokered and supported by the municipal Science & Technology Commission."*

In addition, as illustrated by our informants, managers of Neptune sourced in areas of the United States, Japan, and Europe for breakthrough research and many more for state-of-the-art development capabilities. Managers of Neptune purposefully attended international fairs, exhibitions and visited foreign firms, with the deliberate aim of expanding the pool of potential partners. During their interactions with managers from foreign countries, they identified technologies and collaborators of great potential value to their own firm.

Decision making and internal assimilation: The sourcing managers played the same role of decision makers as managers in Pluto did in deciding on their collaboration partners. However, unlike the case of Pluto that applied the top-down assimilation of collaborative intentions with external partners, Neptune managers relied more on face-to-face meetings than on electronic communication. We learnt from our informants that they were various face-to-face communications among executive managers, middle level managers and R&D employees to create awareness and foster consensus on the innovation collaboration projects. Team briefings were also used to enable project managers to communicate and consult with R&D employees. Team briefings took place on a weekly basis or more frequently. According to the R&D director of Neptune,

> *"Our CEO regularly delivered inspiring speeches to employees about the organizational strategic development. Senior managers also meet R&D employees regularly to communicate about the collaborative innovation projects."*

Episode 2: Decentralized Open Search

In this later stage, Neptune took a different trajectory of open search pattern change from Pluto. The change was also due to two reasons. First, during this stage, Neptune hired some new engineers in the R&D department with new work practice and external knowledge. Second, the implementation of office automation systems, and supply chain management system in Neptune provided these new R&D employees access to external knowledge sources and consequently stimulated them to discover innovation opportunities in the interconnected networks.

<u>External sourcing</u>: The organizational informatization of intra-organizational and inter-organizational systems provided R&D employees access to codified knowledge in Neptune's knowledge base and enhanced interactions among individuals for knowledge transfer and sharing. It created a collaborative workplace, provided interconnected networks and systems for enhancing interactions for knowledge access and sharing externally across geographical

regions, and value network partners (e.g., suppliers, customers). These technologies provided a window into the engine room of the innovation, where new innovative ideas may emerge.

Through the interconnected networks with external firms, these new employees in the R&D department discovered some innovation opportunities associated with external knowledge. This triggered an open search culture among R&D employees, a trend that was also encouraged by the R&D director in Neptune. For any innovation project, R&D employees first seek to find out if an external source already had a solution. Neptune also created a secure IT platform that allowed R&D employees to share technology briefs with its suppliers.

> *"If we are trying to find ways to improve our current technology or product, one of our suppliers may well have the solution. Since the creation of our supplier network system, we have had some innovation projects that are jointly staffed with Neptune and suppliers' researchers. In some cases, suppliers' researchers came to work in our labs, and in others, we worked in theirs."*

Decision making and internal assimilation: Similar to Pluto, we also learnt from our informants that during the open search process, R&D employees were given more decision making power for selecting external knowledge. But unlike Pluto, Neptune has a R&D department with approximately 60 R&D professionals. To disseminate externally acquired knowledge, they relied more on regular face-to-face meetings and discussions. Meanwhile, ITs, like groupware systems were also instrumental in cultivating social interactions and connectedness among R&D employees. Electronic message software helped with communication and coordination.

Episode 3: Differentiated Open Search

Through the collaborative innovations with external partners, Neptune had accelerated innovation processes and improved products. However, in the meantime, they realized that there were significant overlaps in sourcing outcomes in their R&D employees' open search and their sourcing also tend to only focused on the current innovation projects. To achieve better innovation outcomes, it required early identification of innovative ideas and technological trends for the entire R&D department. Thus, to overcome these handicaps and to attain greater benefits through external knowledge, a specialized sourcing unit that focused on open sourcing and accumulating external knowledge to support the innovation development of Neptune was formed.

External sourcing: The major tasks of this sourcing unit were the same as Pluto's. But unlike Pluto, the employees in the sourcing unit did not have PhD degrees. They were assigned to the sourcing unit because they were good at using ITs compared to other R&D employees. Their sourcing activities were done mainly through the Internet and the sourced external knowledge was stored in custom-made knowledge management systems.

Decision making and internal assimilation: After a new idea was identified by the employees in the sourcing unit, the knowledge was assimilated throughout the R&D department. R&D managers were the key decision makers of selecting the sourced external knowledge. To disseminate the sourced external knowledge, the communication between the sourcing unit and R&D unit did not take a top-down knowledge assimilation path. In contrast, the two units directly communicated. As suggested by our informants, the sourcing employees were treated as just other R&D employees with different work.

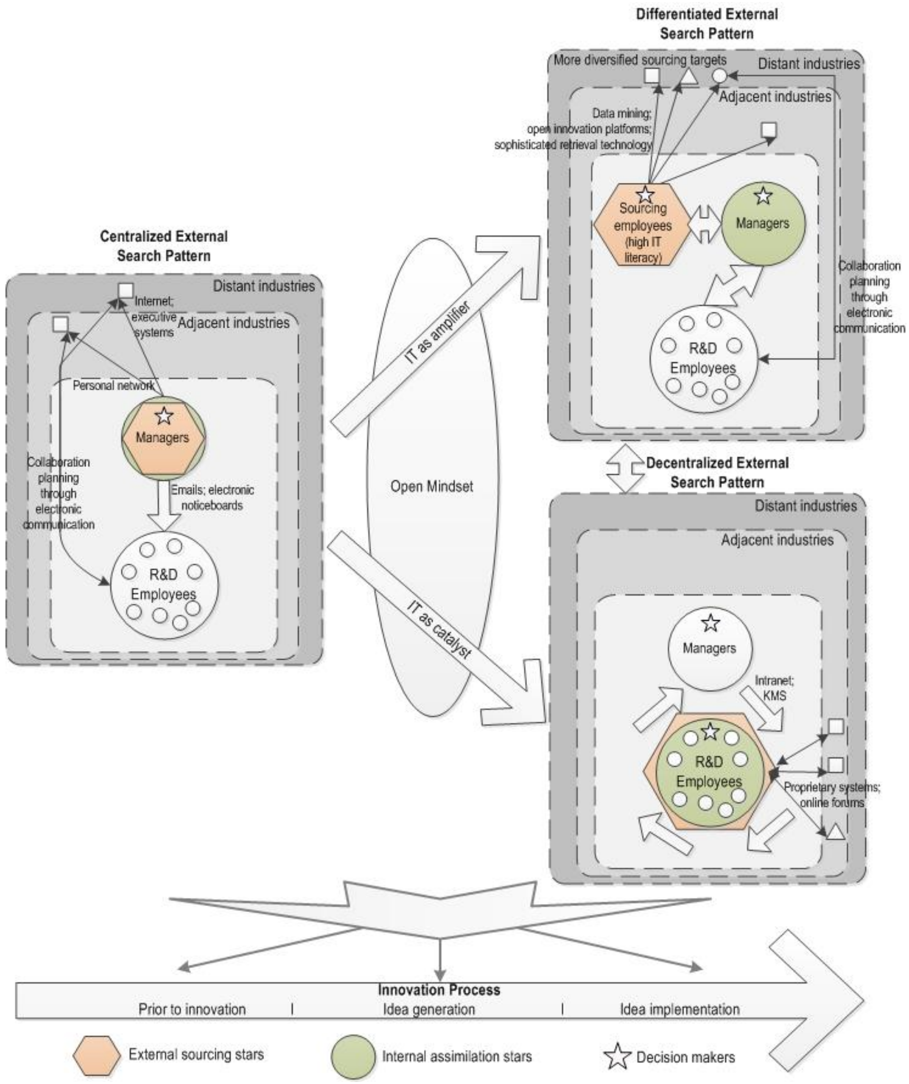

Figure 2.1 Evolution of Three Emerging Open Search Patterns

2.2.3 Discussion of Stage 1 Case Analysis

Changing Work of Key Stakeholders

Three new work patterns in open search and their evolution in two firms are depicted in Figure 2.1. As evident in two cases, the search work became more complex and dynamic with the inclusion of more and different boundary spanners and broadened search domains compared to the work identified in the literature (see Figure 1.1). First, instead of occurring only at the idea generation stage of innovation process, open search could occur along the open innovation process due to different open search objectives. Second, not only managers, but R&D employees took roles of boundary spanners. Specifically, in centralized open search pattern, managers designated part of the internal assimilation work to R&D employees. Compared to the external search patterns in prior literature that oral communication is the only way to communicate with external partners, with communication ITs, R&D employees can work with distributed external partners together on collaborative innovation plan. In differentiated open search pattern, external sourcing work supported by advanced ITs is assigned to employees in the sourcing unit. Managers took a new coordinating role between the employees in the sourcing unit and R&D employees. Managers and employees in the sourcing unit decide the selection of the sourced external knowledge together. In the decentralized open search pattern, the roles and work nature of R&D employees changed from being executor of the sourced external knowledge and conducting routine R&D work to being empowered to have work of external sourcing, decision making and internal assimilation of the sourced external knowledge. They also have more decision making power and autonomy on external sourcing work.

Table 2.2 External Search Work of Key Stakeholders

Work Pattern	**R&D/Senior Managers**	**Employees in Sourcing Unit**	**R&D Employees**
Conventional external search pattern*	External sourcing; decision making; internal assimilation	N.A.	N.A.
Evolved external search pattern*	Decision making; internal assimilation;	External sourcing	N.A.
Centralized open search[#]	External sourcing; decision making; internal assimilation	N.A.	Internal assimilation (work with external partners on collaborative innovation plan)

Differentiated open search#	Decision making (participative); internal assimilation	Decision making (participative); external sourcing	Internal assimilation (work with external partners)
Decentralized open search#	Decision making (participative)	N.A.	External sourcing; decision making (participative); internal assimilation
* Summarized from the literature; # Summarized from the case			

Role of ITs

Advances in ITs induced the evolution of open search pattern in two case firms, their impacts were different. In Pluto, ITs (e.g., data mining tools, data analytics, and open innovation platforms) served as the amplifier to enhance the speed and intensity of external sourcing and selection capabilities. When IT became more powerful, managers have limited ability and time to employ them, which required the IT and technological experts in sourcing, and led to the differentiated open search pattern. In contrast, for Neptune, intra- and inter-firm ITs (e.g., enterprise resources planning systems, supply chain management systems) served as the catalyst to accelerate knowledge access and sharing among R&D employees with value network partners (e.g., suppliers, customers). It stimulated R&D employees to discover innovation opportunities in the interconnected networks and resulted in the new decentralized open search pattern. IT indeed induced the work pattern change of open search in firms.

Research Gaps

Our two case firms are both outstanding in their own industry and leading in open innovation. They have resources to manage three open search patterns. While three patterns of open search were observed in both firms, they took different trajectories of open search pattern change. Besides, there are some slight differences in terms of patterns between the two firms, including how ITs are used, knowledge assimilation methods, and characteristics of sourcing employees. It suggests that there is no one size fits all solution for open search. A more systematic method to understand them is still missing. We do not know how to choose a suitable pattern for an open search in conditions of different open search objectives, for innovation project with different characteristics, and during different phases along the innovation process. Considering the uncertainty of external knowledge, the importance of time to market for an innovation project, open search outcomes with a lot of time input and less desirable output may lead to the failure of the innovation project. Therefore, we need to have a closer examination of the impacts of each pattern and provide guidance on how to allocate resources to make wise selection of these three open search patterns. It is imperative to analyze each pattern individually to differentiate their impacts on open search outcomes and their relationships for appropriate arrangement in an innovation project. It is still unsure how a firm can efficiently conduct open search for different conditions. To answer these remaining questions, it led to the stage 2.

To analyze each pattern, we focus on its efficiency as open search outcome. By "open search efficiency," we mean that these firms achieve adequate or qualified technology or partner expending less time and effort that what might be expended to achieve similar outcomes in both the external sourcing and internal assimilation phase. Specifically, we have three components of open search efficiency, which are sourcing efficiency, assimilation efficiency and innovation impact. Sourcing efficiency refers to the extent to which time, effort and cost is well used for the identification of desirable external technology or partner. Assimilation efficiency is defined as the extent to which time, effort and cost is well used for the assimilation of knowledge about external technology or partner among a given R&D employees who need to implement it to innovation project. To assimilate the sourced external technology, the R&D employees need to recognize the value of it and absorb it. To assimilate the sourced external partner, the R&D employees also need to recognize the value of it and work out a specific collaborative innovation plan to collaborate with the target partner on utilizing technologies from two parties. Open search impact refers to the impact of the identified technology or partner on the organizational innovation, such as complementary knowledge to the organizational internal knowledge, innovativeness and newness of external knowledge, as well as credibility, legitimacy, industrial recognition and even market resources obtained through the collaborative innovation relationship.

2.3 Stage 2 – Exploring the Effectiveness of Open Search

2.3.1 Theoretical Foundation of Open Search Pattern

The work arrangement of the three open search patterns can be traced to three schools of management thought: upper echelons theory and the mechanistic versus organic organization design structure. These serve as the foundation to guide our investigation of the search efficiency in this stage.

In the centralized open search pattern, managers take full control of the search process. This is in line with upper echelons theory, which suggests that the firm is a reflection of its management team (Hambrick 2007; Hambrick and Mason 1984). The managers' experiences and values greatly influence their interpretations and, these in turn affect their choices. Consistent with this perspective, external search is originally viewed as an informal, unstructured activity with executive managers acquiring information in the course of their daily activities (e.g., Aguilar 1967). Additionally, managers' social capital with other firms (e.g., suppliers, buyers, and competitors), political leaders and civil servants, and community leaders is critical to enhancing organizational performance (Acquaah 2007).

Differentiated and decentralized open search patterns are related to the ongoing debate on designing mechanistic or organic organizational structure (Burns and Stalker 1961). Proponents of *mechanistic organizational form* argue that the bureaucratic firm, with clear-cut division of activities, and assignment of roles, is technically superior to all other forms of firm (Weber 1947). Functional specialization reduces work ambiguity, enables individual focus, learning, and decision making, decrease the cost of coordination, and increase efficiency (Kang et al. 2007). Therefore, employees can concentrate on the execution of specified and narrowly defined tasks to accumulate task-related knowledge, and enhance information-processing capabilities (Burns and Stalker 1961).

In contrast, *organic organizational form*, characterized by a lack of formally defined tasks argues that firms with loosely coupled networks of workers, can better adapt to dynamic environments (Burns and Stalker 1961). An organic firm is a fluid and flexible network of multi-talented individuals who perform a variety of tasks. It takes into consideration the ideas of the employees, opening the doors to teamwork among employees, instead of competition or a feeling of powerlessness. This work arrangement is thought to provide incentive to employees to perform to the best of their abilities.

2.3.2 Data Collection

We used the three schools of thoughts on work arrangement to guide our selection of additional firms from a list of high-tech enterprises provided by China Science and Technology Commission to explore the effects of different search patterns on open search efficiency. After paying site visits and calling on the senior management of more than 20 firms, we settled on 7 firms that agreed to participate, satisfied our theoretical sampling criteria and covered a good variety in terms of size and industries (see Table 2.3). The chosen firms had active open search practice so that the researchers could have rich data for analysis and had high within-firm (at the open search level) and across-firm variation. Within-firm variation is especially striking in that the same firm used different strategic actions with varied outcomes and is useful for our aim of building accurate, parsimonious, and generalizable theory.

The data collection process and analysis method were similar to that used in stage 1. In each firm, we first interviewed the manager(s) in charge of the R&D area. This interview focused on the firm's open innovation background including its competitive position, innovation strategies, and an open-ended chronology of its innovation history. To further understand the efficiency of open search work, we conducted interviews with key stakeholders for recently completed open search work with emphases on objectives of open search, pattern of search, interactions with potential technologies/partners, and open search outcomes This practice reduces recall bias and enhances accuracy (Batt 2002). In total, 21 open innovation projects were identified with 9, 7 and 5 employing centralized pattern, differentiated pattern and decentralized pattern respectively.

Table 2.3 Descriptions of Interviewed Firms in Stage 2

Firm*	**Business Description**	**Number of Employees**	**Number of Interviews**	**Interviewees' Position**
Mercury	A heat exchanger manufacturing firm founded in 2006 in China.	158	4	Chief executive officer, chief technical officer, R&D employee
Venus	A Chinese IT-cloud computing solution firm established in 2011.	50	4	Chief executive officer, technology manager, R&D employee
Earth	A Chinese leading digital media firm. It provides content production and operation technologies and services in the field of digital media.	1250	6	Executive vice president, technology manger, R&D employee
Mars	The largest integrated IT services provider in China. It focuses on providing customers	14000	7	Technical director, technology manager, R&D employee

	with sophisticated and applicable IT solutions, driving technological innovations for work and life and enhancing the digitalization process in China.			
Jupiter	A railway electrification system manufacturer in China. Its domestic market share is over 30%.	750	5	Chief technical officer, senior technology manager, R&D employee
Saturn	A multinational firm based in Denmark. It is the world's largest pump manufacturer.	800 (China branch)	5	Chief technical officer, senior technology manager, R&D employee
Uranus	One of the largest tobacco firms in China. It is a Chinese-government owned enterprise.	5800	7	Chief financial officer, senior technology manager, R&D director, R&D employee
Neptune **	The largest and leading solar energy firm in China. Its products range from solar water heaters, solar collectors to solar lights and PV lighting products.	4000	8	Chief executive officer, senior technology manager, R&D employee
Pluto**	A global top American multinational consumer goods firm. Its products include pet foods, cleaning agents and personal care products.	7000 (China branch)	9	Senior technology manager, R&D director, R&D employee
* To protect the confidentiality of participants' data, all firm names have been replaced with pseudonyms. ** Firms had been studied in Stage 1.				

2.3.3 Centralized Open Search

We found the *centralized open search pattern* was employed by all 9 firms. Consistent with upper echelons theory, we found the objective of managers' open search involvement is to meet the firm's long-term innovation goals. Managers look for potential partners to initiate collaborative innovation relationships that were beneficial to the firm. Without specific innovation plan, managers do not have concrete evaluation criteria of external partner, hence, bringing uncertainty to the innovation project.

Sourcing Efficiency

Among the identified open innovation projects by our interviewees, 8 out of 9 centralized open search patterns were completed with high efficiency. Managers usually approached potential partners whom they knew (i.e., direct ties) or to whom they were introduced by mutual acquaintances (i.e., indirect ties). They may also interact with managers from other firms in conferences and social events to explore collaborative innovation opportunities. Although it took some time to reach mutual collaborative intentions, the sourcing efficiency is relatively high, especially when the managers possessed direct or indirect ties to the targeted partners.

