THE EMERGING INNOVATORS IN THE TECHNOLOGICAL KNOWLEDGE ACCUMULATION NETWORKS OF MULTINATIONAL CORPORATIONS

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The last couple of decades have witnessed an enormous expansion of the technological knowledge accumulation networks of multinational corporations (MNCs). These expanded MNC networks incorporate some of their subsidiaries in developing countries. However, our understanding of these emerging innovators in MNC networks is still limited. This dissertation focuses on the knowledge accumulation of subsidiaries that were recently incorporated into MNC networks, using patent data from the US Patent and Trademark Office (USPTO).

The dissertation comprises of three studies. The first study investigates the pattern of internal and external knowledge access by foreign-owned subsidiaries located in China. The results show that the internal and external knowledge sources of overseas subsidiaries might be differently connected to the local generation of new knowledge in distinctive ways. In particular, when building upon complex combinations of knowledge across different technological fields, Chinese-located subsidiaries are more likely to rely upon international rather than local sources. These findings suggest that overseas subsidiaries located in non-traditional 'centers of excellence' might follow a distinctive path of local capability development.

The second study focuses on the strategic considerations when firms access external

technological knowledge. The results show that only certain categories of non-core knowledge are strategically sourced relatively more externally than is core knowledge. In particular, marginal technological knowledge may be accessed externally to experiment with potential technological opportunities in the long run; while background technological knowledge is more likely to be accessed externally to better coordinate supply chain activities and to identify new technological opportunities related to those activities. These findings contribute to a better understanding of the nature of firms' combinative capabilities.

The third study investigates the strategic roles of overseas subsidiaries in the technological knowledge accumulation networks of MNCs, by comparing the technological knowledge inflow and outflow patterns of different subsidiaries. The results suggest that subsidiaries located in China may have come to play a strategic role as specialized hubs, whereas their counterpart peer subsidiaries in the equivalent MNC group in developed countries are more likely to be recognized as 'centers of excellence' in MNC networks. The implications for the organizational restructuring of MNCs are discussed.

Preface

This dissertation would not have been possible without the constant help and support of my advisor, Dr. John Cantwell, whose wisdom, optimism and concern sustained and enriched me throughout my PhD years in Rutgers. I am indebted as well to the members of my dissertation committee, Dr. George Farris, Dr. Michelle Gittelman, and Professor Robert Pearce from the University of Reading in the UK. They have given freely of their time and expertise to advice me. Also, I would like to thank the Technology Management Research Center at Rutgers for providing generous financial assistance on my research.

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CHAPTER 1: INTRODUCTION

Historical accounts emphasize the role of in-house R&D for firms to keep up in the competition of technological innovation (Chandler, 1990). Later, at least partly because of the increasing complexity and costs of technological innovation, firms and scholars have started to appreciate the necessity and benefits of utilizing external technological knowledge in knowledge accumulation process (Cantwell, Noonan, & Zhang, 2008). However, firms are heterogeneous in their ability '*to recognize the value of new, external information, assimilate it, and apply it to commercial ends*', since the accumulation of such absorptive capacity relies on a firm's level of existing knowledge, resulting from its prior investments in in-house R&D (Cohen & Levinthal, 1990). By the same token, Cantwell and Barrera (1996) argued that '*a firm's own problem solving and learning sets the agenda for what is usefully searched for when monitoring the external environment*'. In other words, in-house R&D and external knowledge sourcing work complementarily in the knowledge accumulation process of firms. A shared wisdom today is that firms learn new knowledge by synthesizing and applying current and acquired knowledge, namely a combinative capability (Kogut & Zander, 1992). In general, in-house R&D and external knowledge are two complementary sources, from which firms accumulate technological knowledge by combining current and acquired knowledge.

While the knowledge accumulation of firms involves both internal and external knowledge access, the restructure of Multinational Corporations (MNCs), as knowledge creation has become more geographically dispersed within the firm, requires a closer relationship between internal and external knowledge networks. In particular, to generate competences, overseas subsidiaries have to combine knowledge from both their internal

MNC network, and from a local network of other firms and organizations (Andersson & Forsgren, 2000; Bartlett & Ghoshal, 1986; Birkinshaw & Hood, 1998; Cantwell & Mudambi, 2005). Yet previous literature has been dominated by studies investigating competence-creating activities of subsidiaries located in some geographical 'centers of excellence', especially in the triad areas. However, since 1990s some MNCs, for instance Microsoft, Siemens and IBM, have started to build leading-edge R&D facilities in some developing countries, or to transform some of their existing research laboratories in those countries into competence centers for their individual MNC groups (Gassmann & Han, 2004; Li & Zhong, 2003; von Zedtwitz, 2004). According to WIR (2005), the accumulated R&D investment of MNCs in Mainland China (thereafter China) had reached approximately $4 billion by June 2004. By 2005 there were reportedly as many as 750 foreign-invested R&D centers in China (China Daily, 2005), the number of which has reached around 1100 by the end of 2008 (Bruche, 2009). Under the notion of network MNCs (Andersson & Forsgren, 2000; Ernst & Kim, 2002; Ghoshal & Bartlett, 1990; Ghoshal & Nohria, 1989), subsidiaries are differentiated based on each subsidiary's unique and idiosyncratic patterns of internal and external network linkages (McEvily & Zaheer, 1999; Phene & Almeida, 2003). It is likely that foreign-owned subsidiaries in China may have a distinctive pattern of knowledge accumulation, given their emerging status in the knowledge generation networks of MNCs. Consequently, the first study of this dissertation focuses on the knowledge accumulation pattern of foreign-owned subsidiaries in China that are amongst the most significant contributors to the new emerging market economy dimension of the global knowledge networks of MNCs.

Evolutionary theory emphasizes the path dependence when firms learn new knowledge (Nelson & Winter, 1982). It's also essential for firms to experiment with new capability development through a process of trial-and-error learning (Kogut & Zander, 1992), in which the firm's expectation on future opportunities may play an important role. While the internal knowledge sets the main trajectory for the knowledge accumulation of a firm, the external knowledge provides the opportunities to experiment, i.e. trial-and-error learning, along that trajectory. Previous literature shows that firms tend to rely on external technology sources for peripheral technologies to complement internal R&D in their core areas (Lichtenthaler, 2009). In other words, it is the non-core rather than core technological knowledge of a firm that is sourced from external sources. Since a firm may be reluctant to take the risk of being dependent in its core or strategic important areas of technological expertise (Granstrand, Patel, & Pavitt, 1997; Mowery, 1983), in-house R&D becomes the major source for distinctive core technological knowledge of the firm. While previous literature contributes to our better understanding of why firms retain core technological knowledge generation in house, it explains only half of the story. The access of external non-core knowledge could also involve some strategic considerations of firms, which have been underestimated in previous literature. Such strategic considerations may be especially important for MNCs. While more and more overseas subsidiaries have started to take responsibilities for generating competences for their individual parents, the geographically dispersed knowledge generation networks of MNCs have become a potential strategic asset by exposing the firm to different host locations and thereby diversified external knowledge sources (McEvily & Zaheer, 1999). Such diversified external knowledge sources allow MNCs to experiment with different combinations of internal and external knowledge, and thereby to identify more future development opportunities. By employing the technological categories of Granstrand, Patel and Pavitt (1997), namely core, niche, background and marginal technologies, the second study of this dissertation represents one of the first attempts to empirically test the strategic considerations of firms in their external knowledge accession.

Internalization approach explains the existence of the MNC and the way that it behaves using the concept of internalizing imperfect markets (Buckley & Casson, 2009). In particular, firms involve in foreign direct investments (FDIs) at least partly because technology transfer could be more efficiently conducted within firms than through arm-length markets. Evolutionary theorists further argue that firms do better than market in the sharing and transfer of knowledge '… *because they provide a social community of voluntaristic action structured by organizing principles'* (Kogut & Zander, 1992). While the initial FDIs decisions might mainly involve the considerations of knowledge transfer from headquarters to overseas subsidiaries, the organizational restructuring of MNCs since the 1980s, by allocating more strategic roles to some overseas subsidiaries (Bartlett & Ghoshal, 1986; Birkinshaw & Hood, 1998), has facilitated the two-way knowledge flow between headquarters and subsidiaries, and between subsidiaries (Andersson & Forsgren, 2000). Consequently, many studies have investigated the strategic roles of subsidiaries by looking at the internal knowledge flow patterns of the subunits of MNCs (Gupta & Govindarajan, 1991, 1994; Schulz, 2001). Other literature, on the other hand, emphasizes the relation between the local embeddedness of overseas subsidiaries and their strategic roles (Andersson & Forsgren, 2000; Andersson, Forsgren, & Holm, 2002). Whereas the external technical embeddedness of a subsidiary may positively associate with its importance for peer units' capability development (Andersson, 2003; Pearce, 1989), previous literature that simultaneously investigates the local embeddedness and internal knowledge flows is still rare. Consequently, the third study of this dissertation assesses the strategic roles of different subsidiaries of selected MNCs by incorporating both the internal knowledge flow and external knowledge accession patterns of the subsidiaries in the analysis.

This dissertation focuses on the pattern of internal and external knowledge access by the overseas subsidiaries of MNCs. In addition to incorporate the path dependent learning in the knowledge accumulation of firms, we investigated the potential strategic considerations when firms access certain categories of external non-core technological knowledge. The first two studies employ patents granted to the world largest firms by the United States Patent and Trademark Office (USPTO) for inventions attributable to their subsidiaries in China between 1996 and 2005. The findings of the first study are consistent with the suggestion about the effects of path-dependent learning on the knowledge accumulation of firms. Yet we found that the internal and external knowledge sources of overseas subsidiaries might be differently connected to generate new knowledge in locally distinctive ways. In particular, while internal knowledge contributes to the accumulation of technological knowledge within a field, international external knowledge may sometimes be accessed instead of local external knowledge as the major source for technological knowledge accumulation across fields. This finding suggests that overseas subsidiaries located in non-traditional 'centers of excellence' might follow a distinctive path of capability development.

In the second study, we followed Granstrand, Patel and Pavitt (1997) to differentiate non-core technologies into three categories, namely niche, background and marginal. We found that the foreign-owned subsidiaries in China tend to access external background and marginal technological knowledge, but not external niche technological knowledge (with core technological knowledge as the reference category). In other words, only certain categories of non-core knowledge are strategically sourced relatively more externally than is core knowledge. Since the marginal technologies of a firm may not generate any immediate interests for the firm, it is likely that the firm access external marginal technological knowledge to experiment with potential directions for long-term development; meanwhile, firms may also access external background technological knowledge to better coordinate their supply chain activities and to identify new technological areas related to those activities, given that background technologies are directly related to supply chain activities. The findings suggest that firms may take an option approach toward external knowledge accession.

The third study uses patents granted by the USPTO between 1996 and 2005 to the world's largest firms for inventions attributable to their overseas subsidiaries; in particular, we match the patents invented by foreign-owned subsidiaries in China with those invented by the peer subsidiaries of the equivalent MNC group in developed countries that cite, at least, one of the same patents from their common parent company. The results show that the overseas subsidiaries in developed countries have tended to combine local internal and local external knowledge in generating new technological knowledge, which then has contributed to the competence creating at corporate level. Meanwhile, the overseas subsidiaries in China have relied upon international internal and external knowledge inputs in generating new technological knowledge, which has been mainly used to build their own subsidiary-level competency. Although over time the technological knowledge generated by foreign-owned subsidiaries in China has picked up a significant role in the competence creating of the peer subsidiaries of the equivalent MNC, the contribution of the knowledge is still remained at subsidiary level. The significant knowledge linkages between subsidiaries and the rest of the MNC support the view of the organizational restructuring of MNCs. The knowledge flow patterns revealed in this study suggest that foreign-owned subsidiaries in China may have been assuming a strategic role of specialized hubs, whereas the peer subsidiaries of the equivalent MNC in developed countries are more likely to be recognized as 'centers of excellence' in the knowledge generation networks of MNCs. Moreover, while the organizational structure of MNCs may overcome some of the difficulties in long distant knowledge transfer within the firm, the ability of foreign-owned subsidiaries in China to draw upon international external knowledge suggests that a geographically dispersed organizational structure may also facilitate long distant knowledge transfer across organizational boundaries. It could be another potential advantage of the organization structure of MNCs under open innovation systems.

This dissertation has three major contributions. First, the findings of this dissertation contribute to a better understanding of the knowledge accumulation of firms by incorporating both path-dependent learning and experiments of firms in the analysis. The empirical results suggest that firms may have long-term or short-term strategic considerations in their technological knowledge accumulation process, especially their access of external technological knowledge. The results are consistent with the argument of open innovation literature that emphasizes the importance of external knowledge for firms (Chesbrough, 2006). Moreover, the findings also contribute to a better understanding of the combinative capability of firms by showing what types of technological knowledge have been combined by the firm to generate new knowledge. Second, while knowledge can be transferred more efficiently within a firm than through arm-length markets (Buckley & Casson, 2009; Kogut & Zander, 1992), the ability of foreign-owned subsidiaries in China to access geographically distant knowledge suggests that the geographically dispersed organizational structure of MNCs may also facilitate the geographical distant knowledge transfer across organizational boundaries. Such a geographically dispersed organizational structure of MNCs may represent another potential advantage of MNCs, especially under open innovation systems. Also, the results of this dissertation support the view of organizational restructuring of MNCs by showing significant knowledge linkages between overseas subsidiaries and the parent and peer subsidiaries of the equivalent MNC. Third, many previous literature devoted to explain why foreign-owned firms moved their research and development activities to some developing countries (Gassmann & Han, 2004; Li & Zhong, 2003), this dissertation represents one of the first efforts to explore the knowledge accumulation pattern of foreign-owned firms in one of those developing countries. As we expected, the results show the capability upgrading of foreign-owned subsidiaries in China during the ten-year period studied in this dissertation. More importantly, those subsidiaries in China may follow a different path of capability development by significantly accessing international external knowledge instead of local external knowledge in their knowledge accumulation process. The knowledge inflow and outflow patterns suggest that those subsidiaries and their peer subsidiaries of the equivalent MNC in developed countries may play different strategic roles in the international knowledge generation networks of MNCs. The major implication of the findings is on the evaluation and control policies of MNCs to better manage and coordinate the geographically dispersed knowledge generation activities within the firm.