Open Search Impact

The collaborative relationships brought not only technological resources benefits, but also allowed the focal firm to benefit from its partner's reputation and market resources. For instance, the senior technology manager of Saturn expressed that "*we are relatively new to the Chinese market and has a higher product price than Chinese native brands. Collaborating with the famous Chinese local firm provided us an opportunity to increase our brand awareness in Chinese market*." Through collaboration, firms were either able to create new market segments for their mutual product, or as one partner gained access to a new market, the other had the opportunity to become a value-added supplier. Similarly, Venus is a start-up with ongoing collaborative innovation relationships with several famous research institutions. Its CEO stated that:

> *"Working with experienced scientists and engineers from large research institutions gave us credibility and legitimacy for our products and industrial recognition of our firm, which is what we wanted through open innovation".*

However, this kind of open search impact has potential risk when skills are not compatible on both sides. The unpleasant open innovation project of IT firm Mars is an example. Its technical director illustrated one unsuccessful open innovation project with one famous firm in the IT industry:

> *"We initially considered our collaboration as a potent combination, but we encountered technical conflicts in our development and engineers from two firms took a long time to solve these problems. The project has been significantly delayed."*

Assimilation Efficiency

While centralized open search pattern resulted in efficient sourcing for satisfactory external partners, they posed significant challenge in its knowledge assimilation within the firm. Only 2 out of 9 case firms had efficient knowledge assimilation internally. As observed in stage 1, top-down communication from managers to R&D employees was followed for knowledge assimilation in this pattern. Typically, when the collaborative innovation relationship initiated by managers was formed, the specific innovation project objective and specific innovation technology were yet to be decided. R&D employees often felt uncertain about the external partner and were often not sure what would be the new product and what technology would be used. Extra time and effort were needed by R&D employees to work out a specific innovation project plan together with the partner. As suggested by one of R&D employee of Saturn, *"We got the collaboration decision from the higher level of management. They all have great expectations for this collaboration. But we were uncertain about the partner and our collaboration. It was much more challenging to work out an innovation plan with our partner compared to our previous work."*

Thus, the assimilation efficiency was not high. For the only 2 cases with relatively efficient assimilation, we learnt from the interviewees that incentives were used to encourage R&D employees to be committed to the collaborative innovation project. They also instituted regular meetings to validate and monitor the innovation projects. This mitigated the negative effects of the top-down communication approach used in this centralized search pattern.

Proposition 1: *For centralized open search pattern, managers tend to source partners that are famous or well- established firms to benefit the focal firm with recognition, market resources, and technological resources.*

Proposition 2: *For centralized open search pattern, the sourcing efficiency is high but the assimilation efficiency is low.*

Role of IT

For the centralized open search pattern, IT facilitates the managers to obtain information about external resources and supports managers' inter-organizational relationship and personal network building. As mentioned by the chief technical officer of Mercury, *"I used to rely on newspapers and magazines to keep abreast of industry development and the movements of our competitors. Now with Internet and search engines, I can take the initiative to search for information, rather than passively receive information. And it is more efficient in finding what I want to know."* Our informants also indicated that potential partners could be tapped using electronic mails, video conferencing or chat applications. ITs facilitate interactions by enabling a variety of strong and loose ties among managers from different firms.

However, in the internal knowledge assimilation phase, relying too much on online communication could bring challenges to the firm. In the case of Pluto, communication ITs (i.e., emails, electronic noticeboards, and newsletters) were primarily used and combined with a few face-to-face meetings to disseminate in a top-down manner. These asynchronous, uni-directional communication ITs could not support rich discussions between managers and R&D employees. Hence, R&D employees were not enthused and committed to the collaborative innovation project.

> ***Proposition 3:*** *For centralized open search pattern, informative ITs (e.g., search engines, electronic information sources) and communication ITs (e.g., electronic mails, chat applications) facilitate managers with information sourcing and personal network building during external knowledge sourcing.*

> ***Proposition 4:*** *For centralized open search pattern, communication ITs (e.g., emails, electronic noticeboards) facilitate internal knowledge assimilation but over-reliance on communication ITs decreases assimilation efficiency.*

2.3.4 Differentiated Open Search

From our case firms of Earth, Mars, Jupiter, Saturn, Neptune, and Pluto, we observed *differentiated open search* pattern in play. As indicated by the mechanistic organizational form view that highlights the functional specification in task allocation, a group of specialized employees were assigned to the sourcing unit to take responsibility of sourcing external knowledge in these firms.

Sourcing Efficiency

As we learnt from our informants, 5 out of 7 open search projects using differentiated open search pattern were considered to have a high level of time and effort to attain desirable outcomes. As employees in the sourcing unit were specialized and concentrated on tasks of external sourcing, they tend to adopt a systematic approach to sourcing by using multiple search channels and searching widely to identify the best solution, technology or collaborator. Hence, it took employees in the sourcing unit a long time and great effort to complete sourcing tasks, resulting in relatively low sourcing efficiency. For example, as an employee in the sourcing unit in Pluto described: *"For the project of a deodorization technology, we evaluated more than ten firms and the whole process took more than two years."* We also observed the same in other case firms. For instance, Mars used innovation idea competition to identify a large pool of potential technologies to select a few suitable ones. It expended a great deal of efforts in identifying, collating and evaluating and it took nearly a year.

Open Search Impact

We gathered from our informants that despite the low efficiency in sourcing, the sourced technology was highly satisfactory and beneficial. Employees in the sourcing unit looked at areas that are usually ignored by the managers and R&D employees. It included some start-ups, small and medium enterprises and even pioneering individual innovators. For example, as a large Chinese leading digital media firm, Earth had initiated open innovation projects with several innovative start-ups. Neptune once identified and sourced technology from an individual innovator in Australia. As suggested by the technology director of Neptune, *"our sourcing unit once found a advanced heat storage technology in Australia. We used it in one of our new products, which was absolutely new to the Chinese market"*. Moreover, employees in the sourcing unit were able to target technology that was located in firms from unfamiliar domains. For instance, Jupiter in the railway electric industry sourced technology from an automobile firm and developed a new, revolutionary product for the railway electric industry. The external knowledge, sourced from a wide range of and distant unfamiliar domains, conferred on the focal firm tremendous ability to develop new and radical products, not only from the firm's perspective but also the market's perspective. Meanwhile, innovativeness of external knowledge sourced in this pattern also brought uncertainty to the firm. As mentioned by the technology director in Pluto,

> *"Since we look for latest technology located anywhere, sometimes we cannot not fully understand with it. It took risks to be innovative."*

Assimilation Efficiency

After the employees in the sourcing unit had identified the external knowledge, they need to disseminate the acquired knowledge to the R&D employees. However, for 4 out of 7 open search cases, the internal knowledge assimilation efficiency was not high. According to our informants, this was due to the communication and technology gap between employees in the sourcing unit and the R&D employees. From the two cases of Pluto and Neptune, we identified two different assimilation methods. While Pluto used the manager-to-manager channel to connect the sourcing unit's employees and the R&D employees, Neptune adopted a horizontal communication method with employees in the sourcing unit and R&D employees connecting directly. Consolidating the evidence from other firms, we found that using managers as coordinators was useful in reducing conflicts. However, this approach has limitations: here is a tendency to be more structurally rigid and less flexible in operations (Rogers, 2003) as suggested by the mechanistic view of organization design. Interviewees revealed that there was a communication gap between the sourcing unit and the R&D unit in terms of search needs and results, more so if the firm was operating in a turbulent environment. For example, the senior technology manager of Jupiter mentioned:

> *"Sometimes while we were still sourcing external solutions for the R&D department for their innovation projects, we were shocked to learn that the R&D department had changed their innovation objectives and needs."*

Challenges in knowledge assimilation were also caused by the relatively innovativeness and distant characteristics of the external knowledge identified by employees in the sourcing unit. To successfully understand, interpret and realize the benefits of a new technology from an outside source, it needs a high level of expertise, or "absorptive capacity" in that area (Cohen and Levinthal 1990). As noted by an employee in the sourcing unit of Saturn,

> *"For cutting-edge technologies that we sourced, we need to demonstrate the value to the R&D department. The technological expertise barrier was a challenge because these technologies tend to be new to the firm. The situation was even more challenging when the external sources were from less known firms. Unlike famous firms and research institutions, technology from start-ups or individual innovators are not obviously convincing by their names."*

Proposition 5: *For the differentiated open search pattern, employees in the sourcing unit tend to systematically source external knowledge, technology or partner from a wider range - distant technological areas, start-ups, SMEs and pioneering individuals – which in turn benefits the focal firm with innovativeness.*

Proposition 6: *For the differentiated open search pattern, the sourcing efficiency is low and the assimilation efficiency is low.*

Role of IT

We learnt from our informants that ITs supported and enhanced the sourcing unit's external knowledge sourcing capability by enhancing the speed, intensity, and directionality of knowledge identification and selection. Besides the ITs identified in Stage 1, the intelligent mechanisms built into search and retrieval technologies, together with the sophisticated data structuring, indexing, and tagging techniques, helped navigate the knowledge acquisition process in the right direction quickly. The intelligent data-mining tools included automated search mechanisms to find useful knowledge in public databases, publication and patent analyses as well as trending curves.

For internal knowledge assimilation, we also identified the facilitating roles of ITs in our case firms. Since some acquired knowledge will only useful in the future, organizing and storing them effectively were important. IT supported the sourcing unit to organize and store the acquired knowledge properly to facilitate future retrieval and usage. For instance, informants mentioned the use of organizational memory systems, multi-dimensional databases, and data warehouses to store various forms of data, information, and knowledge. ITs also bridged the gap between the sourcing unit and the R&D department by reducing the coordination and communication costs. For example, in some case firms, a visualization suite was used to test representations of product designs; a 3D computer-aided design (CAD) system which can simulate and model prototypes helped build understanding between employees in the sourcing unit and the R&D employees. According to a senior engineer of Compnay Jupiter,

> *"We have a better idea of R&D unit's requirements with the illustration of a CAD design of the new product, even when their requirements are changing quickly. The CAD drawing can be altered accordingly and be demonstrated to us to facilitate our sourcing task."*

> ***Proposition 7:*** *For differentiated open search pattern, scouting ITs (i.e., data mining tools, data analytics and open innovation platforms) facilitate external knowledge sourcing.*

> ***Proposition 8:*** *For differentiated open search pattern, storage ITs (i.e., multi-media (multi-dimensional) databases, knowledge management systems) and*

visualization ITs (i.e., CAD systems) facilitate internal knowledge assimilation by bridging the gaps between sourcing employees and other R&D employees.

2.3.5 Decentralized Open Search

We observed the *decentralized open search* pattern in our case firms of Jupiter, Uranus, Neptune, and Pluto. In these firms, the R&D employees also engaged in the open search activities besides their traditional R&D work. This work pattern is consistent with the organic organizational form (Burns and Stalker 1961), which emphasizes role flexibility and lack of formally defined tasks.

Sourcing Efficiency

All of the 5 open search projects by R&D employees were completed with high efficiency in our case firms. As suggested by our interviewees, the objective of open search in this pattern was to find solution for more specific needs or specific problems during the idea generation and implementation stages in the innovation process. Considering that the R&D employees, as implementer of innovation projects, knew the problem well and the technology or partner required, time and effort was not required of them to communicate the open search request with different units. As the R&D employees were not specialists of external sourcing, they usually did not perform systematic or extensive sourcing; rather they often sourced for a practical and feasible solution within familiar domains in limited range. Hence, it took less time and effort to identify the desirable technology or collaborator, resulting in high sourcing efficiency. As expressed proudly by a project manager of the Uranus,

"For one particular innovation problem, our R&D employees used only one week to find a solution."

Open Search Impact

Our interviewees illustrated that decentralized open search pattern bring complementary knowledge to the organizational internal knowledge with speed and flexibility, hence, accelerated time to market of the new product. As expressed by a project manager of the Jupiter,

> *"When we were developing a new product, we found our old cooling technology did not meet the requirement. One of our R&D employee found a firm with relevant technology from directory of the Railway Industrial Association, which quickly solved our difficulty."*

Assimilation Efficiency

As we learnt from our interviewees, all of the 5 open search projects using decentralized open search pattern had very high assimilation efficiency. The efficient internal assimilation depended on more frequent and better-quality knowledge sharing among the R&D employees. As suggested by our informants, horizontal communication, e.g., some informal interaction and connectedness mechanisms among R&D employees, are effective in knowledge assimilating. For their open search projects, R&D employees were aware of the potential value of the knowledge they come across, and they could successfully passed it onto those who can make the best use of it. The R&D department head of the Uranus said,

> *"We often have chats in the hallway. Our offices have been designed to be "open" and facilitate instant interactions. Office cubicles are made of glass so that everyone can see and know what everyone else is doing. The office design forces our employees to communicate with each other about the various issues. We also organize brainstorming sessions from time to time to provide opportunities for employees to share their innovation ideas."*

> ***Proposition 9:*** *For decentralized open search pattern, the R&D employees tend to source practical and feasible solutions within familiar domains in limited range for specific innovation needs or problems that they encounter during innovation projects. This search pattern benefits the focal firm by adding complementary knowledge to the organizational internal knowledge.*

Proposition 10: *For decentralized open search pattern, the sourcing efficiency and the assimilation efficiency are both high.*

Role of IT

ITs provided employees with interconnected networks and systems to enhance interactions, gain knowledge access and share knowledge both internally and externally. For instance, Mars used electronic networks of alliances and collaborators to support and cultivate inter-firm knowledge synergies. Our case firms also used ITs to capture knowledge about customers, business partners, inter-firm operational processes and other significant sources of organizational intelligence. For instance, the supply chain management system and the customer relationship management system facilitated information flows across geographical regions and value network partners (e.g., suppliers, customers). RSS technologies also helped employees synthesize and share information from multiple sources while wikis and blogs opened up new opportunities to integrate knowledge and ideas coherently, accelerating knowledge discovery and innovation.

We also learnt from our interviewees that internal e-community of practice, Web conferencing, and groupware systems were instrumental in cultivating social interactions and connectedness among R&D employees. Intranets, message boards, electronic message software, and chat rooms helped with communication and coordination. Enterprise resource planning and knowledge management systems helped build an internal expertise map and enhanced the firm's ability to accomplish internal assimilation.

Proposition 11: *For decentralized open search pattern, external knowledge sharing ITs (i.e., supply chain management systems, customer relationship management, electronic networks of alliances and collaborators, external e-communities of practice) facilitate external sourcing.*

Proposition 12: *For decentralized open search pattern, internal knowledge sharing ITs (i.e., intranet, enterprise resource planning, knowledge management systems, internal e-communities of practice) facilitate internal assimilation.*

2.4 A Cross-Case Analysis of Three Open Search Patterns

While each organizational design perspective adds to our understanding of the open search process, it is also limiting in the explanations it can provide as illustrated by our cases. We argue that the use of alternative perspectives can help provide a better explanation by supplementing a given perspective's limits. In this section, we propose a theory of open search that contributes to a richer understanding of relationships between the three open search patterns and desirable search outcomes. As shown in Figure 2.1, these relationships are explained under different levels of uncertainty, which captures the unique trait of open innovation.

The development of innovations can be seen as a process composed of two phases: 1) idea generation and 2) idea implementation (Melville et al. 2004; Tushman 1977). Since firms constantly conduct open search for collaborative innovation opportunities and that the sourced external technology or partner may form the basis of the innovation project, we also consider the phase of "prior to innovation" before the idea generation and idea implementation phase. Considering the nature of open innovation with the use of purposive inflows and outflows of knowledge during the entire innovation process (Chesbrough et al. 2006), each phase is characterized by different objectives of open search as well as by different uncertainty concerns of knowledge flows. Therefore, in addition to taking into account the three open search patterns, our theory (illustrated in Figure 2.1) includes uncertainty and the temporal dimension. A core concept of the theory is that only one or two open search patterns occur at each phase during innovation process due to the nature of the open search objectives. At each phase, if a high degree of uncertainty is involved in the innovation project, some search pattern may become inefficient (shown as the dotted box in Figure 2.2).

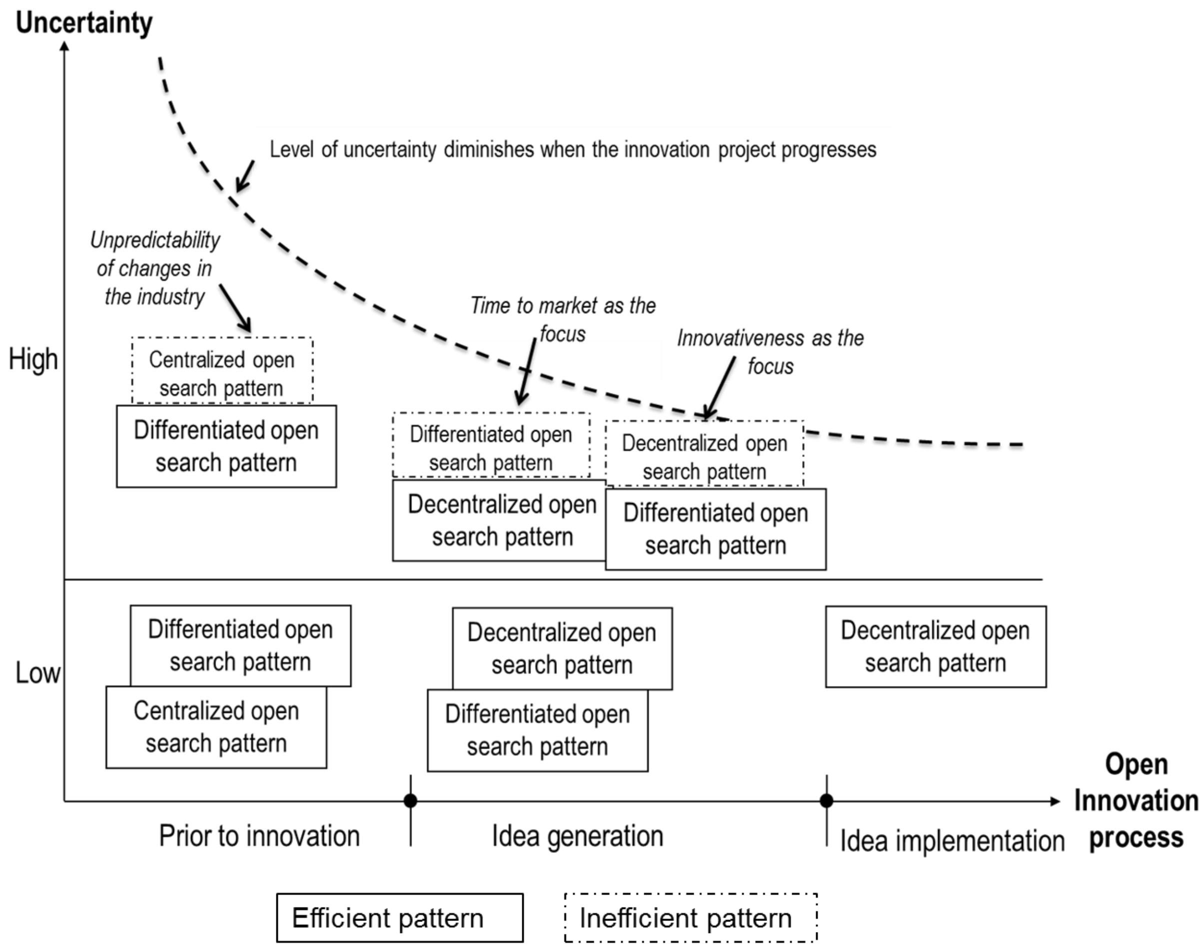

Figure 2.2 A Theory of Open Search along Open Innovation Process

Prior to Innovation

The innovation process begins with the first phase "prior to innovation". Open search in this phase is characterized as proactively exploring collaborative innovation opportunities without a specific innovation plan. Derived from the cases, our theory posits that centralized and differentiated open search patterns take a prominent position in this phase (these two patterns appear in the first phase in Figure 2.2). Managers constantly conduct open search of the external environment when they perceive strategic needs to explore other technological areas. In addition, a major work for sourcing employees is also to proactively search for external innovative knowledge. In contrast, decentralized open search is unlikely to be a prominent search pattern in this phase. This is because ordinary R&D employees tend to focus on their assigned innovation projects without a holistic view of the firm's overall strategies.