This dissertation is organized as follows. Chapter 2 reviews literature, and Chapter 3 develops hypotheses. Data, method and empirical results are described in Chapters 4 and 5. The last chapter discusses findings and implications.

CHAPTER 2: LITERATURE REVIEW

2.1 Organizational Learning Mechanisms

In Schumpeterian literature, organizational learning and thereby firm heterogeneity are expected to be the product of localized search efforts in and around production (Nelson & Winter, 1982). Evolutionary theorists argue that the 'localized search' follows the so-called 'path dependence' nature of learning. It is that firms learn in areas closely related to their existing practice. The 'absorptive capacity' of a firm (Cohen & Levinthal, 1990) implies too that the search for new knowledge requires a relevant established base on which to build. Whereas the 'path dependence' has been well recognized as a general rule in organizational learning, firms need to remain cautious to avoid 'locked in'. Arthur (1989) argues that modern, complex technologies often display increasing returns to adoption, since the technology could be progressively improved through 'learning by using'. Such increasing returns may allure firms to become 'locked in' under a dominant technological trajectory and cause inflexibility (Arthur, 1989). In this sense, it's essential for firms to experiment on new capabilities through a process of trial-and-error learning on top of the path dependent learning. It is that in addition to 'localized search', 'environmental selection' might also be involved in organizational learning (Kogut & Zander, 1992). In particular, firms learn new knowledge by synthesizing and applying current and acquired knowledge, namely a combinative capability, which could be further interpreted as 'the intersection of the capability of the firm to exploit its knowledge and the unexplored potential of the technology…' (Kogut & Zander, 1992). In other words, firms learn new knowledge through combining internal and external learning; moreover, the combination of current capabilities and expectations regarding future opportunities also helps to determine the direction of knowledge learning of firms through trials. In this sense, the knowledge of a firm can be considered as owning a portfolio of options on future development (Bowman & Hurry, 1993; Kogut, 1991; Kogut & Zander, 1992).

Firms, especially large corporations, build up and maintain a spectrum of technologies ranging from distinctive core to marginal technologies in order to explore and experiment with new technologies for the future (Granstrand et al., 1997). From the perspective of real options theory, it could be interpreted as the intuition of ‘keeping options open’ against the unforeseeable future in order to retain the right/ability to future investment choices without being obliged to invest; specifically when developing new capabilities or learning new knowledge, a firm should initially make small investments that ‘not only limit the downside risk of exploration for the firm, but they also help experimentation and learning’ (Bowman & Hurry, 1993). While a high proportion of technology is generated within innovating firms themselves, the acquisition of technological knowledge from other firms and organizations is always involved in the process (Pavitt, 1988a). External knowledge sourcing sometimes provides a cheaper and faster way to gain the initial access to new technological knowledge, which could be simply new to a firm, and thereby facilitates the firm to experiment and exploit the unexplored potential of its current technologies. In particular, the access of external knowledge helps a firm to build up a more diversified portfolio of options on future knowledge development by increasing the variety of combinations of its current capabilities and technological knowledge that is expected to be future opportunities.

2.2 Organizational Boundaries and the Knowledge Accumulation of MNCs

While organizational learning involves both internal and external learning, the latter normally calls forth knowledge exchanges between firms and between firms and other organizations. When the flows of knowledge between firms, and the extent to which firms draw upon external capabilities rises sufficiently, the organizational boundaries between firms may begin to become blurred. For instance, to differentiate knowledge outsourcing from production outsourcing, Brusoni, Prencipe and Pavitt (2001) defined an organization as ‘the network of firms that cooperate to design the whole product, manufacture its component, assemble and market it’. The internal learning of large firms may also involve knowledge creation across various divisions or business units. This is particular true for MNCs, given that more and more overseas subsidiaries have started to take responsibilities for generating competences for their individual parent groups, i.e. the so-called competence-creating subsidiaries (Andersson & Forsgren, 2000; Bartlett & Ghoshal, 1986; Birkinshaw, Hood, & Jonsson, 1998; Cantwell & Mudambi, 2005). The barriers to knowledge exchange between different units of a large firm can become as much of an issue as the boundaries between firms, namely the tension between the pull towards integration and consistency within an MNC group network, both in technological and organizational terms, and the pull towards the local embeddedness in their host country environment (Phene & Almeida, 2003). In this context, previous literature found that subunits need to connect local inter-firm knowledge network and international intra-firm knowledge network (Cantwell et al., 2008; Hedlund, 1986).

Yet the internal and external knowledge sources may still be connected differently across subunits. On one hand, the volume and direction of knowledge flows within an MNC could be different across subsidiaries (Andersson, 2003; Gupta & Govindarajan, 1994, 2000). On the other, although the competence-creating subsidiaries of an MNC share the same organizational boundary, there may still be plenty of rooms for variations in the knowledge acquisition of these subsidiaries. First, different host locations may facilitate different patterns of knowledge acquisition. Literature on geographical clusters shows that in addition to science-technology spillovers, the potential of intra- or inter-industry spillovers helps to explain the attraction of low-order or high-order ‘centers of excellence’ to firms, respectively (Cantwell & Piscitello, 2002). Moreover, unlike the firm-level heterogeneity, subsidiaries must further consider the integration requirement from their individual parent groups, namely the charter of a subsidiary (Birkinshaw & Hood, 1998), when acquiring external knowledge. In other words, subsidiaries may not acquire the external knowledge that beyond the sufficient level for fulfilling their mandates. Further still, subsidiaries may vary in their absorptive capacity due to the different path of knowledge accumulation that is, in turn, influenced by host locations and the corporate governance of MNCs. These potential variations in the internal and external learning may allow strategic considerations from subsidiary initiatives and corporate-level coordination perspective. As suggested by the literature of network MNCs (Andersson & Forsgren, 2000; Ernst & Kim, 2002; Ghoshal & Bartlett, 1990; Ghoshal & Nohria, 1989), subsidiaries are differentiated based on each subsidiary’s unique and idiosyncratic patterns of internal and external network linkages (McEvily & Zaheer, 1999; Phene & Almeida, 2003). More importantly, the geographically dispersed organizational structure of MNCs could be one of the basic competitive advantages of the firm (Andersson et al., 2002; McEvily & Zaheer, 1999). It is at least partly because the geographically dispersed competence-creating subsidiaries of MNCs allow the firm to access more diversified external knowledge.

2.3 Knowledge Accumulation at Subsidiary Level

2.3.1 Channels for knowledge accumulation

The importance of self-accumulation of technological knowledge has been visited and revisited by many scholars. Jaffe and Trajtenberg (1999) showed a rise in the share of 'self-cites' since the 1960s by looking at the citations of patents invented in the US, the UK, France, Germany, and Japan. In the same vein, Pearce (1999b), Cantwell, Noonan and Zhang (2008), Zhao (2006) and etc have found either the dominant role of or the growth of intra-firm knowledge accumulation under different empirical settings. While Bartlett and Ghoshal (1986) and Birkinshaw and Hood (1998) proposed the decentralized organizational structure in MNC's innovation management, the caution of being an 'isolated' subsidiary was introduced at the same time. Besides in the two seminal works mentioned above, interdependence between a subsidiary and other units in equivalent MNC group to maintain the subsidiary's strategic position has been emphasized by many studies. One of important characteristics of the interdependence would be the mutual knowledge flow between focal subsidiary and other units in the same parent group. This interaction could be further broken down into parent-subsidiary and subsidiary-subsidiary knowledge flows. While Gupta and Govindarajan (2000) and Schulz (2003) studied the intra-firm knowledge flow from subsidiary perspective, they treated peer subsidiaries the same as parent company when investigating knowledge providers or recipients in the process.

The knowledge accumulation through external networks by overseas subsidiaries has received tremendous academic attention. Knowledge providers in the external network include suppliers, customers, universities, public research institutes and sometimes even competitors. The knowledge accumulation in foreign-owned subsidiaries through the interaction with their local or global suppliers and customers has long been recognized (Pavitt, 1988a; Pearce, 1999a; White & Poynter, 1984). Moreover, according to Cantwell and Barrera (1996), as well as Cantwell and Colombo (2000), firms may go to their competitors for technological knowledge and aim to be more technological complementary. In the case of technological sourcing from universities and public research institutes, the accumulation process is normally associated with precompetitive research and subsidiaries with higher autonomy that evolve towards a 'competence creating' mandate in the terminology of Cantwell and Mudambi (2005), or the 'world/regional product mandate' in White and Pynter (1984). The image becomes more complicated when incorporating locational factors. Along with the decentralization of the MNC's own network, owning to local imperatives more and more overseas subsidiaries have begun to assume a broader responsibility for both host markets and home markets, even for regional or world markets. At the host country level, subsidiaries sometimes need to source knowledge from local firms, as local firms may possess advanced technological capability in some specialized areas that are not the forte of the MNC's home country (often the case of Korean or European MNCs investing in US (Phene & Almeida, 2003)). At the international level, partly with the assistance of modern communication technologies, subsidiaries can also access knowledge from external resources in other locations outside the host country. Some knowledge sourcing from distant locations may be unavoidable for subsidiaries with a reinforced product mandate role for regional or even world markets.

2.3.2 Factors influencing knowledge accumulation

The knowledge accumulation of an overseas subsidiary is influenced by the architecture of parent MNC group, as well as the capability and the strategic role of the subsidiary itself. Cantwell and Mudambi (2005) defined the competence-creating subsidiary as a subsidiary that has acquired a mandate to undertake some area of product development or some responsibility for international strategy development. Therefore, a competence-creating subsidiary has more local initiatives, autonomies, and higher extent of local embeddedness. Moreover, competence-creating subsidiary mandates tend to be the outcome of subsidiary evolution that depends on a combination of and an interaction between local initiative and parent company assignment (Cantwell & Mudambi, 2005). A similar argument can be found in Birkinshaw and Hood's (1998) study about the interplay between capability development (subsidiary side) and charter (MNC parent side) change during subsidiary evolution process, and also in researches of Dosi (1988) and Frost (2001). In other words, the characteristics of a subsidiary and its parent group all influence the acquisition of competence-creating mandate, and therefore the decisions of knowledge sourcing.

By studying foreign-owned subsidiaries in UK, Cantwell and Mudambi (2005) found that competence-creating subsidiaries have a higher propensity to source knowledge locally, whereas competence-exploiting subsidiaries tend to source knowledge intra-organizationally outside the host country. Similar arguments were made by Frost (2001) based on the nature of the subsidiary's innovation – i.e. whether the subsidiary's innovation is adaptive in nature, so did Chung and Alcacer (2002) based on different types of investment motives – i.e. traditional motives or knowledge-seeking motive. Frost (2001) further contended that technological leadership position and the innovation scale of a subsidiary are positively related to local knowledge sourcing from host country, and that subsidiaries with less innovation scale largely draw upon technical ideas originating in the home country. Therefore, the embeddedness and the capabilities of a subsidiary determine the locations of knowledge sourcing, especially local knowledge sourcing. In particular, subsidiary's ability to gain access to local knowledge sources is likely to be dependent upon its embeddedness in the host country (Cantwell & Mudambi, 2005; Frost, 2001); the characteristics of a local subsidiary may also represent its capability in absorbing knowledge (Cantwell, 1989; Cohen & Levinthal, 1990; Singh, 2007); and the local research activities of a subsidiary could influence its worthiness and credibility as an exchange partner perceived by other firms within local knowledge-sharing networks (Cantwell & Barrera, 1996; Frost, 2001). Finally, local external embeddedness might helps a subsidiary to acquire the competence-creating mandate, but to maintain such a role, interdependency between the subsidiary and other units in the MNC is essential; otherwise the subsidiary may end up as an isolated entity and finally lose its interests in the MNC group (Birkinshaw & Hood, 1998).

Cantwell and Mudambi (2005) found that with a highly concentrated host country industry, foreign subsidiaries tend to source less knowledge from local environment, because dominant local players may discourage or prohibit the transfer of potentially useful knowledge to subsidiaries located adjacent to them (the oligopolistic deterrence), or because those local players attract the best local resources (e.g. suppliers, customers, personnel, and etc) to deter the potential creativity of a subsidiary located in the same vicinity. Moreover, By studying the knowledge seeking and location choice of investments of MNCs, Chung and Alcacer (2002) found that firms from lagging technical locations normally use local knowledge sources in the host country to catch up, whereas those from leading locations tend to source more diverse knowledge from local environment; also, subsidiaries in R&D intensive industries are more likely to source knowledge from local environment.

Frost (2001) found that innovations in home country technological advanced fields will more like to source from home country (Singh, 2007) (even though there are debates in respect of the effectiveness of knowledge sourcing by technological leader vs. technology followers). But some of the home country differences are still unsolved in his study, e.g. in spite of the technological advantages of host country, the level of technological specialization in Japanese-owned subsidiaries has been kept low, compared to subsidiaries from European-owned MNCs (Frost, 2001; Singh, 2007). Some other studies shed light on these differences by including the institutional conditions of home countries. For example, Cantwell and Mudambi (2005) argued that the financial risk of home country is positively associated with local knowledge sourcing in competence-creating subsidiaries. Singh (2007) referred to a potential risk that the firm's own technology will fall into the hands of its competitors (the risk is partly due to the public nature of technology, and partly because of the local intellectual property right (IPR) protection), and argued that home and host country policies are critical too. For the host country, it has been argued that competence-creating subsidiaries are more likely to be located in sites with good local infrastructure (Cantwell & Iammarino, 2000; Cantwell & Piscitello, 2002), and in locations where there is a sufficiently wide dispersion of technologically active local independent firms (Cantwell & Mudambi, 2005). By the same token, Singh (2007) contended that whether there are a lot of other MNCs in local environment is a critical factor of foreign-owned subsidiary's local knowledge accumulation. In general, the higher the quality and dynamism of a location (both tangible and institutional environments) are, the greater the likelihood will be for a subsidiary to source knowledge locally. Moreover, Frost (2001) proved that innovations in technical fields of host country technological advantage will be more likely to draw upon technical ideas originating in the host country (similar results obtained by Almeida (1996), and Singh (2007)). For instance, companies of those regions with a more favorable scientific environment make greater use of scientific knowledge (Coronado & Acosta, 2005).

Today, the number of technologies required per product is increasing in many industries. Companies increasingly have to deal with much more difficult and multidisciplinary technological problems. By studying foreign-owned subsidiaries in German pharmaceutical industry, Cantwell, Noonan and Zhang (2008) showed that as technological complexity rises, firms tend to increasingly rely on inter-organizational network to facilitate knowledge accumulation; more importantly, the influence of technological complexity on local inter-organizational knowledge accumulation is much stronger than that on international inter-organizational knowledge sourcing.

2.4 Knowledge Accumulation of MNCs and Developing Countries

The conventional theories of multinational corporations (MNCs) generally assume that competitive advantages are derived from parent company in home country, whereas overseas subsidiaries, at most, just adapt the existing advantages of parent company (i.e. technologies, products, processes, and etc) to their local markets. In other words, knowledge flow is exclusively one-way, namely from parent company to overseas subsidiaries. Later on, the maturing of modern MNC organizational structure, the shifts of global economic and political environments, and the nature of nowadays technologies lead theorists to appreciate the active role of subsidiaries in terms of generating competitive advantages for the whole MNC groups. Consequently, 'product mandates' (White & Poynter, 1984), 'home base augmenting' (Kuemmerle, 1999), 'competence exploring subsidiary' (He & Wong, 2004); and 'competence-creating subsidiary' (Cantwell & Mudambi, 2005) are identified. In particular, the direction of knowledge flow within a multinational group could be two-way, i.e. from parent company to overseas subsidiary, and vice versa. Whereas our understanding about the knowledge accumulation is largely based on studies on firms in industrialized countries, recently, foreign-owned subsidiaries located in developing regions and countries attracts tremendous academic attention. It has been argued that MNC experience in emerging economies was at least as important as experience in sophisticated developed country markets for assisting successful knowledge transfer (Zhao, Anand, & Mitchell, 2005).

It is generally agreed that one main reason why so many companies are establishing development bases in developing countries is to locally develop products specifically for the host market; in doing so the local development and product adaption can support manufacturing operations and increase competitiveness (Gassmann & Han, 2004). Even in this case, there are rooms for local knowledge accumulation. Given the emphasis of marketing at this stage, local suppliers and customers play an important role in the knowledge accumulation process of foreign-owned subsidiaries; however, the key technological knowledge accumulated in the subsidiaries is basically transferred from individual parent companies, which fits the conventional views of MNCs. Indeed, the situation has started to change since the end of last century. For instance, some companies, like Microsoft, Siemens and IBM, have added sufficient resources to build specific leading-edge platforms, transforming some of their existing research laboratories in China into competence centers for individual MNC groups (Gassmann & Han, 2004; Li & Zhong, 2003; von Zedtwitz, 2004). Consequently, in some developing host countries, at least some foreign-owned subsidiaries extend beyond simple adaptation and interact more intensively with local (potential) partners in terms of knowledge accumulation. Studies have been showing that for establishing R&D in developing countries, especially in China, India, Brazil and etc, the huge human resource potential is of great importance (Niosi & Reid, 2007). The movement of personnel from local firms or organizations to foreign-owned subsidiaries could be an important way for subsidiary knowledge accumulation in those countries. Moreover, while scholars have been emphasizing the role of universities and public research institutes in economic catch-up (Fagerberg & Godinho, 2005; Mazzoleni & Nelson, 2007; Nelson & Pack, 1999), studies showed that the quality of such institutions in some developing countries facilitated the capability development of domestic firms (Niosi & Reid, 2007) and attracted MNCs to establish strategic partnerships and secure human resources for the long term (Gassmann & Han, 2004). For instance, Niosi and Reid (2007) found that China is rapidly emerging as a global contender in Biotechnology and Nanotechnology, as China not only has a good infrastructure of public research in universities and government laboratories (not to mention the appropriate institutional framework and government policies, as well as the skill level of population), but it also hosts a certain number of R&D active private companies; a similar story is found in some other developing countries, such as India and

Brazil. Some scholars argued that the advantage for incumbents to establish strategic alliance with firms or organizations in some developing countries may be access to new technology or to markets where the incumbents have not yet established themselves (Niosi & Reid, 2007). In other words, today at least in some technological fields, domestic firms and organizations in certain developing countries have become qualified local partners in the knowledge accumulation of foreign-owned subsidiaries often from developed countries. However, given this possibility, we're still extremely lacking knowledge on the knowledge accumulation process of foreign-owned subsidiaries in developing countries.

Consequently, this dissertation focuses on the technological knowledge accumulation pattern of foreign-owned MNCs in China. We investigate the pattern in terms of the knowledge across organizational boundaries, geographic boundaries, and technological boundaries. Meanwhile, the analysis incorporates the strategic considerations of firms in their knowledge accumulation. To better understand today's 'networked' MNCs, the dissertation further compares the knowledge accumulation patterns of foreign-owned subsidiaries located in China and some developed countries.

CHAPTER 3: HYPOTHESES DEVELOPMENT

3.1 Hypotheses Development – Study 1

Today, the number of technologies required per product is increasing in many industries, coupled with the blurring of the boundary between science and technology (Wang & von Tunzelmann, 2000). For example, the shift from mechanical to electro-mechanical to electronic systems in the automobile industry (Granstrand et al., 1997; Howells, James, & Malik, 2003; Miller, 1994); in the pharmaceutical industry the rise of biotechnology and ICT applications has been critical, as well as the role of optics and laser technologies for medical instruments. In this context, companies increasingly have to deal with much more difficult and multidisciplinary technological problems associated with short product life cycle. Yet with the limited resources and capability of a single firm, it becomes essential to seek outside support to overcome internal technical limitations.

Firms are heterogeneous in their capabilities when searching for external knowledge. The concept of absorptive capacity implies that the ability of a firm to value, assimilate and/or apply a piece of external technological knowledge depends on its existing knowledge in related technological areas (Cohen & Levinthal, 1990). By the same token, evolutionary approaches (Nelson & Winter, 1982), as well as organizational learning theory (March & Simon, 1958), argue that a firm, when seeking to innovate in terms of either technology or organization, will consider options in the neighborhood of its current activities to avoid attenuating firms' learning capability (Phene & Almeida, 2003). Previous literature discusses the absorptive capacity of a firm as a whole. Yet with the geographically dispersed organization of MNCs, the distribution of absorptive capacity within a firm may not be even. In other words, the corporate-level absorptive capacity in a technological field may not fully represent subsidiaries' absorptive capacity in that field. Since current study focuses on the knowledge acquisition of overseas subsidiaries, we expect that the absorptive capacity at subsidiary-level would fit our purpose better.

H1: MNC subsidiaries are more likely to access external sources, rather than internal sources, for technologically distant knowledge

H2: MNC subsidiaries are more likely to access external sources, rather than internal sources, for knowledge in a technological field in which the subsidiary has high absorptive capacity

The localization of knowledge spillovers makes the knowledge transfer across long geographical distance difficult (Almeida, 1996; Jaffe, Trajtenberg, & Henderson, 1993), unless there are some social mechanisms to assist the transfer (Kogut & Zander, 1993; Singh, 2005). Evolutionary theory argues that firms are social communities that are superior in knowledge creation, transfer and combination (Kogut & Zander, 1993). In this sense, for an MNC its own geographically dispersed organization has become a potential strategic asset, by providing channels to access useful external technological knowledge in various host locations and to transfer the knowledge within the firm. By the same token, Network MNCs literature argues that the different exposure of subsidiaries to host environments could be one of the basic competitive advantages of parent MNCs (Andersson et al., 2002; McEvily & Zaheer, 1999). Moreover, MNCs tend to locate value added activities at host locations where 'knowledge-related assets and markets necessary to protect or enhance ownership specific advantages of investing firms – and at the right price' are available for strategic asset seeking (Dunning, 1998). It is arguable that such a strategic asset is more likely to be found in the technological advanced fields of a host location (Frost, 2001). Yet to take advantage of the technological expertise in a host location, the subsidiaries of foreign-owned MNCs have to develop local embeddedness (Andersson et al., 2002; Birkinshaw et al., 1998; Cantwell & Mudambi, 2005). Among other mechanisms in previous literature, the ability to source local external knowledge well represents the capability development of, as well as the internal charter assignment of, a subsidiary.

H3a: In geographically proximate (vs. international) knowledge accumulation, MNC subsidiaries are more likely to access external knowledge sources, rather than internal knowledge sources.

H3b: MNC subsidiaries are more likely to access external sources, rather than internal sources, for knowledge in the technologically advanced areas of the host country.

3.2 Hypotheses Development – Study 2

Rather than solely focusing on a few ‘core’ technological competencies, large firms must become multi-technology and ‘distribute’ their competencies to reflect different strategic objectives (Granstrand et al., 1997). While knowledge of a firm can be considered as owning a portfolio of options on future development (Kogut & Zander, 1992), we argue that knowledge acquisition contributes to the different strategic objectives of a firm by bringing in options reflecting diversified expectations on future opportunities.

Incremental options provide firms with opportunities down the line to undertake profitable incremental investments (Sharp, 1991). An important source of such options is learning. For instance, when a firm enters a new product or geographic market, the firm learns new knowledge, and the firm will likely to be able to apply that learning when entering another market in the future (Sharp, 1991). Utilizing external knowledge provides a similar learning experience for firms, and the external knowledge itself may also provide options for future development. Through accessing external knowledge, firms may experiment as much as possible the combinations of internal and external knowledge in a manner of trial-and-error learning. Some of the experiments may not have a clear short-term purpose; rather external knowledge might be simply used by firms to brief themselves about possible technological directions in the future. In doing so, a firm maintains a knowledge base and accumulates learning experience to drawn upon when future opportunities arrive if the firm choose to develop the technology by itself; or as suggested by open innovation literature (Chesbrough, 2003, 2006), the firm may also make profit on the technology if other firms want to develop it. In this sense, the geographically dispersed knowledge networks of MNCs may generate advantages for the firm, since the exposure to different locations allows MNCs to access more diversified external knowledge and thereby to experiment more combinations of internal and external knowledge. Also, the experiences obtained may be exchanged within the firm and benefit the following knowledge creation. Yet given the uncertainties of the future, we don't expect firms to invest a large portion of corporate resources in such experiments.

While the out-sourcing and off-shoring of supply chain activities bring benefits to MNCs, they also increase risks, such as the risks of developing dependency on suppliers, the difficulties of adjusting supply chain activities caused by a radical technological innovation on product, and any unforeseeable interruption in supply chain activities. Consequently, a common practice is that even though a firm outsourced a product component to suppliers, the firm still maintains investments in the related technologies of the component, i.e. the so-called system integrator (Brusoni et al., 2001). Even though most firms might have built up a knowledge base for the component before it was outsourced, the firm is likely to continuously source knowledge from its suppliers on the component. In doing so, the firm can coordinate and monitor the supply chain activities within the network (i.e. the network between the firm and its suppliers). More importantly, the efforts to achieving a better understanding of the technologies embedded in an outsourced component may also help the firm to spot promising new areas of development that may lead to systematic changes in a product (Brusoni et al., 2001). Consequently, we expect that firms also tend to utilize external technological knowledge related to their supply chain activities.

In addition to the distinctive core technologies, firms may maintain three categories of non-core technologies. Background technologies enable a firm to coordinate and benefit from technical changes in its supply chain but do not necessarily result in distinctive competencies. For instance, for chemical companies, such as Bayer, the chemical process technologies are background competencies of the firm (Granstrand et al., 1997). Marginal and niche technologies only take a small proportion of corporate technological resources, but marginal technologies might not generate a strong competitive position for the firm (Granstrand et al., 1997). While aircraft technologies are the niche competencies for automobile companies (Granstrand et al., 1997), solar technologies could be the marginal technologies for oil companies, given that solar technologies might represent the future competencies of the energy industry. This typology is firm specific. For example, the knowledge in technological field X may be core technological knowledge for firm A, but marginal for firm B. By identifying the type of external knowledge, we could evaluate the strategic significance of the knowledge for the acquiring firm. Whereas firms may not develop immediate interests in marginal technologies, they do keep such knowledge in their technological knowledge portfolio. We expect that firms use marginal technological knowledge as experiments to brief themselves on possible future technological directions. Moreover, since background technologies are directly related to supply chain activities, we expect that firms tend to use background technological knowledge to coordinate their supply chain activities, and meanwhile to spot technological opportunities along their supply chain. Given the path-dependent nature of learning, we expect that the learning of a firm should be directed by the current expertise, namely the distinctive core technological knowledge, of the firm. In other words, either to identify long-term opportunities, namely potential future technological directions, or to spot opportunities with a clearer purpose, namely new supply chain related technologies, firms learn new knowledge through the combination of their current core technological knowledge and external knowledge.