In this first phase, without any specific collaboration direction, the evaluation of an external partner may not be very concrete. Furthermore, given that a time-lag is likely to occur between the search of external collaborators and commencement of the collaboration project, uncertainties can occur as the focal firm or its external collaborator may go through changes in terms of firm's strategy, products or internal structure. For instance, as mentioned in our Phase 2 case analysis, the open innovation project in Mars, which belongs to the IT industry, was delayed due to technological resource conflicts in the idea implementation phase. IT industry is a volatile industry with fast changing user demands and competitor movements. Hence, the uncertainty of searching for external knowledge prior to innovation becomes high. When the uncertainty is high, the limitation of centralized open search pattern (i.e., managers may evaluate the external partner and its knowledge at the high level without sufficient details) can be magnified. As shown in Figure 2.2, our theory suggests that the differentiated open search pattern is more efficient than centralized open search pattern under condition of high uncertainty in evaluating collaboration partners in this stage. With advanced ITs, employees in the sourcing unit are able to collect and analyze a large amount of information. Also, in this pattern, managers and R&D employees need to participate in the decision making and internal assimilation process to evaluate the external partner. Hence, the potential risk of conflicts can be further weakened.

Idea Generation

During the idea generation phase, the innovation project has commenced and external sourcing stars look for external knowledge to supplement the knowledge gaps or enhance the innovativeness of the project. Our evidence suggests that in general, differentiated and decentralized open search patterns take a prominent position in this phase (these two patterns appear in the second phase in Figure 2.2). The uncertainty in this phase is likely to be associated with the direction of the innovation project such as the requirement of making the new product more innovative and the speed to market. We posit that differentiated open search pattern outperforms decentralized open search pattern when innovativeness is emphasized while decentralized open search pattern is more efficient when speed to market is needed. On one hand, an organic structure has been identified as a suitable organizational design for innovation in a dynamic changing environment(Wade and Hulland 2004). A low level of functional specialization leads to increased flexibility in open search (Zhang and Li 2010). It fosters rapid decision-making, horizontal interactions on diverse perspectives and a range of possible solutions to problems among R&D employees. Hence, decentralized open search pattern accelerates the speed to market. On the other hand, a mechanistic structure allows employees in the sourcing unit to concentrate on the execution of specified sourcing tasks and to accumulate sourcing task-related knowledge, and thus it enhances information-processing capabilities (Burns and Stalker 1961). With the supports of ITs, employees in the sourcing unit are able to perform systematic sourcing on a gigantic amount of information with greater reach into distant technological areas. Thus, cutting-edge innovative external knowledge for the innovation project is likely to be identified with differentiated open search pattern.

Idea Implementation

The idea implementation phase is characterized as more focused problem solving requiring deep understanding of the knowledge internally possessed for the innovation project. During this phase of innovation process, the innovation idea has already been generated and knowledge has already been accumulated on the innovation. Hence, the level of uncertainty is relatively low in this phase. In line with the case findings, our theory posits that decentralized open search may be the major open search pattern in this phase. Since R&D employees are the implementers of the innovation project, they know well about the innovation problem and the required solution or the technology to be used. The open search typically targets at short-term collaboration with limited outflow of internal knowledge such as technology licensing and technology consultation.

2.5 Limitations and Implications

2.5.1 Limitations

As a multiple-case study, we adopt the principles of "analytical generalizability" (Lee and Baskerville 2003; Phillips and Bagozzi 1986). Nonetheless, our study is not without its limitations. First, the data was collected in China, which is a developing country in economic transition. Inter-firm innovation collaborations are encouraged by the Chinese government. While we tried to reduce the selection bias by choosing some samples from multi-national firms, caution is required in generalizing our findings. Second, in the cross-case analysis, uncertainty was chosen as the key dimension to separate open search patterns. While the selection was based on the unique nature of open innovation, further research could employ other dimensions to discuss the combinations of open search patterns.

2.5.2 Theoretical Implications to the Search Literature

Notwithstanding the limitations, this study constitutes one of the first studies to build a deep understanding of the changing work of external search. First, we add to the literature by unveiling three IT-induced patterns of open search: centralized, differentiated, and decentralized. Comparing with conventional search patterns, these three patterns differ in terms of work arrangement, employment of IT applications, as well as search efficiency and impact. A middle-range theory is proposed to elucidate desirable patterns along the open innovation process, which provides a foundation to spur further research on the dynamics of search work, especially given the rise of "open" behaviors.

Second, this study contributes to the boundary spanner literature by proposing the multi-level roles of boundary spanners. Prior literature views boundary spanners as a small group of people (either senior managers or dedicated employees, not both) (Choudhury and Sampler 1997; Whelan et al. 2010). However, the advances of IT have impacted information flows in R&D, enabling employees at all levels to access external knowledge or technology with ease and speed. With such empowerment, every R&D employees can potentially be a boundary spanner. To facilitate desirable search outcomes, three roles of boundary spanners: external sourcing, decision making, and internal assimilation may or should no longer to be assigned to a single stakeholder.

Third, this study explicates the differentiated roles of IT in open search. On the one hand, IT is found to serve as an amplifier and a catalyst to induce different trajectories of open search evolution. On the other hand, we propose that IT mechanisms can be categorized into multiple groups: informative ITs, communication ITs, scouting ITs, visualization ITs and knowledge sharing ITs. While the specific mechanisms may not be exclusive to one open search pattern, this categorization is based on the utility of these mechanisms in different open search patterns in our cases and it can help foster the understanding of how these groups exhibit varied impacts on facilitating/inhibiting efficiency of open search.

2.5.3 Theoretical Implications to Work Arrangement Philosophies

This search adds to the evergreen theoretical debate on superior work arrangement. In organization theory research, scholars have long distinguished between work structures designed for flexibility and specialization. Duncan (1976) suggests that firms require both structures: organic to create innovations and mechanistic to implement and deploy them. But how can firms resolve the paradox by combining organic and mechanistic features? Prior research argues that mechanistic and organic structures are difficult to reconcile within a single firm (Ford and Ford 1994; Lawrence et al. 1967; Lewis 2000), and a firm should reject one structure in favor of another (Courtright et al. 1989; Sine et al. 2006). However, by focusing on the open search work, our study suggests these two organizational forms, together with the upper echelon theory of employing managers, can and should occur simultaneously. By treating open search as a black box, researchers and managers limit their ability to deal with it. By opening the black box of open search and focusing on uncertainty as a unique feature of open innovation, our proposed theory explicitly depicts the appropriate forms of work arrangement in supporting ambidextrous organizational designs for each phase of open innovation process.

2.5.4 Practical Implications

Despite a widespread belief that the work nature of external search is changing as a result of IT-induced open innovation, limited practical guidance is available to help firms' managers understand and manage the work changes. The findings of this study provide managers with the conceptual clarity to use open search patterns appropriately, and enable them to mindfully select appropriate work arrangement so as to achieve desirable open search outcomes.

First, firms' managers need to be aware that three open search patterns (i.e., centralized, differentiated and decentralized) can offer different impacts on open innovation projects. Hence, the selection of open search could be based on the desirable expectations of external knowledge. For instance, should the firm aim to acquire supplementary market resources or enhance its reputation by liaising with well-established firms, centralized open search pattern can be employed before commencing work on a specific innovation. If the objective is to explore innovative and distant technological areas, differentiated open search with systematic sourcing in a wide range can be considered for idea generation. If a firm wishes to achieve high flexibility and speed in solving problems during the middle stages of the innovation process, their R&D employees may find decentralized open search pattern to be a suitable mechanism to access external knowledge

Second, once an open search pattern is selected, a manager must allocate search tasks among key stakeholders. The findings of this study provide a clear roadmap for managers to decide 1) what tasks to be delegated to the subordinates and what to remain under their control; 2) how to allocate the delegated tasks (to separate sourcing unit or to ordinal R&D employee); 3) who to be the decision makers. For instance, if the differentiated open search pattern is chosen for exploring innovative knowledge, managers need to build clear boundaries for external sourcing, internal assimilation and decision makers. A dedicated group of employees need to be hired / selected to systematically conduct external sourcing work. Managers can then take a coordinating role between the employees in the sourcing unit and R&D employees to support the communication and assimilation of the sourced external knowledge. In this way, R&D employees can focus on internal innovation work.

Third, given the different roles of ITs in influencing the search efficiency, this research offers important insights for managers to make a wise investment on expensive IT applications. For instance, for firms keen on revolutionary or radical innovation, managers may consider investing in data mining techniques, data analytics, or open innovation portals to support differentiated open search. These IT applications significantly enhance information processing capability to reach a wide range of domains for innovative and new technology. For firms that want to cultivate collaborative innovation opportunities in peripheral networks with suppliers or customers, investment in intra-firm and inter-firm systems would be a beneficial choice. Enterprise resource planning systems and supplier chain management systems supporting an interconnected network both internally and externally provide firms with the flexibility and efficiency to reach and incorporate complementary external knowledge.

Fourth, managers should pay high attention on cultivating decentralized open search pattern, especially to support the implementation stage of an open innovation project. Through empowering regular R&D employees, decentralized open search pattern is found to provide them with better open search flexibility and efficiency compared to the other two open search patterns. To foster the emergence of this pattern, managers need to provide R&D employees with system-enabled external access. Indeed, with the increasing number of digital natives entering the workplace, more grass root employees are capable of utilizing advanced IT applications (Atuahene-Gima 2005). Furthermore, an open mindset needs to be encouraged within the firm so that R&D employees can switch from traditional self-sustaining R&D work style to be more open-minded toward solutions or technologies that are not developed internally.

CHAPTER 3.

STUDY 2: EXPLORING THE IMPACT OF OPENNESS ON OPEN INNOVATION PERFORMANCE

3.1 Introduction

The mobility of knowledge workers, the velocity of technological change and the globalization of markets have shifted the way that innovations are created in firms. While firms have been internally developing new technologies and transferring these to their own products and services, in what is known as *closed innovation*, there is an increasing trend of leveraging on external knowledge for innovation creation. This is termed *open innovation* - “the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively” (Chesbrough et al. 2006, p.1). With the proliferation of interconnectivity and interactivity through ITs, firms are now frequently engaging in open innovations with customers, suppliers, universities, research institutions and other sources of knowledge (Enkel et al. 2009). Such an emerging type of innovation can result in significant benefits to firms. Primarily, firms can access complementary knowledge from collaborative partners, which in turn encourages creativity and novel solutions, and results in the advent of new technologies or new market possibilities.

Several pioneering firms, such as Procter & Gamble, General Electric, IBM and Siemens, have derived benefits from pursuing open innovation strategies. For instance, through the “Connect and Development” program, Procter & Gamble collaborates with external innovators on more than 35 percent of its new products, and accordingly, its R&D productivity has increased by nearly 60 percent (Huston and Sakkab 2006b). Despite the promising benefits, many other adopting firms have experienced significant obstacles against profiting from external knowledge (Cassiman and Veugelers 2006; Huston and Sakkab 2006a). Since open innovation focuses on the importance of distributed external knowledge, a high degree of project openness in the search for external knowledge leads to an increase in cross-industry innovation potential. However, prior literature suggests that differences in partner characteristics and distances between knowledge domains may deter inter-firm knowledge transfer and learning (Lane and Lubatkin 1998; Mowery et al. 1998; Tsai 2001). Other potential problems may result from insufficient understanding of a partner's differing cultures or modes of that firm, or bureaucratic conflicts. Thus, firms encounter challenges in collaborating with external partners from different technological domains and with distinct organizational backgrounds (Laursen and Salter 2006; Lindegaard 2010).

In addition, open innovation largely relies on IT applications such as computer mediated communication, and environmental scanning tools, etc. (Chesbrough 2003). These IT tools can facilitate knowledge sharing and integration. Furthermore, they can enhance the interaction and communication between collaborative firms. Thus, IT usage in the open innovation process can probably diminish the influence of inter-firm distance. However, the facilitating role of IT usage in bridging the gap between collaborative partners has not been systemically examined in previous research.

Therefore, in this study, we aim to explore this issue and fill the research gap by drawing on the notion of organizational absorptive capacity and extant open innovation literature. We adopted a two-phased research approach. In the first phase, we adopted an exploratory qualitative multiple case study approach with the objectives of exploring the concept behind the degree of openness in an open innovation project; and the IT tools used during the open innovation project, as well as to verify whether the inter-firm distance identified in prior literature is a critical factor in an open innovation context. In the second phase, we adopted a quantitative survey to explore how these factors affect the performance of open innovation projects. Specifically, we are interested in exploring the interplay between a project's degree of openness (i.e., the *degree of openness in search*), various IT-enabled knowledge capabilities (i.e., *IT-enabled exploratory learning capability and IT-enabled exploitative capability*) and inter-firm distance (i.e., *resource distance and social distance*) on the innovating firm's open innovation performance.

This research adds a much-needed perspective on open innovation literature by unveiling various degrees of project openness and the differentiated roles of IT-enabled knowledge capabilities. It also extends the absorptive capacity literature by exploring its determinants in the open innovation context. Toward this end, organizational management can mindfully design and deploy open innovation strategies in future endeavors.

3.2 Literature Review

3.2.1 Degree of Openness

Although the concept of open innovation has attracted immense attention in the past decade, its definition remains ill-defined. The question of the degree of openness in open innovation has been addressed by many researchers (Dahlander and Gann 2010; Laursen and Salter 2006; van de Vrande et al. 2009).

The research on openness has increased and deepened in recent years. Literature review indicates that multiple methods have been used including interviews, case studies and large-scale surveys. Table 3.1 summarizes a set of empirical studies on open innovation with regard to context, sample, key findings and the overall focus of each study. This table, while not exhaustive, illustrates that the conceptualization of openness by different authors is diverse. Table 3.1

emphasizes that large-scale quantitative studies were, until recently, relatively rare. In fact Laursen and Salter (2006); and Van de Vrande et al. (2009) are recent noteworthy examples of large scale studies and that much of the research on different types of openness relies on case studies.

In addition, we investigated how different papers present different definitions of openness and how each was conceptualized in empirical investigations. Table 3.1 lists the different definitions of openness which are referred to in the literature. We found that while authors discussed openness, it is often unclear exactly what type of openness they were referring to.

Researchers of openness have long argued the benefits of an open approach. However, they have also realized that openness is not a binary classification of open versus closed (Chesbrough 2003). The idea behind openness therefore needs to be placed on a continuum, ranging from closed to open, covering varying degrees of openness. More generally scholars have recognized that some aspects of the innovation process are open while others may be closed (Chesbrough et al., 2006). If we accept that openness is a continuum, which is a non-controversial argument in the open innovation community, it follows that we can seek to advance a greater understanding of the benefits and costs of openness. Without considering the disadvantages, the literature is imbalanced and has not leveraged the full potential of openness (Foss, 2003). In this study, it is suggested that firms may vary in their degree of openness when searching for potential useful technology and potential collaborators. In addition, after forming collaborative relationships with their collaborators, they may differ in the way they collaborate with these collaborators.

Table 3.1 Summary of Empirical Studies on Openness

Source	Sample	Key Results	Context
Chesbrough and Crowther (2006)	12 firms in low-tech or mature industries	Open innovation practices common also in low-tech industries. Leveraging external research as complementary rather than as substitutes for internal R&D	Low-tech or mature industries
Christensen et al. (2005)	Current transformation of sound amplification from linear solid state technology to switched or digital technology within the consumer electronics system of innovation	Different use of open innovation practices is contingent upon the position in the innovation system and the stage of the technological regime	Consumer electronics
Fey and Birkinshaw (2005)	R&D activities of 107 large firms based in the UK and Sweden	Firms external search strategy (breadth and depth) is curvilinearly related to innovation performance	Firms with R&D activities
Henkel (2006)	268 developers working with embedded Linux	Firms selectively reveal some technologies to the public as they attach different values to each	Embedded Linux
West (2003)	Three case studies of Apple, IBM and Sun	Proprietary platform firms support open source technologies as part of their platform strategies by balancing the tension between appropriation and appropriability	Proprietary platform vendors
Lichtenthaler and Ernst (2009)	155 medium and large-sized firms in Germany, Austria and Switzerland	The strategy process and content characteristics jointly shape the performance of out-licensing projects	Multiple industries
Lichtenthaler and Ernst (2007)	154 medium-sized and large European firms	External technology commercialization is not fully leveraged, but has great potential if successfully implemented	Multiple industries

3.2.2 Inter-firm Distance

The inter-firm distance concept has attracted considerable attention in the literature dealing with inter-firm collaboration (e.g., Oerlemans et al. 2001; Sternberg 1999), mergers and acquisitions (Cassiman et al. 2005; Makri et al. 2010) , and international joint ventures (Lane et al. 2001).