H4: MNC subsidiaries are more likely to access external sources, rather than internal sources, for the firm's background technologies (in contrast to its core technologies).

H5: MNC subsidiaries are more likely to access external sources, rather than internal sources, for the firm's marginal technologies (in contrast to its core technologies).

3.3 Hypotheses Development – Study 3

Transaction cost theorists, as well as internalization approach, explain the existence of the MNC using the concept of internalizing imperfect markets (Buckley & Casson, 2009). Evolutionary theorists further argue that firms do better than market in the sharing and transfer of knowledge '… *because they provide a social community of voluntaristic action structured by organizing principles'* (Kogut & Zander, 1992). In other words, knowledge could be transferred more efficiently within the firm, even across geographical boundaries, than through markets. The conventional theories of multinational corporations (MNCs) generally assume that competitive advantages are derived from parent company in home country, whereas overseas subsidiaries, at most, just adapt the existing advantages of parent company (i.e. technologies, products, processes, and etc) to their local markets (Dunning, 1996, 2001). In this case, the knowledge flow is largely unidirectional from parents to overseas subsidiaries. Although the internationalization of innovative activities has extended the role of overseas subsidiaries in the last few decades at least for technology leaders, the home country headquarter has been and remains the single most important source and center of knowledge generation (Cantwell, 2006). In other words, internal knowledge sources have continuously played important roles even for modern MNCs, even though the external knowledge sources have become increasingly critical for the competence building of the firm under open innovation systems (Chesbrough, 2006). In this latter case, the knowledge flow within firms is more likely to be multidirectional between parents and subsidiaries, and between subsidiaries.

The last couple of decades witnessed the further expansion of the knowledge generation networks of MNCs by including overseas subsidiaries in some developing countries. Internationalization approach emphasizes the imperfect markets, which might be more relevant for some developing countries than developed countries, for instance, the IPR concerns of many foreign-owned MNCs in some developing countries (Gassmann & Han, 2004). Zhao (2006) argued, in a study of foreign-owned subsidiaries in weak IPR regions, that foreign-owned MNCs tend to rely more on knowledge accumulation within their own organizational boundaries; in doing so the organization of MNC itself provides an alternative institutional device for IPR protection. Moreover, while knowledge accumulation is path-dependent (Nelson & Winter, 1982), an existing knowledge base is essential for further knowledge accumulation. Given their emerging status in the knowledge generation networks of MNCs, it is expected that overseas subsidiaries in some developing countries might have a relatively weak knowledge base. While a firm provides a social community of voluntaristic actions (Kogut & Zander, 1992), we expect that the knowledge from internal sources, especially parents and some well-established peer subsidiaries in developed countries, might outplay other knowledge sources in the initial capability development of overseas subsidiaries in some developing countries.

H6: MNC subsidiaries in China are more likely than MNC subsidiaries in developed countries to draw upon technological knowledge from internal sources.

H6a: MNC subsidiaries in China are more likely than MNC subsidiaries in developed countries to draw upon technological knowledge from their parent of the equivalent MNC.

H6b: MNC subsidiaries in China are more likely than MNC subsidiaries in *developed countries to draw upon technological knowledge from their peer subsidiaries of the equivalent MNC.*

While asset-augmenting, also known as strategic asset seeking (Dunning, 1998; Kuemmerle, 1999), emerged as an alternative motivation for foreign direct investment, the organizational restructuring of MNCs has allowed more strategic roles to be played by overseas subsidiaries since 1980s. In addition to organizational control mechanism (Bartlett & Ghoshal, 1986) and host locational conditions (Almeida & Phene, 2004; Andersson et al., 2002; Birkinshaw & Hood, 1998), local embeddedness of an overseas subsidiary, i.e. the closeness with local customers, suppliers and other partners, is crucial, and sometimes decisive (Andersson, Bjorkman, & Forsgren, 2005), for the subsidiary's performance and capability development. The literature of network MNCs (Andersson & Forsgren, 2000; Ernst & Kim, 2002; Ghoshal & Bartlett, 1990; Ghoshal & Nohria, 1989) implies a similar argument that the subsidiary's capability is shaped by its embeddedness in both internal and external networks.

Whereas many MNCs have undertaken investments to access strategic assets of a host country, such as technological knowledge in locally advanced areas (Frost, 2001), a subsidiary's ability to gain access to local knowledge sources is likely to be dependent upon its embeddedness in the host country (Cantwell & Mudambi, 2005). Organizational charter of a subsidiary may affect its pattern of local knowledge access. For instance, by studying foreign-owned subsidiaries in UK, Cantwell and Mudambi (2005) found that competence-creating subsidiaries have a higher propensity to source knowledge locally, whereas competence-exploiting subsidiaries tend to source knowledge intra-organizationally outside the host country. Similar arguments were made by Frost (2001).

While it does not have to be an exclusive corresponding relationship between the typology of subsidiary R&D and the overall mandates of subsidiaries as a whole, it is found that there may be elements of several types of R&D in many subsidiaries (Cantwell & Piscitello, 2007; Zander, 1999). Given the emerging status of overseas subsidiaries in developing countries, they may conduct more competence-exploiting, instead of competence-creating, type of activities than their peer subsidiaries of the equivalent MNC in developed countries. Consequently, we expect that overseas subsidiaries in developed countries may have a higher tendency to draw upon local external knowledge.

H7: MNC subsidiaries in developed countries are more likely than MNC subsidiaries in China to draw upon technological knowledge from local external sources.

The organizational restructuring of MNCs has facilitated the two-way knowledge flow between headquarters and subsidiaries, and between subsidiaries (Andersson & Forsgren, 2000). The knowledge outflow at subsidiary-level, in addition to the knowledge inflow pattern, starts to play a role in determining the strategic roles of the subsidiary. By differentiating the knowledge flow patterns of the subunits of MNCs, Gupta and Govindarajan (1994) identified four strategic roles of subsidiaries, namely global innovator with high knowledge outflow and low knowledge inflow, integrated player with high knowledge outflow and high knowledge inflow, local innovator with low knowledge outflow and low knowledge inflow, and implementer with low knowledge outflow and high knowledge inflow. Similar ideas are implied by other literature on subsidiary typologies and laboratory typologies, such as Pearce (1989) and White and Poynter (1984). However, most of the literature fails to differentiate the organizational status of the knowledge providers or recipients, namely corporate-level units or subsidiary-level units; for instance, parent and peer subsidiaries as knowledge recipients in an MNC are treated the same in Gupta and Govindarajan's typology. Moreover, Schulz (2001) found that '*collecting new knowledge increases vertical outflows and combining old knowledge intensifies horizontal outflows*', where horizontal outflows is defined as knowledge flow from a subunit to peer subunits, and vertical outflows as knowledge flow from a subunit to its supervising unit (Schulz, 2001). Since collection new knowledge is more likely to be associated with knowledge exploration, we expect that overseas subsidiaries in developed countries are more likely to conduct new knowledge collection activities than their peer subsidiaries of the equivalent MNC in some developing countries.

H8a: MNC subsidiaries in developed countries are more likely than MNC subsidiaries in China to have technological knowledge outflow to their parent of the equivalent MNC.

H8b: MNC subsidiaries in China are more likely than MNC subsidiaries in developed countries to have technological knowledge outflow to the peer subsidiaries of the equivalent MNC.

This chapter develops hypotheses focused on the knowledge accumulation pattern of overseas subsidiaries of large MNCs. The operationalization of the hypotheses tests is discussed in the next chapter.

CHAPTER 4: DATA AND METHOD

This dissertation employs patents granted to the world largest firms by the USPTO between 1996 and 2005. A patent awards to inventors the right to exclude others from the unauthorized use of disclosed invention, for a predetermined period of time. According to USPTO, for a patent to be granted, the innovation must be novel, useful and nonobvious. While the large-scale use of patent data in economic research goes back to Scherer (1965) and Schmookler (1966), in recent years there has been a dramatic increase in the attention paid by scholars to the potential uses to be made of patent statistics in research on innovation. Topics cover the functioning and rationale of patent system (Merges & Nelson, 1994; Sampat, Mowery, & Ziedonis, 2003)), the relationship between technological change and economic development (Athreye & Cantwell, 2007a; Schmookler, 1966), the diffusion of technology (Jaffe & Trajtenberg, 1999; Jaffe et al., 1993), the relationship between science and technology (Jaffe & Trajtenberg, 1993; Meyer, 2002; Trajtenberg, Henderson, & Jaffe, 1997), the relationship between R&D, patents and performance (Griliches, 1990; Hall, Jaffe, & Trajtenberg, 2005; Trajtenberg, 1990), and so on and so forth. The research enthusiasm using patents is largely due to the rich information that could be extracted from them. A patent document contains the title, abstract and full description of the invention, which allows researchers to do content analysis on the technological claims of the patent. While the name and location (city and country) of the individual inventor(s) and assignee (the owner of the invention) allow an investigation into corporate profile of patenting and the regional and national geography of invention, the technological classes to which the patent belongs provide information not only on the rate of inventive activity, but also on its directions. The citation to both the relevant scientific literature and previous patents enables the tracing out of development trajectory of technological knowledge. Other key indicators included in the patent document are the patent application year, grant year, patent family information and etc. In addition, patent statistics are available in large numbers and for a very long time series. For instance, data is public available in computerized format for USPTO patents from 1963 onward and for patent citations from 1975 onward. Consequently, because of the richness of data contained in a patent, patent based studies can support macro-level analysis of national or cross-national trends, more detailed studies at the firm level or even studies at the level of the social network (Cantwell, 2006).

Indeed, patent data is far from perfect. Debate about the advantages and disadvantages of using patents in researches goes back to early researches, such as Scherer (1965) and Schmookler (1966). Several disadvantages have long been recognized by researchers, namely that not all inventions are patented; not all inventions are technically patentable; the propensity to patent greatly varies across firms, technological fields, industries, and national markets (Archibugi, 1992; Basberg, 1987; Pavitt, 1988b). While the empirical survey carried out by Mansfield (1986) showed that firms apply for a patent for about 66% to 87% of their patentable inventions (Cantwell, 2006), Pavitt (1988b) called attention to the fact that R&D also is a biased measure of innovative activities, given sectoral and technological variations in the relative importance of measured R&D in total innovative activities, for instance, the informal R&D activities outside R&D department. Moreover, there are various ways of addressing the patenting propensity difficulties. Among others, the most powerful method is to construct appropriate ratio measures/indices that normalize for variations in the propensity to patent, for example the index of internationalization (Cantwell, 1995), revealed technology advantage (RTA) index (Soete, 1981), the corporate technological competitiveness index (Cantwell & Sanna-Randaccio, 1993). Another approach is to focus on a single industry in a single country (Cantwell, 2006). In addition, the question of the relationship between firm size and innovativeness has long been acknowledged in the debate of using patent data. Studies found that large firms were more likely to patent even if there was not an immediate use, so that the utilization rate of patents tended to be higher for small firms than for large firms (Acs & Audretsch, 1989; Cantwell, 2006; Pavitt, 1988b). Consequently, it is argued that patenting is a robust indicator of innovation, but it provides the best indication of inventive activity for large, rather than for small firms (Cantwell, 2006).

As early as 1970s scholars like Shepherd have pointed out that many patents are never used, that the economic impact of patent is highly skewed, and that patents are often used by firms to block competitors rather to introduce innovations (Archibugi, 1992; Griliches, 1990). However, the share of used patents ranging from 40% to 60% of the total applications was consistently observed in several empirical studies (Archibugi, 1992). While Archibugi supported the use of patent data by arguing that the skewed value of patents is due to the uneven economic impact of the inventive and innovative activities, recently Hall, Jaffe and Trajtenberg (2005) have demonstrated that patents add to the stock market valuation of the firm above and beyond what R&D contributes to this value, and the number of forward citations per patent (the number of subsequent citations that a patent receives from later patents) adding still further value. More importantly, they found that a firm's self-citations add more value than do external citations, which supports the view of patents as steps along the way within corporate technological path or trajectories, irrespective of whether individual patents are used directly in commercialization. This finding is further related to the arguments about the motivations of patenting. In a study of inter-war cartels, Cantwell and Barrera (1998) suggested that "the main motivation for patenting was to help obtain the entry ticket and continued participation in a leading corporate club, to signal and mark out their respective territories or interest and expertise within these large firm clubs, and to facilitate and regularize the exchange of knowledge and the rights to use it to avoid blockages and promote further innovation within the relevant industry", and that these motivations seem to have become more important in recent times. A similar result was obtained by Yale survey in 1987, Carnegie Mellon survey in 2000, Griliches's (1990) study and Hall and Ham Ziedonis's (2001) study.

An international comparison problem generally exist in patent data, as patents are granted by patent office in individual countries, and therefore strongly depend on the institutional rules of each country. Early researches suggested that international differences in the volume of patenting activities in a given foreign country are a more reliable reflection of international differences in the volume of innovative activity (Pavitt, 1988b). Patents granted by the USPTO are mostly recommended, because the US is the largest and technologically the most developed market of the world, and therefore firms, especially large firms, are keen to obtain revenues from their intellectual property, sometimes even if they themselves do not produce for the market (Archibugi, 1992; Cantwell, 2006). More importantly, the USPTO data offers a disaggregation by cross-country, cross-firm, structural and historical dimensions on a scale that is not achievable through other sources like R&D data (Cantwell, 2006).

In spite of all the difficulties in patent statistics, it is argued that the relationship between patenting and technological progress is nonetheless strong enough for patents to represent a very robust proxy for innovation (Acs & Audretsch, 1989; Basberg, 1987; Cantwell, 2006). Griliches (1990) further contended that nothing else even comes close in the quantity of available data, accessibility, and the potential industrial, organizational, and technological detail for the analysis of the process of technical change. One particularly relevant aspect of patents in such analyses is patent citations that not only serve an important legal function to delimit the scope of the property rights awarded by the patent, but presumably convey information about major technological aspects, as well as economic significance, of innovations, for instance, the linkages between inventions, inventors and assignees along time and space; the spillovers and diffusion along geographical, institutional and other dimensions; the importance, generality, originality, or basicness of individual patents; the stock market valuation of assignees; and so on and so forth (Hall et al., 2005). However, Griliches (1990) discussed patent citations with caution, namely that patent citations differ from usual scientific citations to the work of others in that they are largely the contribution of patent examiners whose task is to delimit the reach of the new patent and note the context in which it is granted. On one hand, the objectivity of such citations is greater and may contribute to the validity of citation counts as indexes of relative importance; on the other hand, they may reflect the importance that is put in the field on particular patents but are not a valid indicator for channels of influence, for intellectual spillovers. A recent study of examiner citations suggested that citations may not always reflect a firm's own perceptions of how their knowledge has been constructed, thus complicating the use of patent citations as a means of investigating firm level knowledge flows (Alcacer & Gittelman, 2006). Given the noise in patent citations, several survey researches have been conducted to answer the question whether patent citations measure technological knowledge flows. Duguet and Macgarvie (2005) found that European patent citations are indeed related to firms' statements about their acquisition and dispersion of new technology, but that the strength and statistical significance of this relationship varies across geographical regions and across channels of knowledge diffusion. Using USPTO patents, Jaffe, Trajtenberg and Fogarty (2000) surveyed inventors of cited and citing patents, and found evidence of significant communication between them.

4.1 Data and Method –Study 1

This study uses patents granted to the world largest firms by USPTO for inventions attributable to their subsidiaries in China between 1996 and 2005. During the 10-year period, 554 patents were invented by foreign-owned subsidiaries in China that are affiliates of 51 world largest MNCs from 11 countries/regions and across 14 industries. The 554 patents have 3845 citations. A citation is a pairwise combination of citing and cited patents. With citing patents as the reference category, we examined the pattern of the patents they cite (as an indicator of the technological knowledge sources on which they draw) in terms of assignees, technological classifications, and geographical locations. For technological classification, we employed the 56 technological fields derived from an appropriate combination of the classes and subclasses of the US patent class system (Cantwell et al., 2008). In addition, a more aggregate level classification of a broad range of Chemical, Electrical, Mechanical and Transport technologies (CEMT) is constructed based on a further grouping of technology fields. The 56 technological fields further allow us to measure the technological portfolio and expertise of firms.

Our dependent variable is an indicator of whether the cited knowledge is external knowledge or internal knowledge. External Knowledge (EX) equals one if a citing patent cites a cited patent assigned to another firm/organization; and zero, otherwise.

The necessity to draw upon cross-discipline knowledge and the blurring boundaries between science and technology push up the costs and risks of technological innovations, which have forced firms to seek external helps for technological knowledge. We measured technological complexity (COMP) by pairwise matching the technological classes, technological fields and CEMT categories of citing and cited patents. Therefore, four categories of complexity are identified (in ascending order of the implied complexity of knowledge accumulation) in terms of the share of citations that are intra-technology field and intra-class, intra-technology field but inter-class, inter-technological field and intra-CEMT, and inter-CEMT. The combination of these four categories allows us to study the extent of intra-class citation (the first category), intra-technology field citation (the first two combined), and intra-CEMT (the first three) knowledge sourcing, in other words, the technological complexity in knowledge accumulation.

Literature on absorptive capacity uses aggregate R&D investments of a firm as proxy for the absorptive capacity of the firm (Cohen & Levinthal, 1990). Patent data make it feasible to capture the absorptive capacity in different technological fields and at subsidiary-level. While a citing patent invented by a subsidiary in year t cites a cited patent in technological field i, the subsidiary-level absorptive capacity (SUBAC) is measured by squaring the aggregate number of patents invented by the subsidiary up to year t-1 and in technological field i.

We employed two variables to test H3. For each pair of citing and cited patents, local technological knowledge (LOC) equals one if the inventor of the cited patent is located in China (since all the citing patent in this study were invented in China); and zero, otherwise. To measure the technological advantages of a host location (HOSTADV), we followed Cantwell and Piscitello (2007) to compare the RTA index of home and host locations in each technological field:

$$RTA_{ij} = (P_{ij} / \sum_i P_{ij}) / (\sum_j P_{ij} / \sum_{ij} P_{ij}) \qquad (1.1)$$

where Pij is the number of patents of location i in field j. Again, for each pair of citing and cited patents, HOST-ADV equals one if the cited patent is in a field where China's RTA >=1 and home location's RTA < 1; and zero, otherwise.

We controlled the existing level of technological activities for each subsidiary i in field j (CUR), as well as the subsidiary's age (AGE). We also controlled for the industrial effects by including industry dummies (IND) with food industry as the reference category. For home location effects (HM), we had three dummies to capture host locations as Taiwan, United States, Japan and other countries, with Taiwan as the reference category. We further included the grant year of citing patents (YEAR) in our model.

We used Logistic Regression to predict the pattern of knowledge accumulation, since our dependent variable (EX) is a dichotomous variable that takes values of one and zero. The model may be expressed formally as:

$$Y = f(X, C) \qquad (1.2)$$

where Y is the probability of subsidiary knowledge accumulation drawing upon external knowledge, viz. the probability of EX equaling one; X is a vector of independent variables, and C is a vector of control variables.

4.2 Data and Method –Study 2

This study uses the same dataset of the first study. Our dependent variable is an indicator of whether the cited knowledge is external knowledge or internal knowledge. External Knowledge (EX) equals one if a citing patent cites a cited patent assigned to another firm/organization; and zero, otherwise.

To measure background and marginal technological knowledge, we followed Granstrand et al. (1997). For the parent of each subsidiary (i.e. an MNC as a whole), we calculated the share of corporate technological resources (PSHARE) and the level of expertise of the corporate (FMRTA) in each technological field using USPTO patents between 1996 and 2005. The former (PSHARE) is the percentage share of each of our 56 technological fields in the total patenting of an MNC, reflecting the relative importance of each field in the MNC's technological portfolio. The average share per field is 1/56. The latter (FMRTA) is the Revealed Technological Advantage index (RTA) of the MNC in each technological field.

$$RTA_{ij} = (P_{ij} / \sum_i P_{ij}) / (\sum_j P_{ij} / \sum_{ij} P_{ij}) \qquad (2.1)$$

where Pij is the number of patents of MNC i in field j. We followed Granstrand et al. (1997) and used 'RTA>=2' to define:

I. Core: FMRTA >= 2 and PSHARE >= 1/56

II. Niche: FMRTA >= 2 and PSHARE < 1/56 (2.2)

III. Background: FMRTA < 2 and PSHARE >= 1/56

IV. Marginal: FMRTA < 2 and PSHARE < 1/56

We also tested ‘RTA>1’ as a criterion to define the technological categories. The statistical results have no significant change, so we stick to the definition above in the following discussion. With core technological knowledge as the reference category, three dummy variables are created, namely niche (N), background (B) and marginal (M).

To control the effects of technological complexity, subsidiary-level absorptive capacity and host country technological advantages, as well as geographically boundaries, we included the independent variables from the first study as controls. Moreover, we controlled subsidiaries existing level of technological activities (CUR), subsidiary age (AGE), industrial effects (IND), home location effects (HM), as well as the grant year of citing patents (YEAR) in our model.

We used Logistic Regression to predict the pattern of knowledge accumulation, since our dependent variable (EX) is a dichotomous variable that takes values of one and zero. The model may be expressed formally as:

$$Y = f(X, C) \tag{2.3}$$

where Y is the probability of subsidiary knowledge accumulation drawing upon external knowledge, viz. the probability of EX equaling one; X is a vector of independent variables, and C is a vector of control variables.

4.3 Data and Method – Study 3

This study uses patents granted by the USPTO between 1996 and 2005 to the world's largest firms for inventions attributable to their overseas subsidiaries. We matched the patents invented by foreign-owned subsidiaries in China with those invented by the peer subsidiaries of the equivalent MNC group in developed countries that cite, at least, one of the same patents from their common parent company. Developed countries are defined as high-income countries using the World Bank's country level income data (World Bank). Consequently, the locations of subsidiaries in this study include Mainland China, US, Germany, UK, Italy, France, Japan, Belgium, Switzerland, and Hong Kong. Those subsidiaries belong to 10 world largest firms in 5 industries from 5 home locations. We matched 126 patents invented by foreign-owned subsidiaries in China to 172 patents invented by their peer subsidiaries of the equivalent MNC in developed countries. Both groups of patents cited 130 patents invented by their common parent companies. The setting of this study ensures that the two groups of patents compared are relatively equal descendants of a common group of technological expertise. In particular, we compared the differences of internal and external knowledge inflows of the two groups of patents as measured by backward patent citations, and of technological knowledge outflows as measured by forward patent citations. Figure 1 illustrates the backward citations and forward citations of focal patents in this study. The upper part of the figure illustrates the knowledge inflow as measured by the backward citations of the focal patents in the middle, which were invented by the foreign-owned subsidiaries in China and their peer subsidiaries of the equivalent MNC in developed countries. In knowledge inflow study, those focal patents are citing patents. The lower part of the figure illustrates the knowledge outflow as measured by the forward citations of the same focal patents in the middle. In this latter case, the focal patents are cited patents.

[Insert Figure 1 Here]

Dependent variables in this study are the shares of different knowledge sources, as well as the shares of different knowledge destinations, in patent citations. Backward citations made by the focal patents are used to measure knowledge inflow. For each focal patent i, we calculated the share of cited patents assigned to the subsidiary's parent, peer subsidiaries and the subsidiary itself

$$PA_i=100*PC_i/C_i \qquad (3.1)$$

where PC_i is the number of cited patents assigned to the parent company for a citing patent i, and C_i is the total number of citations made by the citing patent i. By the same token, we calculated the share of cited patents assigned to peer subsidiaries (PR_i), as well as the share of cited patents assigned to the subsidiary itself (SF_i).

If a citing patent cites a cited patent assigned to another firm/organization, the cited patent represents a piece of external knowledge. We calculated the share of external knowledge in the total citations made by a focal patent i. The share was then divided according to the geographical location of the external knowledge. Consequently, we have two variables, namely the share of local external knowledge (LX_i) and the share of international external knowledge (IX_i) in the total backward citations of each focal patent i.

Forward citations received by the focal patents are used to measure the knowledge outflows. For each focal patent i, we calculated the share of forward citations made by the parent company (FPA_i), peer subsidiaries (FPR_i), the subsidiary itself (FSF_i), as well as other firms/organizations (FX_i). It's worth mentioning that for each focal patent i, its PA_i, PR_i, SF_i, LX_i and IX_i add up to 100%, and its FPA_i, FPR_i, FSF_i and FX_i also add up to 100%.

The independent variable is an indicator of whether a patent was invented by foreign-owned subsidiaries in China or by their peer subsidiaries of the equivalent MNC group in developed countries. CN equals one if a patent was invented by foreign-owned subsidiaries in China; and zero, otherwise. Given the emerging status of foreign-owned subsidiaries in China in the international knowledge generation networks of MNCs, the independent variable also captures the potential different strategic roles played by different subsidiaries included in this study.

For the analysis of knowledge inflow, we controlled the technological expertise of firms (FMRTA) (see equation (2.1)) that might influence the knowledge accumulation pattern of over subsidiaries. We also included a control measured as the patenting share of a firm in the total world patenting in a technological field.

$$FMSHARE_{ij} = P_{ij} / \sum_i P_{ij} \qquad (3.2)$$

where Pij is the number of patents of MNC i in technological field j. It is expected that FMRTA and FMSHARE would be highly correlated, so we included them as alternative controls in the regression models.

We further controlled the scope of technological knowledge being generated in different subsidiaries. A diversification index across 56 technology fields is employed, which is defined in the following way:

$$DIV_i = \mu_i / \sigma_i \qquad (3.3)$$

where DIV_i is the diversification index of the knowledge sources cited by the citing patent i, μi denotes the mean of the shares of cited patents of citing patent i across 56 technology fields, and σi represents the standard deviation of the shares of cited patents across 56 technology fields for each citing patent i. Because the DIV index is the reciprocal of coefficient of variation (CV), distributions with larger DIV values have lower-variance across fields than distributions with lower DIV, which is to say that the larger is the number of technology fields on which a citing patent draws, the higher is its

DIV index.

As an alternative of DIV_i we included technology complexity (D_i) measured as 'Technology Distance Index' (Cantwell et al., 2008). When the citing patent and cited patent are in the same technological field, the index equals zero; the index will rise to a very large positive value if the citation between the pair of patents is across technological fields that are highly unrelated.

Finally, since the technological advantages of a host location may significantly affect the external knowledge access pattern of a foreign-owned subsidiary, we controlled the patenting share of the host location of each focal patent i in its technological field j (HS_j). We also included the grant year of the focal patents ($YEAR_i$) for both knowledge inflow and outflow tests, as well as the average year lag of forward citations for each focal patent i (AL_i) as an alternative control of YEAR in knowledge outflow test.