Some studies consider the *resource distance* between partnering firms, which is defined as the degree of technical knowledge domain differences between the focal firm and its open innovation partners (Mowery et al. 1996; Nooteboom 2000; Nooteboom et al. 2007; Parkhe 1991; Sampson 2007). In the first instance, an increase in resource distance has a positive effect on learning by interaction. When firms with different knowledge backgrounds and perspectives interact, they stimulate and help each other to stretch their knowledge for the purpose of bridging and connecting diverse forms of knowledge. However, at a certain point resource distance becomes so large as to preclude the sufficient mutual understanding needed to utilize those opportunities ((Hamel 1991; Lane and Lubatkin 1998; Simonin 1999). Indeed, a certain degree of mutual understanding is needed for collaboration, and familiarity certainly breeds trust (Gulati 1995), which facilitates successful collaboration. However, too much familiarity may reduce the innovative impetus arising from collaboration. Thus, a moderate level of partner resource distance seems to be best for inter-firm knowledge transfer and firm knowledge creation. The challenge then is to find partners who are at a suitable resource distance to provide new knowledge, but not so distant as to preclude mutual understanding.

On the other hand, some studies emphasize the *social distance* between partnering firms, which is defined as the differences in the degree of firm culture, strategic direction, firm structure and management style between social actors participating in the collaboration (Filippi and Torre 2003; Lane and Lubatkin 1998; Parkhe 1991; Van Den Bosch et al. 1999). Firm culture, strategic direction, firm structure and management style decide the way of allocating tasks, responsibilities, and authority, and are strongly related to a firm's problem-solving and decision-making behaviors. They are a set of implicit and explicit routines that enable firms to be coordinated without having to define relevant behavior beforehand.

Regarding the relation between social distance and innovation performance, previous studies have suggested a negative relationship (Kale et al. 2002; Lane and Lubatkin 1998; Parkhe 1991). Inter-firm collaboration involves "socially contrived mechanisms for collective action, which are continually shaped and restructured by actions and symbolic interpretations of the parties involved" (Ring and Van de Ven 1994). Hence the social distance between partners reduces their ability to share knowledge. Furthermore, social distance among partners may lead to an inability on the part of the partners to develop a harmonious relationship and in turn negatively influence collaborative effectiveness (Sarkar et al. 2001). Thus, social distance between partnering firms can negatively affect the quality of interactions in a partnership and thus hinder the complex integration and transformation of disparate pools of tacit know-how into value creation (Simonin 1999).

Table 3.2 Summary of Studies on Inter-firm Distance						
Source	**Paper Type**	**Theoretical Framework**	**Level of Analysis**	**Independent Variable (Including Moderator)**	**Dependent Variable (Including Mediator)**	**Context**
Chung et al. (2000)	Empirical:	• Resource-based view Social structural argument	Dyad	• Resource complementarity • Status similarity • Social capital • Direct prior alliance experience • Reciprocity in exchanging alliance opportunities Indirect prior alliance experience	Likelihood of becoming alliance partners	Strategic alliance
De Jong and Freel (2010)	Empirical: Primary survey data of 316 firms (in 1245 collaborations)	• Absorptive capacity	Dyad	• Absorptive capacity (R&D expenditures, R&D intensity)	• Geographical proximity	R&D collaboration
Makri et al. (2010)	Empirical: Secondary patent data of 82 firms	• Resource-based view • Absorptive capacity	Dyad	• Knowledge relatedness • Science similarity • Science complementraity • Technology similarity • Technology complementarity	• Innovation outcomes	M&A

Oerlemans and Meeus (2005)	Empirical: Secondary patent data of 82 firms	• Resource-based view • Proximity-based argument	Dyad	• Innovation strategy similarity • R&D department • Network activity, or organizational proximity	Firm performance	R&D collaboration
Petruzzelli (2011)	Empirical: Primary survey data of 69 firms	• Organizational learning • Relational view	Dyad	• Technological relatedness (patent profile distance) • Prior ties • Geographical distance	Number of citations received by each university-firm joint patent	R&D collaboration (University-industry)
Raesfeld et al. (2012)	Empirical: Primary survey data of 169 projects	• Resource-based view	Project	• Value chain complementarity (diversity of value chain roles per project) • Technological diversity (the degree to which there is complete coverage of the eight main patent class per project)	• Application development • Commercial performance	R&D collaboration
Sampson (2007)	Empirical: Secondary data of 463R&D alliances	• Knowledge-based view	Dyad	• Technological distance • Alliance organizational form (Bilateral contract and equity joint venture)	• Postalliance patents	R&D alliance

Sarkar et al. (2001)	Empirical: Primary survey data of 561 firms	• Resource-based view • Relational view	Dyad	• Resource complementarity • Cultural compatibility • Operational compatibility	• Relational capital • Mutual trust • Reciprocal commitment • Bilateral information exchange • Performance • Project performance • Strategic performance	Strategic alliance
Wang and Zajac (2007)	Empirical: Secondary data of 584 firms	• Resource-based view • Knowledge-based view	Dyad	• Resource similarity • Resource complementarity • Combined relational capabilities of two firms • Partner-specific knowledge of two firms	• Likelihood of an alliance formation • Likelihood of an acquisition occurrence	Alliance or acquisition

3.3 Limitations of Current Research

Notwithstanding the broad interest in and a vast literature on openness, our understanding of the influence of openness on firm innovation performance remains relatively undeveloped. The current research has the following limitations.

First, the degree of openness for open innovation projects is not clearly defined and examined in previous literature. How does openness influence firms' ability to innovate and appropriate the benefits of innovation? These questions lie at the heart of recent research on innovation (e.g. Chesbrough, 2003; Helfat, 2006; Laursen and Salter, 2006). Their answers require a conceptual frame that defines and classifies different dimensions of openness. In spite of rising interest in using the openness construct, systematic studies of openness remain cumbersome because of conceptual ambiguity. This thesis is motivated by a desire to clarify the definition of "openness" as currently used in the literature on open innovation, and to re-conceptualize the idea for future research on the topic.

Second, in the open innovation context, firms are increasingly collaborating with geographically dispersed partners. IT tools are widely used during an open innovation project. These IT tools can facilitate knowledge sharing and integration. In addition, they can enhance the interaction and communication between collaborative firms. Thus, IT usage in the open innovation process has the probability of diminishing the influence of inter-firm distance. However, the facilitating role of IT usage in bridging the gap between collaborative partners has not been systemically examined in previous research.

We will address these limitations in the study by firstly exploring the open innovation phenomenon through a qualitative study. Then, based on the qualitative findings and literature review, we will develop a research model. Finally, the research model will be tested using a survey approach.

3.4 Research Methodology

To investigate the issues raised, we adopted a two-stage research approach. In the first stage, we conducted an exploratory qualitative multiple case study to explore the limitations of the extant research. In the second stage, we conducted a quantitative survey to further test the findings from our qualitative study. Such a two-stage approach focuses on different aspects of reality and therefore, a richer understanding of a research topic will be gained by combining several methods together in a single piece of research or research program. This position has been supported within the IS stream by a number of authors (Galliers 1991; Landry and Banville 1992; Lee 1991).

Stage 1. Qualitative Study

3.5 Qualitative Study Research Methodology

We chose a case research approach for our initial investigation, as it provides researchers with the opportunity to explore contemporary events in the case firms. The case study method is an appropriate approach for empirical inquiry when the phenomenon to be studied is complex and not easily separated from its organizational context (Pentland 1999). Thus, analysis of a small number of cases was deemed appropriate as such “revelatory cases” (Yin 1994) may provide the required rich insight. Following Eisenhardt (1989a), we used the case study to build theory in a grounded and inductive manner. Bearing this in mind, this study was concerned with initially achieving an increased understanding of the inter-firm distance issue in the open innovation context. Our case study focuses on the activities involved in the implementation and management of open innovation projects. The objectives of the qualitative study are:

- To verify the inter-firm distance concept in an open innovation context
- To explore the concept of the degree of openness in an open innovation project

- To identify the IT tools used and their functions in an open innovation project

3.5.1 Data Collection

Research access was negotiated and our research was conducted from October 2011 to February 2012, involving the conducting of a total of 42 interviews with the middle and top management of the case firms. To ensure that the data was aligned with our topic of interest, informants were not only invited to give an account of what they thought were the critical events, activities and decisions that unfolded during open innovation deployment, but they were encouraged to focus on the organizational change and capability building aspects as well. Each interview took an average of 60 minutes, was digitally recorded, and later transcribed for data analysis.

The interview questions were tailored to the role of the informant and were designed to be open-ended and exploratory in nature. Each question was both non-leading and non-passive, in order to maintain a critical balance between spontaneity and control over the interview (Walsham 1995). To allay any fear of speaking out freely due to the presence of a recorder, each informant was assured of their anonymity and the confidentiality of the data provided, especially when potentially sensitive information was sought (Myers and Newman 2007; Walsham 2006).

While the interviews formed our primary source of data (Walsham 2006), they were supplemented by newspaper articles, organizational documents, internal publications, and information from the corporate website. Notes from direct observation were also used to corroborate the data obtained. For example, the “Connect and Develop” strategy at Firm C elicited considerable attention in the popular press, and there were numerous reports and interviews available on the Internet. These added to the background knowledge of the research, and in combination with the interviews led to improved understanding of developments in the firm.

3.5.2 Case Selection Criteria

For the purpose of case selection, we identified two criteria. First, we considered that the case firms should engage in active open innovation practice and hence, the researchers would have rich data for analysis. Second, we considered that the case firms should have successfully implemented open innovation projects so that the findings derived can be recommended to other firms. Based on these two criteria, nine case firms were chosen (see, Table 3.3).

3.5.3 Firm Background

Table 3.3 Descriptions of Interviewed Firms

Firm*	Business Description	Number of Interviewees	Interviewees' Position	Number of Employees
Firm A	Solar energy	5	Executive vice president, senior technology manager, senior engineer	4000
Firm B	Water pump	4	Chief technical officer, senior technology manager, senior engineer	800
Firm C	Consumer products	5	Senior technology manager, senior engineer	7000
Firm D	Tobacco	7	Chief financial officer, senior technology manager, R&D director, Senior engineer	5800
Firm E	Integrated IT services	5	Technical director, technology manager, engineer	14000
Firm F	Cloud computing solutions	4	Assistant director, manager, engineer	500

Firm G	Database products	4	Manager, engineer	500
Firm H	Digital media	4	Executive vice president, technology manger, senior engineer	1250
Firm I	Copyright asset management service	4	Chief executive officer, technology manager	50
* To protect the confidentiality of participants' data, all firm names have been replaced with pseudonyms.				

3.6 Case Description

This section presents the open innovation process followed by all the interviewed firms. The whole process included two phases: 1) before open innovation project initiation: partner or technology searching; and 2) after open innovation project initiation: inter-firm collaboration. The case descriptions are presented chronologically in two phases. During each phase, we explored the concept of the degree of openness in an open innovation project and highlighted the inter-firm distance concepts that were mentioned by the interviewees. We also identified the IT usage during the open innovation process.

Phase 1: Before Open Innovation Project Initiation: Partner or Technology Searching

In Phase 1, when searching for and selecting a collaborative partner for an open innovation project, some case firms only searched for a potential partner or technology in existing familiar networks, while others openly and actively searched in public domains. Interviewees also confirmed that technical and market resource distance and overlapping knowledge between partners are important. In addition, the IT tools that they used during this phase were identified.

Degree of openness in searching

We learnt from our interviewees, that they factored in various degrees of openness when searching for an external technology or partner. They differed in their search ranges. Some firms searched in existing networks (e.g., technology alliances, suppliers, customers, etc.) for a useful technology or potential collaborator. However, for some other open innovation projects, our interviewees stated that they actively searched externally (e.g., industrial associations, fairs/exhibitions, conferences, etc.) to look for a useful technology or potential collaborator. They might also broadcast their search intentions publicly and were expected to form a collaborative relationship with a partner they did not have relationships with previously or with whom they were not familiar. As the senior technology manager of Firm A remarked:

> *"We used various channels to look for a technology or partner. It led to a large pool of potential technologies or partners. For one project we had previously, we collaborated with an individual innovator in Australia. We totally did not expect that."*

Similarly, as the technology manager of Firm G commented:

> *"In our R&D department, we have special technology scouts to explore new and valuable technologies. They actively attend industrial association events, fairs/exhibitions, conferences, to look for a useful technology or potential collaborator."*

On, the contrary, some firms used a limited network to search for an open innovation technology or partner. For instance, the technical director of Firm H stated:

> *"We focused on collaborating with established universities and research institutions because they are well known and trustworthy. Our projects tend to be on a long-term basis. We do not want to take risks in building*

relationships with firms we are not familiar with. This is because our projects usually need heavy investments and confidentiality is important."

In addition, we learnt that firms differed in their project specificity. Some firms did not have a clear roadmap of the innovation (e.g., the specific technology required for the innovation, the specific goal of the innovation, the timeline of the innovation). They gave their open innovation partners opportunities to work out a plan together. Others might have already decided on the specific details of the open innovation project. For instance, the senior engineer of Firm C explained:

"Most of the time, we did not know which specific technology we were looking for. We just constantly scouted for useful ones for immediate or future use. We paid attention to some cutting-edge technologies."

Resource distance

When looking for an open innovation partner, managers initially searched for firms with different technical resources that they did not possess. This is because accessing or learning new skills from partners is a prevalent rationale for creating a collaborative relationship. The first inter-firm distance concept that interviewees mentioned was technical resource distance. In all the cases we analyzed, the potential partners had technical resources that were distinct yet complemented each another for forseen opportunities. Partners would be able to innovate and create opportunities only by integrating their different skills and resources. For instance, the technical director of Firm H explained:

"We want to improve the products of our existing system for home users. Our partner ICTCAS, has specialized computing techniques that are complementary to our techniques. Developing them together with ICTCAS would save R&D costs, help us to achieve better product performance and ensure system stability."

When looking for an open innovation partner, managers also mentioned that they looked for firms with different market resources that they did not possess. An innovation process includes both idea conceptualization and commercialization. Technical resource is insufficient for an innovation process. Resources and knowledge about the market are also important.

In all cases, firms were adept at certain technologies and also had a thorough understanding of the needs of dissimilar customers. Through collaboration, firms were either able to create new market segments for a mutual product (i.e., mutual market expansion), or to make it possible for one partner to gain access to a new market, while the other had the opportunity to become a value-added supplier. Specifically, their market resources complemented each another. As the senior technology manager of Firm B remarked:

> *"Our firm has an annual production of more than 16 million pumps in the world, which makes us as a leading pump manufacturer. But our firm is relatively new to the Chinese market and our product price is higher than those of native Chinese brands. Collaborating with our partner, which has the largest market share in China's solar water heater industry, provides us with an opportunity to gain increased brand awareness in the Chinese market."*

IT usage

The interviewees suggested that IT tools facilitated their recognition of external resources, even though such resources belonged to distant technical and market domains. All the interviews used IT technologies that assisted in supporting distant knowledge recognition and acquisition. The senior technology manager in Firm C's Conect and Develop department commented:

> *"We look for useful external innovators every day. We have specialized groups of people working on connecting with external resources. These*

people are not only experts in their own scientific areas, but are also IT experts. They are capable of using various IT tools to facilitate their work."

Other interviewees also stated that their R&D employees are encouraged to use IT tools to look for useful external resources. They use sophisticated retribal technology to help link their firms to external innovation possibilities. In addition, they are expert in using the most advanced tools to search numerous web pages, scientific literature and data bases and global patent databases. They are also encouraged to attend various technical exihibitions and conferences to explore the prioneering technologies for their respective industries and those of other industries.

Another way for firms to gain more external resources is to find solutions in other technology brokers. Some interviewees have also been instrumental in creating and supporting a number of Internet-based innovation intermediaries which help link externally sourced solutions to internal problems, such as InnoCentive, Yet2.com, and NineSigma. These innovation intermediaries match seekers (actors describing a concrete problem from their specific industry or domain) and solvers (actors offering a respective solution). Usually the search for a solution is based upon a contest for innovative ideas, which offers financial incentives for the winner. In addition to these cross-firm platforms, single firms are also implementing platforms in an effort to collect ideas, suggestions, and feedback on potential trends from their customers and partners via the Internet. For instance, Firm C established a website to communicate with external resources. Firm C leveraged it to extend its reach to diverse innovators, enabling agile moves in new technology. This firm is interested in collaborating with innovators for technology solutions across more than 150 areas of science.

Phase 2: After Open Innovation Project Initiation: Inter-firm Collaboration

Once the collaborative innovation partner was selected, the two parties needed to decide on a specific plan for the open innovation project and then to implement the plan. Collaborative partners established project specifications and goals.

Social distance

Organizational cultural differences represent one important aspect of inter-firm social distance. Culture is the collection of cognitions, expectations, mindsets, norms, and values within a firm (O'Reilly et al. 1991). Culture is a determinant of how firms make decisions, and it shapes collective behaviors. Findings show that when the partners have a high level of cultural distance, conflicts are overcome with relative difficultly. Distance in norms and procedures, such as in the way of doing things, may make effective communication and exchange of knowledge difficult. Partners should be able to speak the same language, according to the CEO of Firm F, who remarked:

> *"As a startup, we feel it is sometimes very hard to discuss new products, new markets and new ideas with bigger firms. I don't know why exactly, but they don't seem to speak the same language. We have a discussion and it doesn't stick. We don't get any traction on it. It is very difficult because again we both come from different worlds. While we see some value in some of the products they have, they don't seem to see that value."*

Partners with compatible cultures are more likely to understand each another and to work toward common goals. Compatible cultures engender synchronization of expectations and behaviors. Indeed, a manager from Firm G commented:

> *"It feels like there are no organizational boundaries because the two firms are all just kind of kindred spirits in our values on how we treat customers and each other."*

According to our interviewees, differences in procedures between collaborative firms often led to mutaual frustration or loss of faith in the partner's capabilities, whereas differences in problem-solving tactics between collaborative firms often resulted in the problem remaining unsolved. Furthermore, sometimes the management of collaborative firms constantly misinterpreted each other's actions and motives.

For instance, the technology director of Firm A described the challenges they encountered in an open innovation project. This firm had a collaborating partner with completely different organizational structures, managerial rules and types of governance in the manufacturing industry. Firm A is a privately-owned Chinese enterprise with an informal, decentralized and non-bureaucratic structure, whereas its partner is a subsidary of a multinational enterprise with a formal, hierarchical and bureaucreatic structure. Firm A used a "do the right thing from a win-win perspective" mechanism whereas its partner used only established rules and procedures to guide task accomplishment.