We first used T-Test to compare the mean difference across all dependent variables between the foreign-owned subsidiaries in China and their peer subsidiaries of the equivalent MNC in developed countries. We then employed Multivariate Regression to further test the hypotheses:

$$Y = f\,(X, C) \qquad (3.4)$$

where Y is a data matrix containing the response variables, viz. the shares of different knowledge sources, as well as the shares of different knowledge destinations, in patent citations; X is the independent variable CN, and C is a vector of control variables.

Next chapter reports the descriptive and econometric statistic results for the three empirical studies using USPTO patent data.

CHAPTER 5: EMPIRICAL RESULTS

5.1 Hypotheses Test – Study 1

Table 1.1 reports the two-tailed Pearson correlation matrix of dependent and independent variables in this study. No problematic correlation is observed among explanatory variables.

[Insert Table 1.1 Here]

The results of Logistic Regression are reported in Table 1.2, and all the models are statistically significant. Model 1 simply includes all the control variables. Model 2 adds independent variable 'Technological Complexity' (COMP) and confirms H1 that the necessity to draw upon cross-discipline knowledge does increase the probability of external knowledge access. We added 'Subsidiary Absorptive Capacity' (SUB-AC) in Model 3 to test H2. Since we employed the 56 technological fields that are derived from an appropriate combination of US patent classes and subclasses, the experience of a subsidiary in class i_1 under field i may improve its absorptive capacity in other classes and subclasses under field i. Model 3 supports H2 by showing that subsidiaries may start to use external knowledge in technological fields where their subsidiary-level absorptive capacity increases. We also calculated the aggregate number of patents between 1996 and 2005 at the corporate-level for the parent of each subsidiary, and similar results as in Model 4 were obtained but with a significantly decreased model fit (so the model is not reported in Table 1.2).

H3 is not supported by Model 4, in which Local 'Knowledge' (LOC) is negatively significant and 'Host Country Technological Advantage' (HOST-ADV) is negative but not significant at all. The results suggest that the subsidiaries in current study have not been attracted by China's advantages in some technological fields; meanwhile, the subsidiaries tend to rely on local current knowledge and international acquired knowledge in their knowledge accumulation, which seems to be the opposite of the arguments in previous literature on subsidiary evolution (Bartlett & Ghoshal, 1986; Birkinshaw & Hood, 1998). Since technological complexity (COMP) may affect the relationship between the geographical location of knowledge sources (LOC) and inter-/intra-firm knowledge sourcing (i.e. accessing external knowledge (EX) in current study) (Cantwell et al., 2008), we included an interaction term in the model. However, the interaction term was never significant and the model fit was not improved, so we're not reporting the model in Table 1.2. Whereas overseas subsidiaries in the triad areas have traditionally been the focus of this type of analysis, the results on H3 may suggest a different pattern of knowledge accumulation for the subsidiaries located outside of traditional 'centers of excellence'.

[Insert Table 1.2 Here]

The statistic results show that foreign-owned subsidiaries in China tend to rely on local internal knowledge and international external knowledge in their knowledge accumulation. The pattern seems to be contradictory to previous literature on subsidiary evolution, which emphasizes local embeddedness of overseas subsidiaries evolution (Andersson & Forsgren, 2000; Bartlett & Ghoshal, 1986; Birkinshaw et al., 1998). One possible explanation is that according to Andersson and et al (2002), overseas subsidiaries may develop two types of local embeddedness, namely business-embeddedness and technology-embeddedness. It is likely that foreign-owned MNCs have developed business embeddedness in China, which is one of the largest markets in the world, and where foreign-owned R&D is only a recent phenomenon. Moreover, in a study of the emergence of new countries as contributors to technology generation in the world economy, Athreye and Cantwell (2007b) found that '*increasing FDI is a factor causing the emergence of newer countries with the more sophisticated technology generation associated with patenting, but not in the recent surge of newer countries with the basic capabilities needed to become licensors in the world economy*.' Given that current study focuses on a transaction economy as the host location of overseas subsidiaries, we believe that the technology-embeddedness of those subsidiaries may have been instead established through other types of connections, such as licensing, R&D cooperation and etc.

In a study of foreign-owned subsidiaries in German Pharmaceutical industry, Cantwell and et al (2008) found that firms rely on local inter-firm network for technologically complex knowledge and international intra-firm network for less complex knowledge, and they argued that such a pattern confirms the trend of organizational restructuring in MNCs. To benchmark the results, in addition to the interaction term between technological complexity and geographical location of knowledge sources added to the Model 4 in Table 1.2, Table 1.3 further reports the breakdown of the patent citations in current study in terms of geographical, organizational and technological boundaries. To simplify the reading of the table, we use inter-/intra-technological fields, instead of COMP, to measure the knowledge accumulation across technological boundaries. The results in Table 1.3 are consistent with our findings in Table 1.2, and show that international external knowledge has been mainly accessed for complex technological knowledge, i.e. inter-field technological knowledge, and internal knowledge has contributed to the accumulation of less complex technological knowledge, i.e. intra-field technological knowledge. It other words, international external knowledge may sometimes be accessed instead of local external knowledge as the major source for technological knowledge accumulation across fields. Such a different pattern of knowledge accumulation suggests that overseas subsidiaries located in non-traditional 'centers of excellence' might follow a distinctive path of capability development.

[Insert Table 1.3 Here]

To look deeper into the pattern of how subsidiaries access internal and external knowledge, we further identified the geographical origins of cited patents. In particular, the internal knowledge sources of a subsidiary include parent, peer subsidiaries and the subsidiary itself; by the same token, its external knowledge sources include external innovators located in home country, a third country and its host country. We then ran the Multinomial Logistic Regression using independent variables in this study to predict the knowledge sources, with parent as the reference category. We also calculated the RTA index (see equation (2.1)) for each firm in each technological field (FMRTA). We then included a dichotomy variable FM-EXP to control the technological expertise of firms. For each pair of citing and cited patents, FM-EXP equals one if the cited patent is in a technological field, in which the assignee of the citing patent has technological expertise, i.e. FMRTA > =1; and zero, otherwise. Table 1.4 reports the regression results. The 'Intercept' in the first model shows that in general foreign-owned subsidiaries in China still access a significant amount of knowledge from their individual parents, which is consistent with Table 1.3 above. Moreover, the coefficient of 'Subsidiary Absorptive

Capacity' (SUB-AC) in the second model suggests that the increasing absorptive capacity at subsidiary-level actually encourages the subsidiaries to drawn upon technological knowledge generated by peer subsidiaries. For all three external sources, the results confirm the importance of international sources as in Tables 1.2 and 1.3. 'Host Country Technological Advantage' (HOST-ADV) is marginal significant in 'External Local' model. In other words, the technological advantages of China in terms of patent applications are attractive to foreign-owned subsidiaries, however the effects are still weak. It is understandable based on the development stage of China. Finally, the coefficients of 'Technological Expertise of the Firm' (FM-EXP) in the last two models show that the subsidiaries significantly rely on their individual parents for specialized technological knowledge of the corporate, which is consistent with our findings above, as well as previous literature on the knowledge accumulation of large MNCs.

[Insert Table 1.4 Here]

Table 1.4 shows that significant knowledge linkages do exist between foreign-owned subsidiaries in China and their individual corporate. The subsidiaries in this study seem to be an integrated part of the knowledge generation networks of their individual MNCs. Under the notion of network MNCs (Andersson & Forsgren, 2000; Ernst & Kim, 2002; Ghoshal & Bartlett, 1990; Ghoshal & Nohria, 1989), subsidiaries are differentiated based on each subsidiary's unique and idiosyncratic patterns of internal and external network linkages (McEvily & Zaheer, 1999; Phene & Almeida, 2003). Consequently, the knowledge accumulation pattern identified above may suggest that foreign-owned subsidiaries in China have been playing a different role in the networks of MNCs. An investigation of the complete pattern of knowledge accumulation including knowledge inflows and outflows should testify the speculation here. Such an investigation is conducted in Study 3 below.

5.2 Hypotheses Test – Study 2

Table 2.1 reports the two-tailed Pearson correlation matrix of dependent, independent and control variables in this study. No problematic correlation is observed among explanatory variables.

[Insert Table 2.1 Here]

Table 2.2 reports the hypotheses test for H4 and H5, which are confirmed. Model 1 in Table 2.2 simply includes all the control variables for this study. Model 2 shows that firms tend to access external background and marginal technological knowledge of the firm to complement their current expertise. In other words, firms normally combine acquired background or marginal technological knowledge with current core to generate new technologies.

[Insert Table 2.2 Here]

The results show that the subsidiaries in current study tend to access external background and marginal technological knowledge, but not external niche technological knowledge (with internal core technological knowledge as the reference category). In other words, only certain categories of non-core knowledge are strategically sourced relatively more externally than is core knowledge. Brusoni and et al argued that firms maintain investments in the technologies of the outsourced components to coordinate their supply chain, because decisions to outsource product are different from decisions to outsource technological knowledge (Brusoni et al., 2001). While they focused on why firms want to maintain a knowledge base for outsourced components, our finding helps to show how firms maintain such a knowledge base. In particular, even though firms may decide to outsource a component but not the technological knowledge of the component, they might still draw upon external background technological knowledge to complement to their internal knowledge.

Whereas background technologies are directly related to the supply chain activities of the firm, it seems that marginal technologies do not generate any interests for the firm, at least in the short term. In fact, about 10% of the marginal knowledge accessed by the subsidiaries in current study is in technological fields, in which by the time of access even the parents of these subsidiaries have had no innovation experience at all (i.e. zero PSHARE and zero FMRTA). This 10% of marginal knowledge access suggests that firms might occasionally experiment in genuine new knowledge combinations. In particular, firms may access marginal technological knowledge to learn possible technological directions in the long run; when technological opportunities arrive in the future, such preparations could generate advantages for the firm. Indeed, firms have to rely on their core technologies as benchmarks, and access marginal technological knowledge to experiment any possible combinations. Such experiments could be very preliminary, and the firm may not immediately invest to explore the generated technologies, but rather wait until related technological opportunities emerge in the future. The arrival of the opportunities may bump up a previous marginal technology to a niche, background or even core technology of the firm. In this sense, the access of external marginal technological knowledge provides beneficial options for firms.

The above discussion implies that firms' access of external marginal technological knowledge is akin to the purchase of options, and firms may hold these options open until

technological opportunities arrive. However, for example, if the firm's access of external marginal technological knowledge has always generated core technologies, we may not expect that the firm treat the marginal knowledge as options. Table 2.3 shows the components of technologies being analyzed in current study. For each pair of citing and cited patents, we applied the method of Granstrand and et al (1997) on both the citing and cited patents to define their technological categories. Since each citing patent may cite several cited patents, we could identify the 'Cited Technologies' (i.e. as defined by cited patents) for 'Invented Technologies'
(i.e. as defined by citing patents). The third column shows that firms tend to cite marginal technologies when they innovate in that category, the rule of which also applies to core and background technologies. The only exception in Table 2.3 is 'Niche Technologies'. Marginal, instead of niche, technological knowledge becomes the major component of niche technologies. However, the definition of niche technologies suggests that such technologies of a firm may generate competence for the firm in the future, which may well match the nature of marginal technological knowledge as providing options for the future. Since 77.5% of all the citations in current study are acquired knowledge, the last column reports the constituents of invented technologies in terms of acquired knowledge. A similar pattern is observed as in the third column.

[Insert Table 2.3 Here]

Another related issue is whether firms further develop the marginal knowledge after accessing it from external sources to reflect the nature of option. While the data does not allow us to test such a further technological development, we picked out several subsidiary invented patents in background or marginal technological fields, and then analyzed whether the firm continues to patent in those fields. We found that firms may not further develop acquired knowledge in some cases. For instance, the Chinese subsidiary of a German metal company named W C Heraeus invented a patent in its marginal technological field ‘cleaning agents and other compositions’ in 1998. It is the only patent of W C Heraeus in this field over the 10-year period of current study. There are similar cases in other firms, such as Texaco, an US oil company, and NCR, an US office equipment manufacturer. On the other hand, we also found that some firms, such as Intel, Microsoft and TDK (a Japanese electrical equipment manufacturer), did apply other patents in the following years in their background or marginal technological fields that we picked out.

5.3 Hypotheses Test – Study 3

To illustrate the differences of technological knowledge generated by foreign-owned subsidiaries in China and that by their peer subsidiaries of the equivalent MNCs in developed countries, we identified the technological categories for the 130 parent patents (cited patents), the 126 citing patents invented by Chinese subsidiaries, and the 172 citing patents invented by peer subsidiaries in developed counters. Since this study investigates the citing patents invented by MNC subsidiaries in different locations that cite the same group of patents invented by their common parent, we’re focusing on the intra-firm knowledge flow patterns. While overseas subsidiaries tend to draw upon existing technological expertise from their parents (Cantwell et al., 2008), the results in Table 3.1 are consistent with this expectation, namely, the cited parent patents are concentrated in Core technological category of the firm (i.e. 86.92%). Table 3.1 shows that the parent patents in this study do not include any technologies in Niche category. This result could be explained by the focus of this study, i.e. foreign-owned subsidiaries in China, which accordingly determines the patents included in the study. Given that Chinese subsidiaries were still in the early stage of taking responsibilities for competence building during the studied period, they may largely limit their knowledge accumulation in the existing technological competences and manufacturing technologies of their individual parents, i.e. the Core and Background technological areas of the firm. While Niche technologies may represent the future competences of the firm, we expect that those technologies might be the target of more advanced overseas subsidiaries in terms of competence building. Finally, Table 3.1 shows that the descendants of technological knowledge tend to remain in the same technological category of the original knowledge. While the 130 cited parent patents are distributed in Core, Background and Marginal technological categories, their descendants, measured by the citing patents invented by overseas subsidiaries, are still in those three categories.

[Insert Table 3.1 Here]

We further employed the measure of technological complexity in Study 1. In particular, we identified the four categories of technological complexity for subsidiary-invented patents, namely (in ascending order of the implied complexity of knowledge accumulation) the share of citations that are intra-technology field and intra-class, intra-technology field but inter-class, inter-technological field and intra-CEMT, and inter-CEMT. Table 3.2 shows that the technologies invented by subsidiaries in developed countries tend to draw upon knowledge from more technological distant areas; for instance, 12.17% of the cited knowledge comes from a different technological field, and 9.89% of cited knowledge comes from even more distant technological areas, i.e. inter-

CEMT. On the other hand, the patents invented by Chinese subsidiaries were largely built on knowledge within the same technological class, in other words, less technologically complex knowledge.

[Insert Table 3.2 Here]

Table 3.3 further includes the knowledge accumulation across geographical and organizational boundaries, in addition to technological boundaries, in the comparison. The results show that Chinese subsidiaries not only drawn upon less technologically complex knowledge in inventing new technologies, but they also rely on local knowledge sources to a much lesser extent than their peer subsidiaries in some developed countries. This finding is further investigated below.

[Insert Table 3.3 Here]

Table 3.4 reports the two-tailed Pearson correlation matrix of independent and control variables in this study. Some alternative control variables, such as FMRTA and FMSHARE, are highly correlated. Therefore, they're not simultaneously included in regression models.

[Insert Table 3.4 Here]

For all the dependent variables in this study, a T-Test was run to compare the mean differences between patents invented by foreign-owned subsidiaries in China and those by their peer subsidiaries of the equivalent MNC group in developed countries. The results are reported in Table 3.5. There are significant differences in terms of knowledge components of the two groups of patents. The 'knowledge inflow' column shows that foreign-owned subsidiaries in China tend to use technological knowledge being generated in parent company and peer subsidiaries of the equivalent MNC group, whereas their peer subsidiaries of the equivalent MNC in developed countries have a higher tendency to use the knowledge being generated by the focal subsidiary itself. Since foreign-owned subsidiaries in China only started to upgrade their capabilities in the studied decade, the technological knowledge from parent companies or existing internal 'centers of excellence' may serve as the foundation for the knowledge generation in these subsidiaries. The results are consistent with the findings in previous studies that the knowledge development of foreign-owned subsidiaries in some developing countries are more likely to rely on internal knowledge networks (Zhao, 2006). The external knowledge inflow analysis shows that while local external knowledge contributes significantly in the generation process of the subsidiaries in developed countries, it is international external knowledge that plays a significant role for the subsidiaries in China. It seems that the role of local embeddedness in the capability development of overseas subsidiaries is not supported by the results of foreign-owned subsidiaries in China. We will further discuss this finding below.

The 'knowledge outflow' column in Table 3.5 shows that foreign-owned subsidiaries in developed countries are more likely to contribute to the subsequent knowledge development of parent companies; meanwhile foreign-owned subsidiaries in China tend to contribute more to the subsequent knowledge generation of the focal subsidiary itself. The findings are consistent with our expectations given the emerging status of foreign-owned subsidiaries in China in knowledge generation networks of MNCs. Finally, T-Test doesn't reveal any significant difference between these two groups of patents in terms of their knowledge outflow to other firms/organizations. In general, the results from T-Test tentatively confirm our hypotheses, except H8b, in this study. We then employed

Multivariate Regression to further test our hypotheses, as well as the knowledge flow patterns we observed through T-Test.

[Insert Table 3.5 Here]

Table 3.6 reports the regression results for dependent variables measuring knowledge inflow. The coefficients and model fits reported in each column under the models are the results of simple or multiple regressions. Models 1 and 2 report the coefficients of independent variable CN without controls in predicting internal knowledge inflow and external knowledge inflow patterns, respectively. Models 3 and 4 report the results after adding controls. We report the results using 'Firm's Technological Expertise' (FMSHARE) and 'Knowledge Distance' (D) (we also tested the models with alternative controls that achieve consistent results but are not reported in the Table). The results are largely consistent with those of T-Test. The multivariate regression hypotheses tests on the independent variable CN, which are reported in the last two lines in Table 3.6, are significant across all models. In other words, there are significant differences between foreign-owned subsidiaries in China and their peer subsidiaries in developed countries in their internal and external knowledge inflow patterns. Models 1 and 3 confirm our hypotheses 6 that MNC subsidiaries in China are more likely than MNC subsidiaries in developed countries to draw upon technological knowledge from internal sources. H7 is confirmed by Model 2. However, a significant inconsistency is observed in Model 4; in particular, the sign and significant level of the coefficients of independent variable CN changed, although the multivariate regression hypothesis test on CN is still significant (see the last two lines in the Table). The control variable 'Patent Share of Host Country' (HS) is highly significant in Model 4. Given the technological gap between China and some developed countries, the results suggest that the technological advantage of host country is one of the major reasons for overseas subsidiaries to source local external knowledge, which is consistent with previous literature on subsidiary capability development, as well as that on FDIs.

[Insert Table 3.6 Here]

Table 3.7 reports the regression results for dependent variables measuring knowledge outflow. Since the external knowledge outflow is not significant in the T-Test, as well as in multivariate regression models, we didn’t report FX in the Table. Model 1 includes only independent variable CN in the regression to predict internal knowledge outflow patterns. The results are consistent with those of T-Tests. Model 2 adds controls in the regression. Given the high correlation between YEAR and ‘Average Citation Year Lag’ (AL), we included them separately in the model and reported the results with YEAR in the table. After controlling YEAR in Model 2, the coefficient of CN becomes positively significant for ‘Knowledge Outflow to Peer Subsidiary’ dependent variable. In other words, the significant knowledge outflow from foreign-owned subsidiaries in China to their peer subsidiaries in the equivalent MNC group has been an emerging phenomenon in recent years. The results suggest an improvement of the capability and strategic status of the subsidiaries in China within the international knowledge generation networks of their parent MNCs. Finally, the hypotheses tests on the independent variable CN, which are reported in the last two lines in Table 3.7, are significant across all models. Therefore, our H8a and H8b are supported.

[Insert Table 3.7 Here]

Figure 2 illustrates the knowledge flows patterns we identified in this study. In general, the results show that the overseas subsidiaries in developed countries have tended to combine local internal and local external knowledge in generating new technological knowledge, which then has contributed to the competence creating at corporate level. Meanwhile, the overseas subsidiaries in China have relied upon international internal and external knowledge inputs in generating new technological knowledge, which has been mainly used to build their own subsidiary-level competency. Although over time the technological knowledge generated by foreign-owned subsidiaries in China has picked up a significant role in the competence creating of the peer subsidiaries of the equivalent MNC, the contribution of the knowledge is still remained at subsidiary level. The results suggest that the overseas subsidiaries in this study have been playing different strategic roles in the knowledge generation networks of MNCs. In particular, the foreign-owned subsidiaries in China may have been assuming a strategic role of specialized hubs whereas the peer subsidiaries of the equivalent MNC in developed countries are more likely to be recognized as 'centers of excellence' in the network.

[Insert Figure 2 Here]

The results of this study support the view of the organizational restructuring of MNCs by showing a significant multidirectional knowledge flow pattern between parent and subsidiaries, and between subsidiaries within the MNC, and such internal knowledge linkages are significant across subsidiaries with different capabilities and strategic status in the networks of MNCs. Moreover, we observed an interesting phenomenon that international external knowledge has played an important role in the knowledge generation process of foreign-owned subsidiaries in China, although those subsidiaries are less likely to use international external knowledge in general if we control the technological advantages of host country (see Models 2 and 4 in Table 3.6). On one hand, it is agreed that knowledge transfer is largely localized (Jaffe et al., 1993); on the other hand, this study shows that the overseas subsidiaries of MNCs might access geographically distant knowledge across organizational boundaries. The results suggest that the geographically dispersed organizational structure of MNCs might facilitate long distant knowledge transfer even across organizational boundaries. When external knowledge sources become critical for firms due to open innovation systems (Chesbrough, 2003, 2006), this finding may suggest another potential advantage of the geographically dispersed organizational structure of MNCs.

A case study about Ericsson in China (thereafter Ericsson China) showed that within a decade of initiation in 1997, the Chinese R&D of Ericsson has extended into roles that address the pursuit of new sources of competitiveness, not only for operations in China but also for the longer-term enhancement of wider scope; and this is seen to include both distinctive innovation and accessing new scientific research potentials (Zhang & Pearce, 2006). To support such upgraded competence building activities, knowledge inputs from local environment for the R&D of Ericsson in China are essential. Correspondingly, some collaboration between Ericsson and Chinese firms and universities were identified in the case study. However, although current dissertation focuses on the similar period of time, an opposite yet interesting finding was identified in all three studies, namely foreign-owned subsidiaries in China use local knowledge only to a very limited extent.

To further investigate this discrepancy, we identified the USPTO patents invented by Ericsson China between 1996 and 2005. During the ten years period, Ericsson China only applied for one US patent for its inventions. In other words, the increasing R&D activities in Ericsson China (Zhang & Pearce, 2006) didn't result a higher propensity of the firm to apply US patents for its technological inventions at least in the studied period. The patented technology was invented in 1998, of which a US patent was granted in 2000. The technology is about reducing the adjacent channel interference between cells. While the patent is in telecommunication field, all of its cited patents are within the same technological field. This patent made six citations to previous US patents, two of which are intra-firm citations, i.e. citations to two patents invented by Ericsson's US subsidiaries. The cited patents of Ericsson US are about similar technologies that reduce cell frequency interference. This suggests that this patent of Ericsson China may still fall in the adaptation or applied research categories, in which the demand for local technological knowledge inputs in terms of patent citations may be limited. The patent invented by Ericsson China didn't cite any US patent invented in China, which is consistent with our findings in current dissertation.

Zhang and Pearce (2006) showed that many competence-creating activities of Ericsson China were conducted in collaborating with its peer subsidiaries in other countries, especially those in developed courtiers. While we classified a US patent being invented by foreign-owned subsidiaries in China only if the first inventor of the patent is located in China, this setting may exclude patents, which foreign-owned subsidiaries in China significantly contributed to but were not listed as the first inventor. More importantly, even though the analyses using patent data could provide useful insights about the technological innovation activities of firms, this simple comparison of Ericsson China's patent and some qualitative evidences (the case study) suggests that patents only measure technological knowledge sources to a limited extent, especially in some developing countries. In particular, patent citations couldn't capture the increasing local knowledge exchange between foreign-owned subsidiaries in China and other (domestic and foreign-owned) firms or organizations in the host country. Indeed, the institutional conditions in China may also contribute to the limited number of US patents available in the country, which could be another reason for the knowledge accumulation pattern identified in this dissertation.

CHAPTER 6: DISCUSSION AND CONCLUSION

This dissertation uses patent data from USPTO to investigate the internal and external knowledge access patterns of the overseas subsidiaries of MNCs. We focused on foreign-owned subsidiaries located in China, a non-traditional 'center of excellence' location. In the first study, our findings are consistent with the suggestion about the effects of path-dependent learning on the knowledge accumulation of firms. Yet we found that the internal and external knowledge sources of overseas subsidiaries might be differently connected to generate new knowledge in locally distinctive ways. In particular, foreign-owned subsidiaries in China drawn up local external knowledge sources to a very limited extend. Moreover, while internal knowledge contributes to the accumulation of technological knowledge within a field, international external knowledge may sometimes be accessed instead of local external knowledge as the major source for technological knowledge accumulation across fields.

To generate competences, overseas subsidiaries have to combine knowledge from both their internal MNC network, and from a local network of other firms and organizations (Andersson & Forsgren, 2000; Bartlett & Ghoshal, 1986; Birkinshaw & Hood, 1998; Cantwell & Mudambi, 2005). The findings of this study suggest that overseas subsidiaries located in non-traditional 'centers of excellence' might follow a distinctive path of capability development. In turn, MNCs may support the capability development of the subsidiaries in some developing countries based on the characteristics of knowledge accumulation pattern of those subsidiaries. In particular, the geographically dispersed organizational structure of MNCs may be motivated to supply information regarding international knowledge sources to subsidiaries in developing countries. For instance, the corporate evaluation and incentive policies may be adjusted to encourage the subsidiaries in developed countries to communicate with their peer subsidiaries in developing countries. Finally, the results also suggest that different strategic roles may have been played by foreign-owned subsidiaries in China. To further test this possibility, future research may look at both knowledge inflow and knowledge outflow of overseas subsidiaries. Moreover, it's also essential to include subsidiaries located in different host locations. The third study in this dissertation represents one of the attempts to address this research question.

In the second study, by differentiating non-core technologies, we found that foreign-owned subsidiaries in China tend to access external background and marginal technological knowledge, but not external niche technological knowledge (with internal core technological knowledge as the reference category). In other words, only certain categories of non-core knowledge are strategically sourced relatively more externally than is core knowledge. Based on the significance of each category of technologies to firms, the results show that firms may access external marginal technological knowledge to experiment with potential directions for long-term development; meanwhile, firms may also access external background technological knowledge to better coordinate their supply chain activities and to identify new technological areas related to those activities.

This study is one of the first efforts to empirically test the path-dependent learning and experimental learning together, which have been argued to work complementarily as organizational learning mechanisms (Kogut & Zander, 1992). The experiments that firms may perform by combining different external knowledge and internal knowledge suggest firms could strategically, rather than passively, use external knowledge to explore long-term and short-term technological opportunities. While open innovations emphasize the utilization of external knowledge, as well as the bottom-up innovation within an organization (Chesbrough, 2003), MNCs may take advantages of their geographically dispersed organizational structure by encouraging the experiments in overseas subsidiaries in different locations. In doing so, the MNC could enlarge the possibility of identifying future opportunities. Our findings also contribute to a better understanding of combinative capabilities by showing that firms normally combine acquired background or marginal technological knowledge with current core to generate new technologies. We employed real option approach to explain some of the knowledge access to external marginal technologies. In future research, it would be interesting to look at the condition, under which a previous marginal technology moves to niche or even core technological category.