These large differences in almost every aspect of the organizational operation practices had a large negative impact on the success of the collaboration between between Firm A and its partner. The differences caused the most significant challenges during their collaborative project. The senior technology manager of Firm A remarked:

> *"The most significant challenge for our collaboration is our different organizational cultures. It has caused some conflicts. Both of us needed to coordinate with each other in order to solve the problems."*

Our interviewees suggested that the effect of these organizational differences became obvious when both collaborative partners made decisions and solved problems throughout the collaboration. This point is demonstrated by the senior technology manager of Firm E, who explained:

"Our firm has a flat organizational structure. Our personnel have the power and authority to handle all situations. It takes less time to make decisions. Our partner, on the other hand, involved only those people whose formal job descriptions were related to a particular issue. Its personnel had to check constantly with higher executives in the firm for permission to act. This is a big difference we encountered during our collaboration."

Each firm had a different approach to problem solvingand this was indicated by the project manager of Firm H who commented:

"We viewed problems as opportunities both to solve immediate issues and to examine/change processes so that the problems would not recur. However, our partner simply wanted a specific situtation to be corrected immediately and viewed our interest in the process as a delaying tactic. This difference made our collaboration challenging and required lenghty negotiations."

IT usage

We identified knowledge visualization tools (e.g., CAD/CAM systems), knowledge discovery tools, and business intelligence tools that were used by interviewees in the interviews. These IT applications enabled firms to learn from each other and facilitate the process of the commercialization of existing technology.

Packaging design is a very important factor in consumer product markets. Firm C used a 3D computer-aided design (CAD) system to increase innovation in the packaging and marketing of its products. This facilitated the intergration of different sources of knowledge within and outside the firm in the design process and facilitated test representations of package designs with collaborators.

Our interviews with Firm E, revealed that during one open innovation project, the project team members expended extensive brainstorming together by using the visualization/simulation tools. The aim of these brainstorming exercises was to bring together a number of people with different but relevant knowledge and experience, in order to create ideas. Ideas for new product design concepts were produced in 3D CAD drawings. These CAD drawings would be used throughout the entire development and manufacturing process: from the initial concept to the manufacturing stage. Once the model was produced and virtual product testing commenced, teams of people from both organizations examined the virtual model and commented on their likes and dislikes. These tools helped collaborative partners to reach mutual understanding.

Another use of IT is to manipulate and share component designs. Engineers specify various parameters and test performances, creating new knowledge without needing to build physical models. This interaction supports shared higher-level learning about the assumptions underlying a model and improves model representation. It can reduce the number of iterations, enhance learning, and dramatically reduce the time frame from the designing stage to the marketing of a product. The senior technology manager of Firm F confirmed:

> *"Our continuous interaction in using the CAD modeling tool system is quite useful for both product design and manufacturing. We carried out many design experiments. This saved us plenty of time, and we also acted intuitively. With the resulting drawings, we were able to have a much higher level of discussion. We could discuss specific product features with our partner. This approach is much more effective."*

In addition, there are a number of ITs that can facilitate the interviewed organizations in retaining and reactivating knowledge for innovation. These technologies include electronic knowledge repositories (e.g., databases, digital archives), document or knowledge management systems, organizational memory systems and electronic communities for interaction and communication. These technologies not only enable the retention of organizational knowledge but also facilitate employees' reactivation of the knowledge for current projects. They can assist firms to retain prior knowledge, quickly search for relevant background information for external knowledge, and facilitate employees in communicating and articulating knowledge to each other. For example, employees who encounter a complex problem may directly contact those who have previously tackled similar problems through the expert finding function in the systems or posting questions in community forums.

Firm C has a substantial R&D orgnization, with over 6,500 scientists. It has over 29,000 existing patents with an average of 5,000 added yearly. Employees distributed globally can communicate with each other through an internal website called InnovationNet. Researchers use this to make connections and share data and information. In 2002, there were over 9 million documents online, and this number is growing rapidly. The true value of InnovationNet to Firm C is its ability to accelerate innovation by allowing thousands of employees across the globe to make new connections, collaborate with co-workers and cross-fertilize their knowledge in a variety of specialized fields.

Other essential components of inter-firm learning are communication, dialogue, and coordination. Electronic communication is preferable when distance and time zones are obstacles to fast response. IT improves coordination and communication between collaborating firms. If the communication is frequent, emotionally intense, and involves the sharing of confidence and reciprocity, then the social interaction is considered a strong tie based on trust. Strong ties are needed for inter-firm learning during new product development to cope with complex, ambiguous information, uncertainty, intense interaction, and the urgency in highly competitive industries to reduce time to market.

For instance, e-community of practice, web conferencing, and groupware systems are all instrumental in cultivating social interactions and connectedness among collaborative organizations. Message boards, electronic message software, and chatrooms can facilitate communication and coordination. The electronic communication tools are important for avoiding conflicts. Even when misunderstandings occur, these tools may help resolve them. The IT applications used by Firm H are conferencing (e.g., web conferencing, video conferencing), messaging (e.g., e-mails, instant messaging). They have regular face-to-face meetings every month. However, considering their geographical distance, most communication and interaction occurred online. The senior technology manager of Firm I remarked:

> *"We encouraged our project members to communicate online more frequently with the engineers of our partner. In fact, the communication between managers from both organizations is also necessary."*

Similarly, the senior technology manager of Firm D commented:

> *"Online communication is necessary for R&D collaboration considering the uncertainty and interdependency of the nature of the tasks. Sometimes, communication gives us an opportunity to have personal interaction with our partners, which helps us in developing trust and mutual understanding."*

3.7 Case Findings

Several research findings are identified from our interviews. First, we found that project openness varies among different open innovation projects and was manifested as different degrees of openness in the search for an external technology or a partner. The first manifestation of openness is that firms differed in their range of searches. Some firms searched in existing networks (e.g., technology alliances, strategic alliances, suppliers, customers, etc.) for a useful technology or potential collaborator. However, some actively searched externally (e.g., industrial associations, fairs/exhibitions, conferences, etc.) to look for a useful technology or potential collaborator. Some also broadcast their search intentions publicly and were expected to form a collaborative relationship with a partner with whom they did not have a prior relationship or one they were not familiar with. The second manifestation of openness is that firms differed in terms of project specificity. Some firms did not have a clear roadmap of the innovation (e.g., the specific technology required for the innovation, the specific goal of the innovation, the timeline of the innovation). Others might have already decided on the specific details of the open innovation project.

Second, we found that inter-firm resource distance indeed existed in the open innovation context. Different resources can stimulate technological innovations, which may lead to creating innovative ideas or solutions, expanding current markets, creating new market segments, or entering into a new market. In addition, our case firms also encountered organizational social distance during their open innovation projects and they felt it was challenging. Thus, inter-firm resource is an important factor in examining open innovation performance.

Third, we identified a list of IT tools that facilitate the open innovation process. As an IT-enabled phenomenon, in the open innovation process, IT facilitates inter-firm learning and helps collaborators to cope with the complexity of new product development. The barriers between firms are made more permeable due to the influence of IT. However, what specifically are these technologies, and how are they used to support open innovation? How do they, on the one hand, shape the strategic orientation of industrial firms towards their external environment, and on the other, facilitate the creation and realization of actual innovation? These are the issues we sought to resolve in our study.

In previous literature, many authors have highlighted the role of Information and Communication Technologies (ICTs) in vastly increasing the ability of firms to work across different geographical and organizational boundaries (Pavitt 2003). Through our case studies, we found that the IT usage in open innovation projects surpasses the role of ICTs. We extended previous analyses by moving beyond the role of ICTs (computers, Internet, communications devices, etc.) and focused on a range of new technologies, including simlation, modelling, virtual reality, data mining and rapid prototyping technologies and their role in the movement towards open innovation.

We classify the IT applications identified from our interviews into six sets:

- **Environmental scanning tools.** In the open innovation process, firms used IT supports to search for potential collaborators. For instance, Internet and social media tools made the searching and environmental scanning more efficient. Furthermore, firms needed some learning tools to facilitate their understanding of the external knowledge. For instance, data reading technology and interpretation systems facilitated the comprehension and internalization of external knowledge. Furtheromore, IT-based systems, like innovation intermediary platforms/crowdsourcing platforms, corporate initiatives, can also help in identifying, collecting, and extracting useful knowledge from a wide variety of knowledge resources with high speed and great accuracy.

- **Organizational memory systems.** In the open innovation process, firms used IT-based systems to manipulate and interpret information received from their partners. For instance, data warehouses, knowledge management systems, knowledge repositories (e.g., databases, digital archives) were largely used.

- **Interpretation systems.** Our case firms used business intelligence, data analytics, decision support systems, and knowledge discovery tools to interpret the large amount of knowledge and identify the useful ones.

- **Computer-based design applications.** This set of IT tools assisted firms in supporting the development of design drawings and prototypes and permitted the sharing of technical information. The identified tools include computer-aided design (CAD) systems, Computer-aided manufacturing (CAM) systems, and other visualization and simulation tools.

- **Electronic communication tools.** During the open innovation projects, IT applications revolutionized the communication between firms by establishing more linkages based on contextual value-laden shared knowledge. For instance, conferencing and messaging tools used between partnering firms to enhance interaction and coordination were used.

- **Collaborative management (coordination) tools.** Collaborative management tools facilitated and managed group activities, such as scheduling and time management, and task assignment. Electronic calendars (also called time management software), project management systems and workflow systems were used uring the open innovation projects.

The identified IT tools were summarized in Table 3.4.

Table 3.4 The Emergence of IT Tools

IT tools	Description	Function
Environmental scanning tools		
Innovation intermediary platform/crowdsourcing platform	• Used for R&D problem solving, idea marketplace, like Innocentive, IdeaConnection, Yet2.com, TekScout, NineSigma.	Use of IT-based systems by an enterprise to search or scan external environment for technology trends, market demand, competitor state, potential collaborators, etc. It can also help identify, collect, and extract useful knowledge from a wide variety of knowledge resources with a high speed and accuracy.
Corporate initiatives	• Created by firms to collect R&D solutions, ideas, like Ideas Project by Nokia, Connect and Develop by Proctor & Gamble, My Starbucks Idea by Starbucks.	
Search engines	• Designed to search for information on the World Wide Web.	
Directory services (e.g., online corporate yellow pages)	• Serve as expertise locators.	
Data reading/digital capture technology/Data mining	• The goal is to extract information from a data set and transform it into an understandable structure for further use.	
Organizational Memory systems		
Data warehouses	• A database used for reporting and analysis.	Use of IT-based systems by an enterprise to manipulate and interpret information received from its partners.
Knowledge management systems	• A subset of Enterprise content management software and which contains a range of software that specializes in the way information is collected, stored and/or accessed.	
Document management systems/content management systems	• A computer system (or set of computer programs) used to track and store electronic documents and/or images of paper documents. It is usually also capable of keeping track of the different versions modified by different users (history tracking).	
Knowledge repositories	• An organized collection of data in digital form.	

(e.g., databases, digital archives)		
Organizational memory systems	• Functions to provide a means by which knowledge from the past is brought to bear on present activities, thus resulting in increased levels of effectiveness for the firm.	
Interpretation systems		
Business intelligence	• A broad category of applications and technologies for gathering, storing, analyzing, and providing access to data to help enterprise users make better business decisions.	Use of IT-based systems by an enterprise to store and retrieve information related to previous exchanges with its partners.
Data analytics	• A subset of business intelligence based on statistics, prediction, and optimization.	
Decision support system	• A computer program application that analyzes business data and presents it so that users can make business decisions more easily.	
Knowledge discovery tools	• The creation of knowledge from structured (relational databases, XML) and unstructured (text, documents, images) sources.	
Computer-based design applications		
Computer-aided design (CAD) systems	• Also known as computer-aided design and drafting (CADD), is the use of computer systems to assist in the creation, modification, analysis, or optimization of a design.	Support the development of design drawings and prototypes and permit the sharing of technical information.
Computer-aided manufacturing (CAM) systems	• The use of computer software to control machine tools and related machinery in the manufacturing of workpieces.	
Visualization tools	• Software system for 3D computer graphics, image processing and visualization.	
Simulation tools	• Is the practice of developing and prototyping products in a completely digital 2D/3D environment.	

Electronic communication tools		
E-mail	• A method of exchanging digital messages from an author to one or more recipients.	Electronic communication tools send messages, files, data, or documents between people and hence facilitate the sharing of information.
Faxing	• Also called telecopying, is the telephonic transmission of scanned printed material.	
Voice mail	• A computer based system that allows users and subscribers to exchange personal voice messages.	
E-community of practice (e.g., wikis, BBS)	• A virtual community for peers with diverse skills and experience to share information.	
Internet forums (also known as message boards or discussion boards)	• A virtual discussion platform to facilitate and manage online text messages.	
Online chat	• A virtual discussion platform to facilitate and manage real-time text messages.	
Instant Messaging	• A form of communication over the Internet, that offers an instantaneous transmission of text-based messages from sender to receiver.	
Telephony	• Telephones allow users to interact.	
Videoconferencing	• Networked PCs share video and audio signals.	
Data conferencing	• Networked PCs share a common whiteboard that each user can modify.	
Application sharing	• Users can access a shared document or application from their respective computers simultaneously in real time.	
Electronic meeting systems (EMS)	• Electronic meeting systems have evolved into web-based, any time, any place systems that will accommodate "distributed" meeting participants who may be dispersed in several locations.	
Intranet	• A computer network that uses Internet Protocol technology to	

	share information, operational systems, or computing services within an firm.	
Collaborative management (coordination) tools		
Electronic calendars (also called time management software)	• Schedule events and automatically notify and remind group members.	Collaborative management tools facilitate and manage group activities. • Scheduling and time management • Resource management • Task assignment
Project management systems	• Schedule, track, and chart the steps in a project as it is being completed.	
Online proofing	• Share, review, approve, and reject web proofs, artwork, photos, or videos between designers, customers, and clients.	
Workflow systems	• Collaborative management of tasks and documents within a knowledge-based business process.	
Enterprise bookmarking	• Collaborative bookmarking engine to tag, organize, share, and search enterprise data.	
Prediction markets	• Let a group of people predict together the outcome of future events.	
Extranet systems (sometimes also known as "project extranets")	• Collect, organize, manage and share information associated with the delivery of a project (e.g.: the construction of a building).	
Social software systems	• Organize social relations of groups.	
Online spreadsheets	• Collaborate and share structured data and information.	

Stage 2. Quantitative Study

In the second stage of this study, we drew on the identified findings from the qualitative stage to further explore the open innovation phenomenon by means of a quantitative survey.

3.8 Theoretical Foundation

Referred to as a firm's ability to "recognize the value of new, external knowledge, assimilate it and apply it to commercial ends" (Cohen and Levinthal 1990, p.1), organizational absorptive capacity (ACAP) is deemed critical to organizational learning and innovation (Cohen and Levinthal 1990; Zahra and George 2002). Most research using the Cohen-Levinthal concept has hypothesized that higher internal absorptive capacity assists firms in capitalizing on external innovations. Firms with high absorptive capacities will be more successful when applying ACAP.

As an important lens to understand how acquired knowledge can be transferred to desirable organizational outcomes, ACAP has been applied to study organizational innovation performance with other firms in mergers and acquisitions (Ahuja and Katila 2001), international joint ventures (Lane et al. 2001), as well as in the supply chain (Malhotra et al. 2005) and strategic alliance contexts (Koza and Lewin 1998). Zahra and George (2002) proposed that ACAP can be conceptualized as: *exploratory learning*, (i.e., knowledge recognition and comprehension) and *exploitative learning* (i.e., knowledge application and implementation) (Lane et al. 2006; Lichtenthaler 2009; Zahra and George 2002). In addition to these components, social integration mechanisms (i.e., social interaction among knowledge sharing parties) are also often treated as an important concept in ACAP (Jansen et al. 2005; Todorova and Durisin 2007; Zahra and George 2002), which can impact organizational innovative outcomes. IT contributes to the assimilation, creation and application of knowledge (Kleis et al. 2012), thereby significantly building firms' knowledge absorptive capabilities. In the IS field, Joshi et al. (2010) studied IT-enabled absorptive capacity and IT-enabled social integration capability together and named it IT-enabled knowledge capabilities. Following Joshi et al. (2010), we will examine the effects of *IT-enabled exploratory learning*, *IT-enabled exploitative learning* and *IT-enabled social integration capability*. We also posit that these three dimensions of IT-enabled knowledge capabilities have differential effects on knowledge absorption. From our interviews, we identified a list of IT tools used in open innovation projects. In the quantitative study, we will develop the three dimensions of IT-enabled knowledge capabilities by using these IT tools.

In this study, by examining the three dimensions of IT-enabled knowledge capabilities, we provide a more comprehensive understanding of how firms acquire, assimilate, and exploit external knowledge (Lane et al. 2006). Additionally, we explore how the different types of inter-firm distances can be affected by different components of IT-enabled knowledge capabilities to induce open innovation. Although open innovation is an IT-enabled phenomenon, prior literature has not systematically discussed how IT usage could minimize the absorption challenges of inter-firm distance.

3.9 Research Model

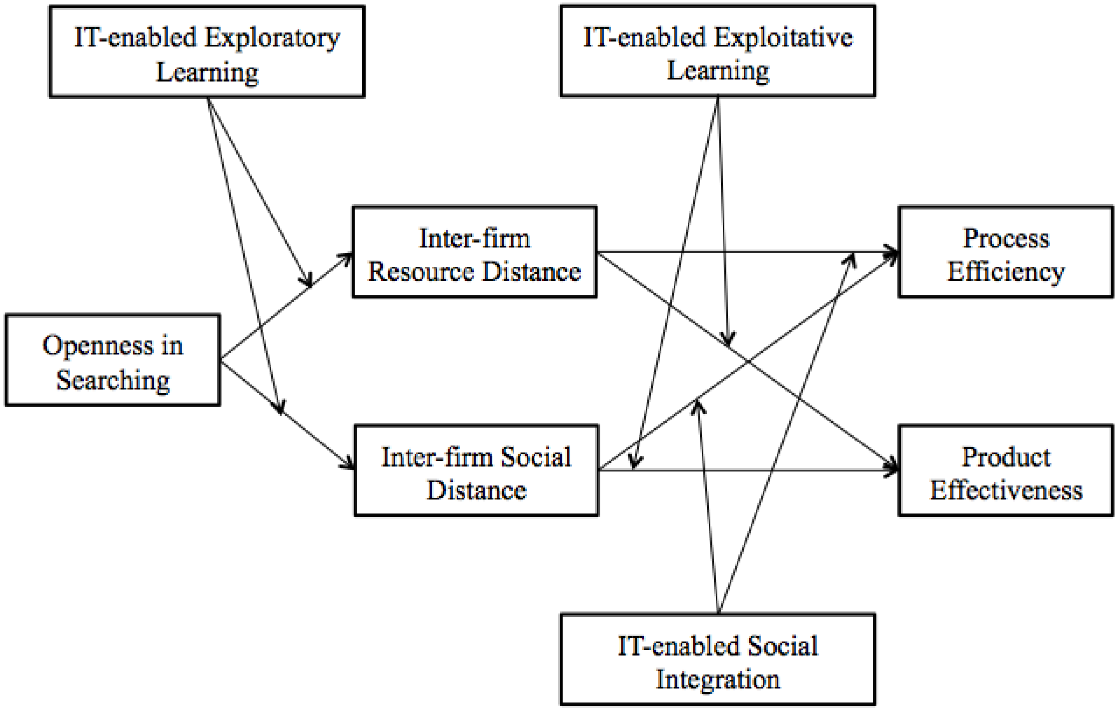

Figure 3.1 Research Model

3.10 Hypotheses

3.10.1 Degree of Openness in Searching

We developed the construct of openness in searching based on the findings of our qualitative study and limited suggestions from prior literature. In prior literature, Pisano and Verganti (2008) built upon the open innovation model in their focus on the degree to which "membership" is open to anyone who wants to join. This form of openness distinguishes between completely open innovation (e.g., crowdsourcing) and closed networks (like private clubs), and the types of governance ranging from hierarchical to flat. In this study, *openness in searching* is defined as the degree of the open search area and the specificity of the innovation project plan. For a high degree of openness in searching, we enabled the focal firm to broadcast their technical needs in the form of open calls to the public or an undefined group of externals. In contrast, for a low degree of openness in searching, the focal firm could only search in existing networks with familiar potential collaborators. In addition, the openness in searching is also manifested as the focal firm does not have a clear roadmap of the innovation (e.g., the specific technology required for the innovation, the specific goal of the innovation, the timeline of the innovation). Hence the open innovation project is open for discussion and decision-makng collaboratively with the firm's partners.

To begin a search in an external environment, firms work within a large search range and use a large number of search channels. The large search range and various search channels used lead to a high reach of potential partners. Thus the variations of the partner characteristics in the potential partner pool are increased. Innovators in marginal areas are also included in the potential partner pool, such as individual innovators, start-ups, or firms in a different industry. It increases the possibility for the focal firm to choose a partner from different knowledge domains and those possessing different organizational designs. Hence, open searching in an external environment results in high inter-firm resource sharing and an increased social distance between collaborative partners.

In addition, if the focal firm lacks a clear idea of the specific technology required for the innovation, they may not form a specific description to limit the number of potential open innovation partners. They may expect to form a collaborative relationship with a partner with whom they did not have a prior relationship or with an unfamiliar partner. This can also increase the distance between the focal firm and its open innovation partner. Thus we hypothesize:

> ***H1a:*** *Openness in searching has a positive effect on the inter-firm resource distance between a focal firm and its partners.*

H1b: *Openness in searching has a positive effect on the inter-firm social distance between a focal firm and its partners.*

3.10.2 Inter-firm Distance

Resource Distance

In our context, *resource distance* is defined as the degree of differences in technical knowledge domains between two collaborative firms.

We argue that too small a resource distance may imply a lack of novelty. When the technical knowledge bases of partners become too similar, they may also experience reduced benefits from the collaborative innovation. In the innovation literature, inter-firm collaboration is seen as a means for firms to combine heterogeneous resources in new ways (Ahuja 2000). Pooling distinct perspectives and capabilities encourages creativity and novel solutions, and consequently results in the creation of new technologies or new market possibilities (Cassiman and Veugelers 2006). Empirical evidence provides some support for these arguments, albeit in slightly different contexts. Cassiman et al. (2005) found that when two merged firms are technologically complementary, their R&D productivity increases. Furthermore, Baum et al. (2000) showed that biotech firms allied with varied types of partners outperform those engaging in alliances with only a single type of partners.

Therefore, the above arguments suggest a positive relationship between the inter-firm resource distance and the value of the new product developed through open innovation projects. Thus we hypothesize:

H2a: *The inter-firm resource distance between a focal firm and its partners has a positive effect on product effectiveness.*

However, when the collaborative partners have different resources, the coordination burdens significantly increase because their divergent perspectives must be resolved before the development can move forward (Olson et al. 1995). As Moorman and Miner (1998) suggested, innovation process efficiency largely depends on how quickly the development team handles coordination issues and problems in each development stage. When the inter-firm resource distance increases, the coordination requirement also increases, especially when the process involves a wide range of functions (Prahalad and Ramaswamy 2000). Therefore, with a high inter-firm resource distance, collaborative partners are required to have articulated or frequent interactions to complete each task, which decreases the innovation process efficiency significantly.

In addition, because of the higher inter-firm resource distance, speedy problem-solving between the collaborative partners becomes more difficult; and hence the necessary back-and-forth and trial-and-error procedures preclude the possibility of structuring a formalized coordination mechanism to control the innovation process in a timely manner. Therefore, the inter-firm resource distance makes it difficult to speed up the innovation process, and results in low process efficiency. Thus we hypothesize:

> **H2b:** *The inter-firm resource distance between a focal firm and its partners has a negative effect on process efficiency.*

Social Distance

The *social distance* between partnering firms, is defined as the degree of firm culture, strategic direction, firm structure and management style differences between social actors participating in the collaboration (Filippi and Torre 2003; Lane and Lubatkin 1998; Parkhe 1991; Van Den Bosch et al. 1999). Firm culture, strategic direction, firm structure and management style decide the way of allocating tasks, responsibilities, and delegating authority and are strongly related to a firm's problem-solving and decision-making behaviors. They form a set of implicit and explicit routines that enable firms to be coordinated without having to define prior relevant behavior.

A high inter-firm social distance suggests that two firms have become socialized to different norms and beliefs of their respective fields and organizations. It may result in a different set of perspectives and heuristics than those with similar working styles. This enables the collaborative partners to view and approach problems more unconventionally; a factor that might be crucial to the production of novel solutions. For example, Jeppesen and Lakhani (2010) suggested that successful solution generation in a broadcast search context will be positively associated with the social marginality of problem-solvers. Hence, when collaborative partners possess different social norms, it may lead to high product effectiveness.

In addition, inter-firm social distance leads to collaborative partners taking different styles in decision-making, problem-solving and performance measurement. These different working styles increase the consideration sets, and consequently may enhance the ability to avoid or detect errors in innovation projects. Hence, the developed product effectiveness can be improved.

Therefore, the above arguments suggest a positive relationship between the inter-firm social distance and the value of the new product developed through open innovation projects. Thus we hypothesize:

> **H3a:** *The inter-firm social distance between a focal firm and its partners has a positive effect on product effectiveness.*

In terms of social distance, similar cultures, strategic directions and operational procedures between partners ensure that a common set of working assumptions will be adopted in the knowledge transfer process (Tsai 2001). It will result in a smooth working relationship between collaborating partners (Lane and Lubatkin 1998). Additionally, common organizational structural and management practices assume the availability of a shared communication code and mutual understanding (Mowery et al. 1996). Conversely, coordination conflicts and communication difficulties can limit the sharing of knowledge and learning, thus leading to unfavorable innovation outcomes (Van Den Bosch et al. 1999). Thus if innovation partners have very different organizational structures and management practices, they will encounter difficulty in effectively and efficiently communicating with each other, which will impede the open innovation process efficiency. Thus we hypothesize:

H3b: *The inter-firm social distance between a focal firm and its partners has a negative effect on process efficiency.*

3.10.3 IT-enabled Knowledge Capabilities

IT-enabled knowledge capabilities facilitate the open innovation process (Enkel et al. 2009). Given the different nature of IT-enabled knowledge capabilities, we aim to explore how these capabilities can exhibit differentiated moderating effects of inter-firm distance on firms' open innovation.

IT-enabled Exploratory Learning Capability

Exploratory learning activities include the recognition and comprehension of external knowledge (Lichtenthaler 2009). To explore external knowledge, firms need tools aiding their recognition of the frontiers in science and technology (Kane and Alavi 2007). Some supporting IT tools include environmental scanning techniques (e.g., search engines, innovation platforms like Innocentive), data reading technology and interpretation systems (Joshi et al. 2010; Subramani 2004). We posit that IT-enabled exploratory learning capability can enhance the impact of openness in searching on inter-firm distance. Firms with high IT-enabled exploratory learning capability can identify relevant open innovation partners located in distant technical domains (Joshi et al. 2010). For instance, innovation platforms facilitate firms with high openness in searching to reach further for open innovation partners. Interpretation systems enable the information of open searches to be organized and rearranged, and thus firms are able to discover potential partners in distant areas. Therefore, when firms are equipped with IT exploration tools, it is more possible for them to have an open innovation partner with different characteristics. Thus we hypothesize:

> **H4a:** *When the level of IT-enabled exploratory learning capability is high, the positive effect of openness in searching on inter-firm resource distance will be strengthened.*

> **H4b:** *When the level of IT-enabled exploratory learning capability is high, the positive effect of openness in searching on inter-firm social distance will be strengthened.*

IT-enabled Exploitative Learning Capability

Exploitative learning comprises the activities of applying and implementing knowledge (Lichtenthaler 2009). ITs that support these activities provide *IT-enabled exploitative learning capability*. It is reflected in IT applications such as visualization, simulation tools, computer-based design applications (e.g., CAD and CAM systems), knowledge repositories (e.g., databases, digital archives), document or knowledge management systems, and organizational memory systems (Chi et al. 2007; Subramani 2004). Similar to Hypothesis 4b, IT-enabled exploitative learning capability can reduce the negative effects of inter-firm resources and social distance on innovation outcome product effectiveness (i.e., the right half of the inverted U shape which is depicted in H2a and H3a). Different from exploratory learning, exploitative learning affects partners through leveraging complementary assets and combining existing applied knowledge

(Kane and Alavi 2007). For instance, CAD/CAM systems help to digitize a new product's design and make it available among partners in the innovation development process. Hence, they assist open innovation partners in learning from each other and collaboratively achieving better innovation outcomes. Thus we hypothesize:

H5a: *When the level of IT-enabled exploitative learning capability is high, the positive effect of inter-firm resource distance on product effectiveness will be strengthened.*

H5b: *When the level of IT-enabled exploitative learning capability is high, the positive effect of inter-firm social distance on product effectiveness will be strengthened.*

IT-enabled Social Integration Capability

ITs that help support communication and direct interactions among partners provide *an IT-enabled social integration capability*. It is reflected in IT applications such as web conferencing, text messaging (e.g. instant messaging), collaboration technology and groupware systems (Chi et al. 2007). Social integration mechanisms assist in building social capital in a collaborative relationship (Zahra and George 2002). They promote connectedness, interaction, and communication among innovation participants. Furthermore, IT tools enable faster information distribution beyond a firm's boundaries. Social integration mechanisms assist members in achieving mutual understanding and cultivating a shared frame of references. While inter-firm distance may cause communication barriers and coordination conflicts between partners, IT-enabled social integration capability can assuage this problem. With IT-enhanced connectivity, members from different organizations find it easier to share interpretations of the information, making consensus development more efficient. Thus we hypothesize:

H6a: *When the level of IT-enabled social integration capability is high, the negative impact of inter-firm resource distance on process efficiency will be weakened.*

H6b: *When the level of IT-enabled social integration capability is high, the negative impact of inter-firm social distance on process efficiency will be weakened.*

3.10.4 Control Variables

Prior literature suggests that organizational open innovation performance may be influenced by its internal R&D characteristics. Thus, firm size and R&D intensity are included as control variables in our model (Joshi et al. 2010; Lane and Lubatkin 1998). As a firm's open innovation performance also depends in part on the external environment in which the firm operates, the effect of the industry sector on it is also controlled (Joshi et al. 2010). In addition, the consideration of prior relationships may also affect a firm's subsequent collaboration (Mowery et al. 1996), while it is also considered as a control variable.

3.11 Quantitative Study Research Methodology

3.11.1 Construct Measurement and Questionnaire Development

Degree of openness in search was measured with items as formative indicators (see Table 3.5). The scale for measuring it was developed through our first stage qualitative study findings. For IT-enabled knowledge capabilities, we adapted items based on the absorptive capacity literature (Lane et al. 2006; Lichtenthaler 2009; Todorova and Durisin 2007) and the list of IT tools identified from our first stage qualitative study findings. After the initial development of these scales, the interviewed R&D managers who were involved in managing open innovation projects at their respective firms were reviewed the scale and commented on it. Minor modifications were made on some items to address the concerns. The scale was further validated by following Moore and Benbasat (1991)'s procedures, which will be illustrated in the following.

The other survey instruments are developed by adopting and adapting existing validated scales. The scale used to measure inter-firm resource distance was based on the work of Cassiman et al. (2005). For inter-firm social distance, it was adapted from the work of Sarkar et al. (2001). These were contextualized to the domain of open innovation project. Resource distance measured the extent to which a focal firm is different from its open innovation partner in terms of their knowledge domains and market segments. Social distance assessed the extent to which a focal firm is different from its open innovation partner in terms of their managerial styles, organizational structural and organizational culture.

Following Pavlou and El Sawy (2006), we measured open innovation process efficiency using three indicators respectively, which was measured relative to major competitors in the following aspects: overall development costs, overall efficiencies of NPD process, and accelerated time-to-market. Similarly, product effectiveness was also measured relative to major competitors: improvements in product quality/functionality, major innovations in products as a whole, and creation of new product concepts.

We will follow Moore and Benbasat (1991)'s procedures to conceptually validate the items. Table 3.5 lists the measurements.

For control variables, firm size was coded as the number of employees, and firm age was represented as the number of years of firm establishment. Industry sector was coded as dummy variables for different industries. R&D intensity is measured through the annual R&D expenditures as a percentage of sales of the focal firm. Project size was coded as the number of employees participate as project member for a given open innovation project, and project cost was the monetary cost for a given open innovation project.

Table 3.5 Operationalization of Constructs		
Independent Variables	**Item Description** (1-7 Likert scale, 1=Strongly disagree, 7=Strongly agree)	**Reference**
Degree of openness in searching	• Our firm actively searched externally (e.g., industrial associations, fairs/exhibitions, conferences, etc.) to look for useful technology or potential collaborator. • Our firm broadcasted your technical needs in the form of open calls to the public or an undefined group of externals (e.g., website of your firm, crowdsourcing websites, Internet-based innovation communities/platforms, and the above-mentioned sources, etc.) to look for useful technology or potential collaborator. • Our firm interacted with users (e.g., lead users, users on social media pages of your firm, etc.) to look for useful idea or technology or potential collaborator. • Our firm did not have a clear roadmap of the innovation (e.g., the specific technology required for the innovation, the specific goal of the innovation, the timeline of the innovation). • Our firm expected to form the collaborative relationship with partner you did not have prior relationship before or you are not familiar with.	Self-developed
Resource distance	• Our firm and our partner are in the same technological field. • The R&D skills and knowledge that possessed by our firm are different from our partner's. • Our firm and our partner serve different customers. • Our firm and our partner compete in the same market.	Adapted from (Cassiman et al. 2005)
Social distance	• The organizational social norms prevalent in my firm are different from our partner. • The organizational values prevalent in my firm are different from our partner. • The organizational structure of our firm is different from our partner's.	Adapted from (Sarkar et al., 2001)

	• The operational procedure of our firm is different from our partner's.	
IT-enabled exploratory learning capability	• Our firm uses information technologies to scan the environment for new technologies. • Our firm thoroughly observes technological trends with the help of information technologies. • Our firm uses information technologies to search for external new technologies. • Our firm thoroughly collects industry information with the help of information technologies. • Our firm has information on the state-of-the-art of external technologies due to the help of information technologies. • Our firm frequently acquires technologies from external sources with the help of information technologies. • Our firm periodically uses information technologies to interact with external partners to acquire new technologies. • Our employees regularly use information technologies to approach external institutions to acquire technological knowledge. • Our firm often uses information technologies to transfer external technological knowledge to our firm in response to technology acquisition opportunities.	Adapted from (Lichtenthaler 2009)
IT-enabled exploitative learning capability	• Our firm regularly transforms technological knowledge into new products/services with the help of information technologies (e.g., CAD/CAM, visualization and simulation tools, etc.). • With the help of information technologies (e.g., interpretation applications, etc.), we regularly match new technologies with ideas for new products. • With the help of information technologies (e.g., interpretation applications, etc.), we quickly recognize the usefulness of new technological knowledge for existing knowledge. • Our firm constantly applies technologies in new products/services with the help of information technologies (e.g., CAD/CAM, visualization and simulation tools, etc.) in	Adapted from (Lane et al. 2006; Lichtenthaler 2009)

	applying technologies in new products. • Our firm easily implements technologies in new products with the help of information technologies (e.g., CAD/CAM, visualization and simulation tools, etc.) in applying technologies in new products.	
IT-enabled social Integration capability	• With the help of information technologies (e.g., online messaging/conferencing tools), our firm can communication effectively with our partner. • Our firm uses information technologies (e.g., online messaging/conferencing tools) to effectively communicate with our partner. • Our firm uses information technologies (e.g., groupware systems) to facilitate our interactions with our partner. • Our firm uses information technologies to build connectedness with our partner.	Adapted from (Todorova and Durisin 2007)
Dependent Variables	**Item Description** (1-7 Likert scale, 1=Strongly disagree, 7=Strongly agree)	**Reference**
Process efficiency	• Overall development costs • Overall efficiencies of NPD process • Accelerated time-to-market	Adopted from (Pavlou and El Sawy 2006)
Product effectiveness	• Improvements in product quality/functionality • Major innovations in products as a whole • Creation of new product concepts	Adopted from (Pavlou and El Sawy 2006)
Control Variables	**Item Description**	**Reference**
Firm size	Firm size is measured through the number of firm employees.	Adopted from (Kleis et al. 2012)
Firm age	Firm age is the number of years from the organizational found year to current year.	Adopted from (He and Wong 2004)
R&D intensity	R&D intensity is measured through the annual R&D expenditures as a percentage of sales of the focal firm.	Adopted from (Lane and Lubatkin 1998)
Industry	Industry is measured through the industry category of the focal firm.	Adopted from (Kleis et al. 2012)
Project Size	Project size is measured through the number of	Adopted from

	employees participate as project member for a given open innovation project.	(Keller 2001)
Project Cost	Project cost is measured through the monetary cost for a given open innovation project.	Adopted from (Keller 2001)

Our survey instrument was refined in the following steps. First, to enhance the conceptual validity, we conducted a two-stage Q-sorting. As suggested by Moore and Benbasat (1991), two-step Q-sorting is useful to verify the content validity, convergent validity and discriminant validity of measures. Ten Ph.D. students were recruited from the department of information systems at a large university in Singapore. In one unlabeled and one labeled sorting sessions, they correctly classified 90% and 95% of the items into the intended constructs. The results show good quality of measures.

Second, the questionnaire was peer reviewed by several colleagues identify and rectify potential problems due to the framing and phrasing of the questions. Next, the questionnaire was translated to Chinese. To ensure comparability and equivalence in meaning, the method of back-translation was adopted (Brislin 1970). Two graduate students conducted the translation work independently. The authors compared the translated version with the original one and made changes when necessary. In addition, eleven R&D managers who were involved in managing open innovation projects at their respective firms reviewed the questionnaire and commented on its content validity, terminology, clarity of instructions, and response formats. Minor modifications were made on some items to address the concerns.

3.11.2 Data Collection

The survey approach was used to test the hypotheses. Our sampling frame included firms from four industries that have a broad presence in the China economy (chemical and pharmaceutical, electronic and other electrical equipment, industrial and commercial machinery equipment, and fabricated metal and other material industries). We followed the key informant approach to collect data from one R&D manager at each firm because executives in these roles were most likely to be knowledgeable about the items dealt with in our survey (Phillips and Bagozzi 1986). They were requested to identify a recent completed open innovation project and answer the questionnaire based on it. For firms that do not have open innovation project, their answers were eliminated from the sample. For other organizational level questions, they were requested to answer the quesions based on their organizational condition in the year 2012 (Data collection was conducted in January 2013).

The survey questionnaire was sent to 733 organizations. From the R&D managers who received the invitations, 258 completed the surveys. It represents a response rate of 35.2%. On average, the R&D managers had been in their positions for 8.1 years (standard deviation (S.D.) = 5.7). Summary information regarding the industry distribution of the sample, the size and annual sales of the firms is presented in Table 3.6.

Table 3.6. Demographic Profile of the Sample (N =258)

Industry	**No. of Firms**	**Percentage**
Chemical and pharmaceutical	53	20.5
Electronic and other electrical equipment	66	25.6
Industrial and commercial machinery equipment	76	29.5
Fabricated metal and other material	63	24.4
Number of Employees	**No. of Firms**	**Percentage**
<100	53	20.5
100-249	82	31.8
250-499	62	24.0
500-1,000	27	10.5

>1,000	34	13.2
Sales (Millions)	**No. of Firms**	**Percentage**
<10	18	7.0
10-100	95	36.8
100-500	92	35.7
500-1,000	31	12.0
>1,000	30	11.6

To assess the nonresponse bias, we conducted two tests. First, we verified that early and late respondents did not significantly differ in their demographic characteristics and responses on principal constructs. Early respondents were identified by selecting those that responded in the first two weeks. All t-tests between the means of the two groups showed no significant differences ($p < 0.1$ level). Second, we compared the difference between the expected and observed number of responses across the four industries in our sampling frame. Chi square test result showed no significant differences ($p < 0.1$ level). Hence, the two tests did not suggest any evidence of response bias in the collected data.

3.11.3 Data Analysis and Results

Data Analysis Approach

For this study, structural equation modeling (SEM) analysis was chosen since it can simultaneously analyze all paths with latent variables in one analysis (Gefen et al. 2011). Within SEM, Partial Least Squares (PLS) was chosen over co-variance based SEM for two reasons. First, it is an appropriate method for testing predictive research models (Jöreskog and Wold 1982) because it can assess the measurement model (relationships between items and constructs) within the context of the structural model (relationships among constructs). PLS maximizes the explanation of variance and prediction in the theoretical model and is especially suitable for research involving a relatively small sample size. Second, PLS is a suitable choice for the model with interaction effects as in our model

(Wetzels et al. 2009). Interaction terms were computed by cross-multiplying the standardized items of the relevant constructs (Wetzels et al. 2009). We used SmartPLS 2.0 to analyze the data.

Assessment of Common Method Bias

Because each response came from a single key informant, common method bias could be present (Podsakoff et al. 2003). To address this bias procedurally, we allowed respondents to answer anonymously to reduce their evaluation apprehension and to minimize social desirability bias. Next, to evaluate the presence of common method bias, we performed three tests. First, we conducted Harmon's one-factor test on the reflective construct variables to check common method bias (Podsakoff and Organ 1986). We entered all the reflective principal constructs into a principal components factor analysis. Factors with eigenvalues >1 were extracted from all the measures in this study and in total accounted for 59% of the variance. The first factor accounted for 34% of the variance. Since a single factor did not emerge and one-factor did not account for most of the variance, this suggested that the results were not due to common-method bias. These results indicate that common method bias is not a major concern.

Second, we followed the method developed specifically for PLS analysis by Liang et al. (2007). We included a common method factor in the PLS model whose indicators included all of the constructs' indicators. We then calculated each indicator's variances substantively explained by the principal construct and by the method factor. We found that the average variance explained (AVE) by the indicators is 0.73, whereas the average method-based variance is 0.007. None of the method factor loadings are significant. These tests suggested that common method variance is unlikely to pose a serious threat to the validity of the results.

Third, the correlation matrix (Table 3.8) did not indicate any exceptionally correlated variables (highest correlation among principal constructs is r = 0.62); evidence of common method bias usually results in very high correlations r >0.90 (Bagozzi et al. 1991).

In summary, these three tests suggest that common method bias does not account for the study's results.

Measurement Validation

To validate our instrument, convergent and discriminant validities were tested (Hair et al. 2006). We assessed convergent validity by examining the Cronbach's α (CA) (>0.7), composite reliability (>0.7), average variance extracted (AVE) (>0.5), and factor analysis results (Straub et al. 2004).

The descriptive statistics, reliabilities, and AVE of the principal constructs are shown in Table 3.7. The correlation matrix and the square root of AVE of the principal constructs are shown in Table 3.8.

As the results shown in Table 3.7, the factor loading of each item is found to be larger than 0.7 on its own construct. In addition, all the values for CA and CR are greater than 0.7 and the values for AVE are greater than 0.5, satisfying the criteria suggested by Straub et al. (2004). These results demonstrate sufficient convergent validity for all constructs. Discriminant validity was assessed by examining the indicator-factor loadings and comparing AVEs with inter-construct correlations (Gefen and Straub 2005). The results in Table 3.7 show that all indicators load more strongly on their corresponding constructs than on other constructs in the model and the square root of AVE is larger than the inter-construct correlations in Table 3.8. Overall, the results demonstrate sufficient discriminant validity of all constructs.

Table 3.7 Factor Loadings and Descriptive Statistics						
	Item Loading	**Mean**	**Std Dev**	**CA**	**CR**	**AVE**
IT-enabled Exploratory Learning Capability (IT-Epr)						
ITEXPLOR1	0.91	4.93	1.27	0.96	0.97	0.77
ITEXPLOR2	0.92					
ITEXPLOR3	0.88					
ITEXPLOR4	0.89					
ITEXPLOR5	0.81					
ITEXPLOR6	0.87					
ITEXPLOR7	0.88					
ITEXPLOR8	0.86					
ITEXPLOR9	0.89					
IT-enabled Exploitative Learning Capability (IT-Epi)						
EXPLOIT1	0.86	4.60	1.19	0.93	0.95	0.78
EXPLOIT2	0.94					
EXPLOIT3	0.91					
EXPLOIT4	0.85					
EXPLOIT5	0.87					
IT-enabled Social Integration Capability (IT-Soc)						
SOCIAL1	0.92	5.00	1.24	0.94	0.96	0.85
SOCIAL2	0.90					
SOCIAL3	0.91					
SOCIAL4	0.96					
Degree of Openness in Searching (Open)						
OPEN1	0.86	4.53	1.25	0.89	0.92	0.70
OPEN2	0.81					
OPEN3	0.87					
OPEN4	0.86					
OPEN5	0.77					
Inter-firm Resource Distance (ReDis)						
RESDIS1	0.95	4.44	1.47	0.95	0.96	0.86
RESDIS2	0.92					
RESDIS3	0.90					
RESDIS4	0.94					
Inter-firm Social Distance (SoDis)						
SOCDIS1	0.95	4.16	1.29	0.93	0.95	0.82
SOCDIS2	0.91					
SOCDIS3	0.83					
SOCDIS4	0.94					
Process Efficiency (Proce)						
PROCESS1	0.91	4.79	1.28	0.98	0.96	0.89
PROCESS2	0.96					
PROCESS3	0.95					
Product Effectiveness (Produ)						
PRODUCT1	0.94	5.20	1.28	0.93	0.95	0.87
PRODUCT2	0.93					
PRODUCT3	0.93					

Table 3.8 Correlations													
	IT-Epr	**IT-Epi**	**IT-Soc**	**Open**	**ReDis**	**SoDis**	**Proc**	**Prod**	**Age**	**FSize**	**R&D**	**Cost**	**PSize**
IT-enabled Exploratory Learning (IT-Epr)	0.88												
IT-enabled Exploitative Learning (IT-Epi)	0.20	0.88											
IT-enabled Social Integration (IT-Soc)	-0.02	0.42	0.92										
Openness in Searching (Open)	0.12	-0.00	-0.32	0.84									
Inter-firm Resource Distance (ReDis)	-0.11	-0.11	-0.22	0.38	0.93								
Inter-firm Social Distance (SoDis)	-0.15	-0.15	-0.28	0.44	0.41	0.91							
Process Efficiency (Proc)	-0.12	0.40	0.62	-0.40	-0.38	-0.40	0.94						
Product Effectiveness (Prod)	0.11	0.28	0.08	0.19	0.44	0.11	0.21	0.93					
Firm Age (Age)	0.01	0.07	-0.02	-0.06	-0.09	-0.10	0.09	-0.06	-				
Firm Size (FSize)	0.05	0.05	-0.00	0.05	0.34	-0.01	0.05	0.13	0.33	-			
R&D Investment (R&D)	-0.05	-0.05	-0.09	0.03	0.01	-0.06	0.05	0.07	0.04	0.37	-		
Project Cost (Cost)	0.00	0.06	0.06	0.04	0.01	0.01	0.06	0.14	-0.01	0.12	0.07	-	
Project Size (PSize)	-0.00	0.02	0.12	0.01	0.03	-0.02	0.05	0.04	-0.06	0.17	0.20	0.45	-

- Excluded because of a single measure

+ Diagonal elements are the square root of AVE

Testing the Proposed Research Model

The proposed research model was tested with PLS. The PLS results are shown in Figure 3.2, including standardized path coefficients, significance based on two-tailed t-tests for our hypotheses, and the amount of variance explained (R^2). The significance levels were assessed with 500 bootstrap runs. The moderating effects of IT-enabled knowledge capabilities were tested as part of the overall structural model with interaction terms formed by cross-multiplying all standardized items of each constructs, following the procedure of Chin et al. (2003). We mean-centered the scores of the indicators before creating the interaction terms to minimize multicollinearity, which might arise from high correlations between the interaction and the main effects terms.

For the structural model testing, we first estimated a structural model of dependent variable with only control variables (Model 1). Next, we added the direct effect of independent variables (Model 2). Finally, we added the theoretical variables of control variables, direct effect of independent variables, and the interaction constructs (Model 3) to determine their additional effects on explaining the additional variance of performance.

Table 3.9 shows the results of hypotheses testing of inter-firm resource distance and social distance. For the inter-firm resource distance, the full model (Model 3) explains 34% of the variance in the inter-firm resource distance. It also shows that none of the control variables are significant. With the addition of the direct effect of theoretical variables (Model 2) to the control variables model (Model 1), 29.7% incremental variance in the inter-firm resource distance was explained. As hypothesized, the degree of openness of searching positively affects the inter-firm resource distance, thus supporting H1a. However, with the addition of the interaction effect of theoretical variables (Model 3) to the previous model (Model 2), only 3% incremental variance in the inter-firm resource distance was explained. The interaction of IT-enabled exploratory learning capability and degree of openness in searching, is not significant, and thus does not support H4a.

For the inter-firm social distance, the full model (Model 3) explains 39% of the variance in the inter-firm social distance. It also shows that the control variable industry dummy 2 is significant. With the addition of the direct effect of theoretical variables (Model 2) to the control variables model (Model 1), 31% incremental variance in the inter-firm social distance was explained. As hypothesized, the degree of openness of searching positively affects the inter-firm social distance, thus supporting H1b. However, with the addition of the interaction effect of theoretical variables (Model 3) to the previous model (Model 2), only 3% incremental variance in the inter-firm social distance was explained. The interaction of IT-enabled exploratory learning capability and degree of openness in searching, is not significant on the inter-firm social distance, and thus does not support H4b.

Table 3.10 shows the results of hypotheses testing of process efficiency and product effectiveness. For the process efficiency, the full model (Model 3) explains 52% of the variance in the process efficiency. It also shows that none of the control variables are significant. With the addition of the direct effect of theoretical variables (Model 2) to the control variables model (Model 1), 45% incremental variance in the process efficiency was explained. As hypothesized, the inter-firm resource distance negatively affects the process efficiency, thus supporting H2a and the inter-firm social distance also negatively affects the process efficiency, thus supporting H3a. With the addition of the interaction effect of theoretical variables (Model 3) to the previous model (Model 2), 2% incremental variance in the process efficiency was explained. As hypothesized, the interaction of IT-enabled social integration capability and the inter-firm social distance is significant, and thus support H6b. However, the interaction of IT-enabled social integration capability and the inter-firm resource distance is not significant, and thus does not support H6a.

For the product effectiveness, the full model (Model 3) explains 41% of the variance in the product effectiveness. It also shows that the control variable project cost is significant. With the addition of the direct effect of theoretical variables (Model 2) to the control variables model (Model 1), 28% incremental variance in the product effectiveness was explained. As hypothesized, the inter-firm resource distance positively affects the product effectiveness, thus supporting H2b. However, the inter-firm social distance does not significantly affect the product effectiveness, thus rejecting H3b. With the addition of the interaction effect of theoretical variables (Model 3) to the previous model (Model 2), 7% incremental variance in the product effectiveness was explained. As hypothesized, the interaction of IT-enabled exploitative learning capability and the inter-firm resource distance is significant, and thus support H5a. However, the interaction of IT-enabled exploitative learning capability and the inter-firm social distance is not significant, and thus does not support H5b.

Table 3.9 Results of Hypotheses Testing						
Dependent Variables	**Inter-firm Resource Distance**			**Inter-firm Social Distance**		
	Model 1	**Model 2**	**Model 3**	**Model 1**	**Model 2**	**Model 3**
Control variable						
Firm Age	-0.13	-0.12	-0.07	-0.10	-0.06	-0.05
Firm Size	0.13	0.09	0.08	0.05	0.01	0.02
R&D Investment	-0.03	0.00	0.02	-0.09	-0.06	-0.05
Industry dummy 1	-0.06	-0.00	-0.01	-0.06	-0.01	-0.01
Industry dummy 2	0.09	0.08	0.09	-0.17*	-0.18*	-0.16*
Industry dummy 3	0.05	0.00	0.01	0.02	-0.02	-0.01
Project Cost	-0.02	-0.02	-0.02	0.00	0.00	-0.00
Project Size	0.01	0.01	-0.00	-0.02	-0.02	-0.03
Direct effects						
IT-enabled Exploratory Learning Capability		0.25**	0.17*		0.20**	0.17*
Openness in Searching (H1a, H1b)		0.37**	0.36**		0.46**	0.43**
Interactions						
IT Exploratory *Openness (H4a, H4b)			0.21			0.15
R^2	0.04	0.31	0.34	0.05	0.36	0.39
Number of observations	258					
*p <0.05; **p <0.01						

Table 3.10 Results of Hypotheses Testing						
Dependent Variables	**Process Efficiency**			**Product Effectiveness**		
	Model 1	**Model 2**	**Model 3**	**Model 1**	**Model 2**	**Model 3**
Control variable						
Firm Age	0.10	0.08	0.05	-0.10	-0.06	-0.07
Firm Size	0.00	0.01	0.02	0.15*	0.07	0.07
R&D Investment	0.06	0.09	0.07	0.02	0.06	0.04
Industry dummy 1	-0.07	-0.09	-0.09	-0.14	-0.05	-0.05
Industry dummy 2	-0.11	-0.10	-0.08	-0.02	-0.07	-0.04
Industry dummy 3	-0.23	-0.12*	-0.11	-0.02	-0.01	0.03
Project Cost	0.07	0.05	0.07	0.14	0.13*	0.12*
Project Size	0.03	-0.04	-0.07	-0.07	-0.07	-0.06
Direct effects						
Inter-firm Resource Distance (H2a, H2b)		-0.19**	-0.19**		0.49**	0.46**
Inter-firm Social Distance (H3a, H3b)		-0.16*	-0.17*		-0.06	-0.03
IT-enabled Exploitative Learning Capability					0.33**	0.29**
IT-enabled Social Integration Capability		0.54**	0.48**			
Interactions						
IT Exploitative *Resource (H5a)						0.19*
IT Exploitative *Social (H5b)						0.11
IT Social *Resource (H6a)			-0.02			
IT Social *Social (H6b)			0.19**			
R^2	0.05	0.50	0.52	0.06	0.34	0.41
Number of observations	258					
*p <0.05; **p <0.01						

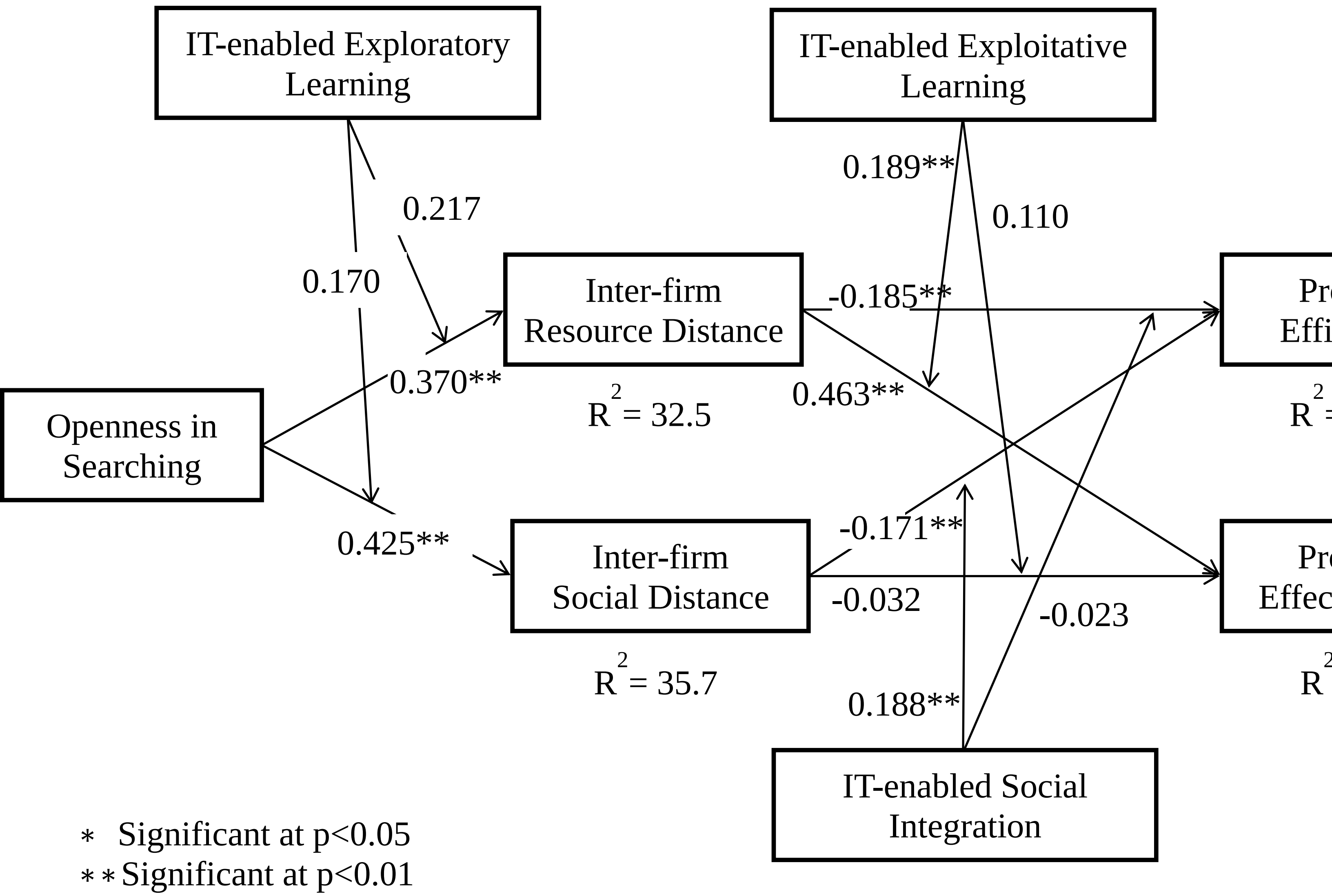

Figure 3.2 Research Model with PLS Results

Table 3.11 summarizes the hypotheses testing findings.

Table 3.11 Summary of Hypotheses Testing

Number	Hypothesis	Finding
H1a	Openness→resource distance (+)	Supported
H1b	Openness→social distance (+)	Supported
H2a	Resource distance→product effectiveness (+)	Supported
H2b	Resource distance→process efficiency (-)	Supported
H3a	Social distance→product effectiveness (+)	Not supported
H3b	Social distance→process efficiency (-)	Supported
H4a	IT-enabled exploratory learning ×openness→resource distance (+)	Not supported

H4b	IT-enabled exploratory learning ×openness→social distance (+)	Not supported
H5a	IT-enabled exploitative learning ×resource distance→product effectiveness (+)	Supported
H5b	IT-enabled exploitative learning ×social distance→product effectiveness (+)	Not supported
H6a	IT-enabled social integration ×resource distance→process efficiency (+)	Not supported
H6b	IT-enabled social integration ×social distance→process efficiency (+)	Supported

3.12 Discussion

3.12.1 Key Findings

This study uncovers four key findings. First, our study suggests the enablement role of IT in supporting the open innovation model. Various IT tools are widely used in open innovation projects and facilitate the entire open innovation process. Second, we found that open innovation project openness in the searching process has a positive impact on the inter-firm distance between the focal firm and its partner. Third, both inter-firm resource distance and social distance were found to have a negative influence on the efficiency of the open innovation project process. On the contrary, we noted that inter-firm resource distance is positively related to product effectiveness while we failed to detect a significant relationship between inter-firm social distance and product effectiveness. Fourth, we saw that IT-enabled exploitative learning capability facilitates the inter-firm learning when knowledge is implemented for a new product development by two parties. Hence, the relationship between inter-firm resource distance and product effectiveness is positively moderated. Similarly, IT-enabled social integration capability positively moderates the relationship between inter-firm distance and process efficiency by offering inter-firm connectivity and interactivity.

But IT-enabled exploitative learning capability does not moderate the relationship inter-firm social distance and product effectiveness and IT-enabled social integration capability does not moderate the relationship inter-firm resource distance and process efficiency. It is possible that IT-enabled exploitative learning capability focuses on the learning aspect between collaborative partners, hence does not interact with inter-firm social distance. Similarly, IT-enabled social integration capability facilitates collaborative firms to have more interactive communication and achieve mutual understanding, hence does not interact with inter-firm resource distance. Additionally, we did not detect a significant moderating effect of IT-enabled exploratory learning capability on the relationship between degree of openness in searching and inter-firm distance. Instead, IT-enabled exploratory learning capability directly affects inter-firm distance in a positive way.

3.12.2 Limitations and Suggestions for Future Research

Nonetheless, our study is not without its limitations. First, the data was collected in China, which is a developing country in a state of economic transition, with innovation collaborations being encouraged by the Chinese government. The findings based on China may be different from the conditions in other countries, and thus may result in potential generalizability problems when our research is applied outside the Chinese context. However, we expect this problem to be minimal since results from prior collaborative innovation studies that utilized samples from Chinese firms (e.g., Zhang and Li 2010) do not appear to be systematically different from the studies conducted in other countries (e.g., Leiponen and Helfat 2010) in terms of innovation collaboration. In fact, it would be useful for researchers of future research endeavors to enhance and test our model with data collected in different institutional contexts.

Another limitation that warrants mention in this research is the cross-sectional versus longitudinal nature of the study. In particular, a longitudinal study of the open innovation project process would have provided more information and may have enabled a more accurate portrayal of the consequences of open innovation. This suggests a useful avenue for additional research. Studies adopting a more longitudinal focus are also essential to understanding why some firms are better at profiting from open innovation. Such studies will yield insights into the exact nature of IT-enabled knowledge capability, how they develop and evolve in a firm, and how they can be leveraged for better open innovation performance.

Third, though we collected data from four industries that reflect a broad presence in the Chinese economy, they were all from the manufacturing sector. Our model can be tested in other industries including the service industry to examine the generalizability of our findings. Thus, this would be a useful avenue to extend our future research.

3.12.3 Implications for Theory and Research

While engaging in open innovation may be a growing trend, it is clear that a stronger theoretical foundation is needed in order to extract the potential it offers. Information systems have much to contribute to the development of this strategy due to the pivotal role of digital technologies in enabling open innovation initiatives. However, thus far, research on this important business paradigm has been conducted by the IT stream from a very narrow perspective. Our research, however, adds a much needed perspective to open innovation literature by building on the business value of IT in supporting open innovation for firms. With the rapid advances in IT, firms are able to engage in new product development virtually with other geographically distant firms (LaValle et al. 2011; Nambisan 2002). Though there is a general understanding about and broad evidence for IT to leverage external resources, there is limited theoretical and empirical research on examining the effectiveness of using IT-enabled knowledge capabilities to facilitate the successful implementation of open innovation projects. To fill this research gap, this study exposes the differentiated roles played by IT-enabled exploratory learning capability, IT-enabled exploitative learning capability and IT-enabled social integration capability, in open innovation projects. This study develops a theory for open innovation by demonstrating the IT-enabled knowledge capability and the degree of project openness in the searching process, and its impact on open innovation performance.

Second, this study serves as one of the earliest works in defining the degree of openness in open innovation projects and investigating the influential role of openness. Although the question of openness in open innovation has been addressed in the previous literature, the definition of open innovation and the strategies that firms can apply in successfully implementing open innovation have yet to be systematically examined. This study will fill this research gap by investigating the impact of varying degrees of openness in the searching process on organizational open innovation performance. In addition, this study also explores the openness concept through both qualitative multiple case studies and a large-scale quantitative survey. This paper contributes to the existing, predominantly case-based literature on open innovation, by operationalizing the degree of openness and exploring how these degrees of openness are associated with new product development performance using survey data. Furthermore, these results point to the unexpected conclusion that the completion of projects incorporating openness is slower compared to projects incorporating less openness.

Third, this work expands the reconceptualization of the ACAP theory of Zahra and George (2002) by invoking it within the IT context. It systematically establishes that the knowledge capabilities influencing the open innovation performance can be, in part, created and augmented through IT. Building on the findings of qualitative multiple case studies and the ACAP theory, this study develops the concept of IT-enabled knowledge capabilities, which enables us to both theoretically and empirically demonstrate the roles and importance of different ITs in driving firms' open innovation as manifested in the forms of two open innovation project outcomes: process efficiency and product effectiveness. In other words, IT provides for and enables a set of knowledge capabilities, which build on and support each other to differentially impact open innovation.

3.12.4 Implications for Practice

Despite a widespread belief that the open innovation model is imperative for creating and profiting from technology, limited practical guidance is available to assist managers in understanding and managing the open innovation activities as this is a novel approach. The findings of this study provide managers with the conceptual clarity of project openness in the searching process, and enables them to mindfully select appropriate degrees of openness as well as to decide on suitable IT facilitators, so as to achieve desirable innovation outcomes. First, managers need to be aware of the essential business value of IT in the open innovation context. The basic contention here is that merely investing in building external collaborative relationships and incorporating external knowledge may not necessarily improve organizational innovation performance. It is the implementation of IT within open innovation strategies that is more important. For example, managers need to routinely take IT into consideration when formulating and executing open innovation projects. In recognizing the value of IT as an enabler of open innovation processes, managers may legitimize the role of the CIO and elevate it from that of just a technologist, to a champion of the implementation of open innovation.

Second, the results of this study may also suggest that managers need to pay attention on mindfully designing and deploying different IT capabilities for supporting open innovation projects. For instance, IT-enabled exploratory learning significantly enhances a firm’s ability in its open search for an open innovation partner in a different area of expertise. Firms can use the environmental scanning tools to explore potential partners within a large range of expertise. For a firm intending to bridge the knowledge gap with a partner, the IT systems used in open innovation activities (e.g., visualization tools, knowledge management systems, decision support systems, collaborative innovation systems) should be employed to facilitate inter-firm learning. For a firm that wishes to cultivate shared social norms and mutual understanding with a partner, the communication ITs (e.g., emails, video conferencing tools), which provide IT-enabled social integration capabilities, can be deployed to achieve an efficient open innovation process. These IT tools provide seamless connections to innovation collaborators and facilitate the easy transfer of aggregate relevant information from innovation collaborators.

Third, managers should take heed that the success of open innovation lies in the effective control of inter-firm distance. Our findings point to the conclusion that in the searching process, greater openness in projects leads to slower completion in comparison with projects incorporating less openness; however, openness in projects also result in better product effectiveness. This is due to the inter-firm distance between the focal firm and its open innovation partner participating in an open innovation project. Thus if the new product time to market is critical, then managers should consider forming a relationship with a partner with similarities in knowledge domain and organizational design.

CHAPTER 4.

CONCLUSION

Open innovation is an indispensable factor in an increasingly competitive and fast-paced environment, precipitated by new technological developments. The recent open innovation in almost all countries and all domains has at least one merit: It has put the notion of openness in the forefront. Indeed, although proprietary and exclusive strategies are essential features of our modern economies, openness has also proved to be important elements of the innovation process. A recent example is the development of the Apple iPod: the external entrepreneur Tony Fadell developed the idea and concept, Apple hired a 35-person team and partners from Philips, Ideo, General Magic, Apple, Connectix and WebTV to develop the iPod system. A huge alliance worked behind the curtain to produce the Apple product. There are also other prominent examples from other sectors. In this thesis we focused on the open innovation from an organizational perspective. Modern technology is becoming so complex that even large firms cannot afford to develop a new product alone. Consequently, there is a strong trend toward openly searching or external knowledge and incorporating external collaborators in innovation process (Hagedoorn and Duysters 2002).

However, extant research on open innovation focused primarily on emphasizes why organizations acquire resources from external environment for innovation (e.g., Keupp and Gassmann 2009). Limited research to our knowledge has examined how organizations manage and leverage their external collaborators for value creation.

Firstly, similar to the traditional closed innovation processes, industry is starting to professionalize the internal processes to manage open innovation more effectively and efficiently. As the first step of open innovation, Open search for external knowledge therefore becomes critical. Nevertheless, it is currently still more trial and error than a professionally managed process. The variance between a best practice in open search and the average is huge. This difference will significantly impact how firms benefit from external knowledge. Therefore, understanding the process during which firms effectively and efficiently open search for external knowledge is important. Further investigation along these lines is thus required.

Secondly, while the possibilities of opening the innovation process are growing, metrics systems are not yet adapted to monitor and measure the value of activities. In the context of open innovation, one critical characteristic of organizational open search behavior is the openness of the search in external environment. How does the openness of their open search behavior influence the firms' open innovation process and outcome performance? These questions lie at the heart of recent research on open innovation and has not been investigated comprehensively (Chesbrough 2003; Helfat and Quinn 2006; Laursen and Salter 2006).

Lastly, although organizational openness has considerable potential to contribute to innovation performance, significant internal supporting resources are entailed to unlock its potential (Chesbrough and Garman 2009). IT is important for the deployment of open innovation strategy. Effective ITs may help reduce knowledge search cost and facilitate knowledge sharing (Chi et al. 2010; Joshi et al. 2010) and impact the implementation of open innovation in firms. Prior literature emphasized that IT creates the necessity for the implementation of open innovation (Dodgson et al. 2006). However, there is a lack of research investigating how IT can be used to effectively support organizational deployment of open innovation strategy and foster innovation performance.

Therefore, this thesis focused on filling the three research gaps in the current literature: the open search process in an external environment, the impact of an open search on innovation performance, and the role of IT in the open innovation context. And thus it aims to investigate the successful implementation of open innovation activities to create value for organizations. This thesis comprised two empirical studies: Study One specifically focused on the open search process and the role of IT in this process, while Study Two focused on the impact of the "openness" of an open search on project innovation performance and the tools from IT that support open innovation projects.

Open search is a fundamental activity that should positively enhance the operations of firms. This thesis adopted a deep, but contextual perspective into how firms evolved from their use of conventional search patterns to their use of open search patterns, their impacts on search outcomes, and the conditions under which they would be effective. Based on these analyses, this study proposes a tentative theory on the open search and highlights the key implications for the search literature and the organizational design literature. Practical implications on when and how different open search patterns should be deployed were also highlighted. This study is the initial step towards developing an insightful theory on how ITs fundamentally transform the nature of work in firms, especially with regard to the use of the open search in their organizations.

Additionally, this thesis seeks to gain further insights into how the increasing openness in external searches enhances the operations of organizational open innovation projects. It focuses on the impact of open search on open innovation project performance and how open innovation project is supported by different IT-enabled knowledge capabilities. Particularly, our study discovers three distinct types of IT-enabled knowledge capabilities, i.e., IT-enabled exploratory learning, IT-enabled exploitative learning and IT-enabled social integration capability. The findings reveal that openness in searching creates a positive impact on project effectiveness, but results in a negative influence on the efficiency of the process in an open innovation project.

We believe that this thesis contribute to extant literature for academics and practitioners. Particularly, this thesis reveals three new patterns of open search due to the enabling role of IT, and these are: centralized, differentiated, and decentralized open search patterns. Drawing on the perspectives of the upper echelon theory and organic/mechanistic organizational forms, we developed a theoretical exposition of open search research by 1) evaluating the impact of each open search pattern on efficient search outcomes; 2) understanding appropriate IT mechanisms for each identified pattern; and 3) revealing the relationships of three open search patterns by considering uncertainty as a unique trait of open innovation. We seek to contribute to building a middle-range theory on open search by discovering the different open search patterns and their varying impacts on search outcomes. It also provides managers with the conceptual clarity to use open search patterns appropriately, and enables them to mindfully select appropriate work arrangements so as to achieve desirable open search outcomes.

On the other hand, as open search becomes increasingly adopted for organizational innovation, a more comprehensive understanding of the outcomes of the open search is required as well as how this influences the performance of an open innovation project. In this thesis, we investigated how specific degrees of openness in the searching process shape the inter-firm distance between open innovation partners, and consequently lead to open innovation product effectiveness and process efficiency. Based on the absorptive capacity theory, this study uncovers the differentiated roles of IT-enabled exploratory learning capability, IT-enabled exploitative learning capability and IT-enabled social integration capability in open innovation projects. It develops a theory for open innovation by demonstrating the IT-enabled knowledge capability and degree of project openness in the searching process, and its impact on open innovation performance. Practically, this study also suggests that managers need to pay attention to mindfully designing and deploying different IT capabilities for supporting open innovation projects.

Generally, it is evident that more firms are increasingly exploiting the power of external knowledge and incorporating it into their innovation processes to create values. While the adoption of open innovation may be a growing trend, it is evident that a more insightful theory is needed in order to discern the maximum potential it offers. Other than the theories investigated in this thesis, future research can further investigate other aspects of open innovation. For instance, one phenomenon worth exploring is that of cross-industry innovation. Supported by IT, firms can now reach distant knowledge areas through open search, and hence cross-industry innovation is rapidly gaining popularity. While most studies on open innovation focus on traditional external sources within the same value chain, such as customers, suppliers, competitors or cooperation partners, future research can explore innovation created in cross-industry cooperation. Furthermore, there is a lack of insight into how cross-industry innovation is responsible for explorative or exploitative outcomes of open innovation.

In the domain of the open search process, there are considerable opportunities for researchers of future studies to conduct more in-depth investigations. For instance, citing the cross-case analysis of Study One, uncertainty was chosen as the key dimension in separating open search patterns. While the selection was based on the unique nature of open innovation, further research could employ other dimensions to discuss the possible combinations of open search patterns.

For sure, not everything can be open and closed behaviors will always be necessary to innovation. Yet, we believe, like Nelson (2004) that any innovation is somehow built upon something that is open and thus, that this something must remain open. Open and closed dimensions are two complementary facets of innovation that are equally important. Open innovation does not substitute for corporate innovation but co-evolve with it. Today's business reality is not based on pure open innovation but on firms that invest simultaneously in closed as well as open innovation activities. Too much openness can negatively impact firms' long-term innovation success, because it could lead to loss of control and core competences. Moreover, a closed innovation approach does not serve the increasing demands of shorter innovation cycles and reduced time to market. The future lies in an appropriate balance of the open innovation approach. This demand creates an increasing urge for future research to identify the cause-and-effect relationship of open and closed innovation activities, find the appropriate contributors and integration mechanisms. Generally, the opportunities for future research abound and further research will contribute positively to a better understanding of mechanisms on open innovation.

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