We compared the knowledge inflow and outflow patterns of foreign-owned subsidiaries in China and their peer subsidiaries of the equivalent parent MNC in some developed countries in the third study. The findings show that the overseas subsidiaries in developed countries have tended to combine local internal and local external knowledge in generating new technological knowledge, which then has contributed to the competence creating at corporate level. Meanwhile, the overseas subsidiaries in China have relied upon international internal and external knowledge inputs in generating new technological knowledge, which has been mainly used to build their own subsidiary-level competency. Although over time the technological knowledge generated by foreign-owned subsidiaries in China has picked up a significant role in the competence creating of the peer subsidiaries of the equivalent MNC, the contribution of the knowledge is still remained at subsidiary level.

While previous literature about the strategic roles of overseas subsidiaries focuses on either the internal knowledge flow pattern or the local embeddedness of subsidiaries, this study links these two mechanisms. By showing the different combinations of knowledge inflow and outflow patterns, the results suggest that the subsidiaries located in China may have been assuming a strategic role of specialized hubs, whereas the peer subsidiaries of the equivalent MNC in developed countries are more likely to be recognized as ‘centers of excellence’ in MNC networks. Moreover, the results are consistent with the view of the organizational restructuring of MNCs by showing a significant multidirectional knowledge flow pattern between parent and subsidiaries, and between subsidiaries within the MNC. Further still, the findings on international external knowledge access of foreign-owned subsidiaries in China are consistent with our findings in the first study. The ability of those subsidiaries to access geographically distant knowledge again suggests the potential advantages of the geographically dispersed organizational structure of MNCs. While we limited our analysis on the knowledge descendants of a common group of parent expertise in this study, future study could extend the investigation to other patents or knowledge generated by overseas subsidiaries, and thereby include more subsidiaries in different host locations.

Finally, we exclusively used patents and patent citations in this dissertation. The rich information provided by the data allows us to construct different measurements. Yet it would be helpful to include other data in related future studies.

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Figure 1. The Backward Citations and Forward Citations of Patents

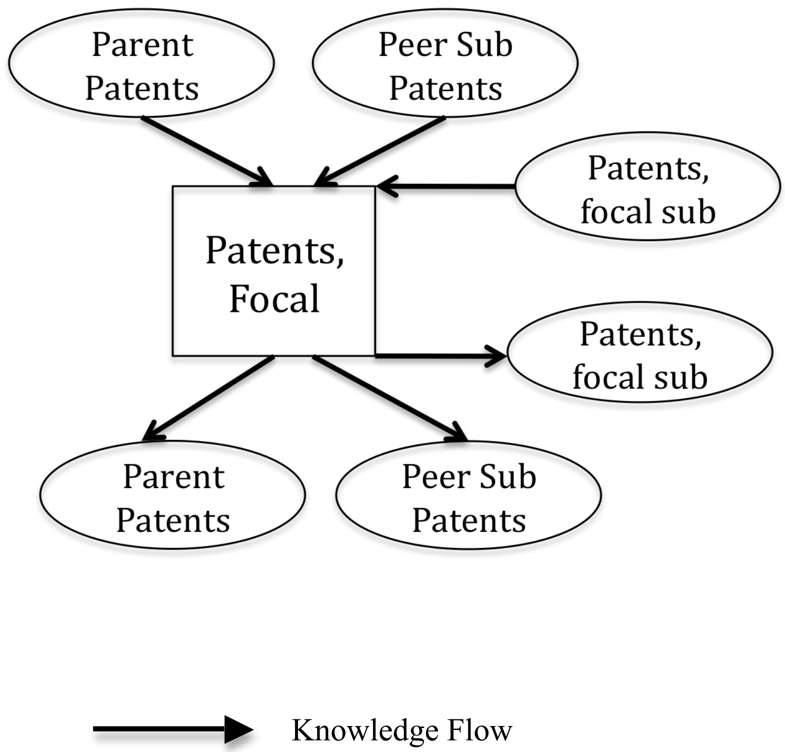


Table 1.1. Two-Tailed Pearson Correlation Matrix – Study 1

	Variables	N	Mean	Std Dev	1	2	3	4	5
1	**External Knowledge Access**	3845	0.7748	0.4178	1				
2	**Technological Complexity**	3845	1.5784	1.0310	0.1721	1			
					<.0001				
3	**Subsidiary Absorptive Capacity**	3845	12889	21910	-0.1985	-0.2668	1		
					<.0001	<.0001			
4	**Host country Technological Advantages**	3845	0.0765	0.2658	0.0825	0.0474	-0.1688	1	
					<.0001	0.0033	<.0001		
5	**Local Knowledge**	3845	0.0434	0.2039	-0.3616	-0.0824	0.1523	-0.0277	1
					<.0001	<.0001	<.0001	0.0859	

Table 1.2: Logistic Regression Coefficients for Variables Predicting External Knowledge Access

Variables	Model 1	Model 2	Model 3	Model 4
Intercept	-332.1***	-258.7**	-178.3+	-188.8+
Explanatory Variables				
Technological Complexity		0.2921***	0.2704***	0.2739***
Subsidiary Absorptive Capacity			0.00004***	0.00004***
Host country Technological Advantages				0.0643
Local Knowledge				-3.8843***
Controls				
Subsidiary Current Knowledge	-0.0056***	-0.0048***	-0.0146***	-0.0128***
Subsidiary Age	0.0445+	0.0439+	0.0419	0.0432
Year	0.1668***	0.1298**	0.0898+	0.0950+
Industries				
Chemicals	-1.6184*	-1.7625**	-1.6993*	-1.7491
Pharmaceuticals	-2.2937***	-2.1714**	-2.1014**	-2.1140**
Metals	1.0417	0.9893	0.9878	0.9642
Mechanical Engineering	13.9238	14.0676	14.1239	14.1182
Electrical Equipment	-1.1595+	-1.0257+	-0.9277	-0.8608
Office Equipment	-0.8538	-0.7336	-0.6276	-0.5256
Motor Vehicles	1.8869	1.8258	1.801	1.7727
Aircraft	-0.315	-0.2408	-0.1115	-0.1652
Paper Products	-0.6237	-0.4777	-0.393	-0.4387
Non-Metallic Mineral Prod	-2.0923**	-2.2448**	-2.3526**	-2.3723**
Coal and Petroleum Prod	13.9954	13.9607	13.966	14.4351
Professional and Scientific Instruments	14.0398	14.2683	14.2484	14.2376
Other Manufacturing	-3.4577***	-3.3294***	-3.1836***	-3.2168***
Home Countries				
US	0.5530**	0.5250*	0.3026	0.3300
Japan	0.5034	0.5348	0.2788	0.2747
Other Countries	0.5859+	0.4271	0.2071	0.1756
No. of Obs	3845	3845	3845	3845
Likelihood Ratio - Chi-Squared)	431.5514(19)***	461.9325(20)***	492.1306(21)***	803.7162(23)***
Pseudo R-Square	16.19	17.26	18.32	28.76

Notes: ***, $p < 0.001$; **, $p < 0.01$; *, $p < 0.05$; + $p < 0.10$

Table 1.3: Three-way Breakdown of Patent Citations

Geographical Boundary	Organizational Boundary	Tech-Field Boundary	No. of Patents	Percent
International	Intra-Firm	Intra-Field	**642**	**16.70%**
	Intra-Firm	Inter-Field	68	1.77%
	Inter-Firm	Intra-Field	2264	58.88%
	Inter-Firm	Inter-Field	704	18.31%
Local	Intra-Firm	Intra-Field	147	3.82%
	Intra-Firm	Inter-Field	9	0.23%
	Inter-Firm	Intra-Field	8	0.21%
	Inter-Firm	Inter-Field	**3**	**0.08%**
Total			3845	100.00%

Table 1.4: Multinomial Logistic Regression to Predicting Knowledge Access from Different Knowledge Sources

Variables	Baseline = Internal Knowledge Sourcing from Parent				
	Internal		External		
	Internal Local	Internal - Peer Subsidiaries	External Local	External Home Country	External Third Country
Intercept	-1.1606+	-0.5768	-14.3433	1.4039***	2.8198***
Technological Complexity	-0.2333	-0.2330	0.3937	0.4104***	0.1381*
Subsidiary Absorptive Capacity	0.00002***	0.00002***	-0.0000	-0.00003***	-0.0000
Host Country Technological Advantages	0.1077	-1.6882	1.4492+	0.6029**	0.4549*
Technological Expertise of the Firm	-0.2415	-0.6658	9.7845	-1.2831***	-1.9710***
Likelihood Ratio - Chi Square (df)	634.4120 (20)***				

Notes: ***, $p < 0.001$; **, $p < 0.01$; *, $p < 0.05$; + $p < 0.10$

Table 2.1: Two-Tailed Pearson Correlation Matrix – Study 2

	Variables	N	Mean	Std Dev	1	2	3	4	5	6	7	8
1	**External Knowledge Access**	3845	0.7748	0.4178	1							
2	**Technological Complexity**	3845	1.5784	1.0310	0.1721 <.0001	1						
3	**Subsidiary Absorptive Capacity**	3845	12889	21910	-0.1985 <.0001	-0.2668 <.0001	1					
4	**Host country Technological Advantages**	3845	0.0765	0.2658	0.0825 <.0001	0.0474 0.0033	-0.1688 <.0001	1				
5	**Local Knowledge**	3845	0.0434	0.2039	-0.3616 <.0001	-0.0824 <.0001	0.1523 <.0001	-0.0277 0.0859	1			
6	**Niche Technological Knowledge**	3845	0.0029	0.0534	0.0289 0.0734	-0.0112 0.4890	-0.0315 0.0507	0.0212 0.1880	-0.0114 0.4792	1		
7	**Background Technological Knowledge**	3845	0.1844	0.3879	0.1215 <.0001	0.2433 <.0001	-0.2796 <.0001	0.0600 0.0002	-0.0816 <.0001	-0.0255 0.1143	1	
8	**Marginal Technological Knowledge**	3845	0.0892	0.2851	0.1469 <.0001	0.3033 <.0001	-0.1841 <.0001	0.1263 <.0001	-0.0622 0.0001	-0.0168 0.2987	-0.1488 <.0001	1

Table 2.2: Logistic Regression Coefficients for Variables Predicting External Knowledge Access

Variables	Model 1	Model 2
Intercept	-188.8+	-41.5284
Explanatory Variables		
Niche Technological Knowledge		15.2894
Background Technological Knowledge		0.3349*
Marginal Technological Knowledge		1.6124***
Controls		
Technological Complexity	0.2739***	0.2020***
Subsidiary Absorptive Capacity	0.00004***	0.00003**
Host country Technological Advantages	0.0643	-0.2644
Local Knowledge	-3.8843***	-3.8523***
Subsidiary Current Knowledge	-0.0128***	-0.0087***
Subsidiary Age	0.0432	0.0448+
Year	0.0950+	0.0213
Industries		
Chemicals	-1.7491	-1.6751*
Pharmaceuticals	-2.1140**	-1.9491**
Metals	0.9642	1.1693
Mechanical Engineering	14.1182	14.3607
Electrical Equipment	-0.8608	-0.7162
Office Equipment	-0.5256	-0.2068
Motor Vehicles	1.7727	1.5474
Aircraft	-0.1652	0.2682
Paper Products	-0.4387	-0.3426
Non-Metallic Mineral Prod	-2.3723**	-2.3542**
Coal and Petroleum Prod	14.4351	14.5743
Professional and Scientific Instruments	14.2376	14.1369
Other Manufacturing	-3.2168***	-3.1878***
Home Countries		
US	0.3300	0.5818*
Japan	0.2747	0.4902
Other Countries	0.1756	0.243
No. of Obs	3845	3845
Likelihood Ratio - Chi-Squared)	803.7162(23)***	835.0799(26)***
Pseudo R-Square	28.76	29.76

Notes: ***, $p < 0.001$; **, $p < 0.01$; *, $p < 0.05$; + $p < 0.10$

Table 2.3: Technological Components of Generated Technologies

Generated Technologies	Knowledge Components	Percent - All Citations	External Citations/All Citations	Percent - External
Core Technologies	Core	**94.52%**	74.63%	**93.27%**
	Niche	0.03%		0.04%
	Background	2.77%		3.35%
	Marginal	2.68%		3.35%
Niche Technologies	Core	12.96%	98.15%	13.21%
	Niche	**29.63%**		**30.19%**
	Background	0.00%		0.00%
	Marginal	57.41%		56.60%
Background Technologies	Core	39.30%	91.04%	35.52%
	Niche	0.00%		0.00%
	Background	**59.20%**		**62.84%**
	Marginal	1.49%		1.64%
Marginal Technologies	Core	16.85%	98.50%	16.73%
	Niche	0.75%		0.76%
	Background	3.00%		3.04%
	Marginal	**79.40%**		**79.47%**

Table 3.1 Technological Categories for Parent- and Subsidiary-Invented Patents

Technology Categories	**Cited Patents – Parent Patents**		**Citing Patents**			
			CN Subs Patents		**DV Subs Patents**	
	Freq	**Percent**	**Freq**	**Percent**	**Freq**	**Percent**
Core Technologies	113	86.92%	118	93.65%	153	88.95%
Background Technologies	16	12.31%	8	6.35%	16	9.30%
Marginal Technologies	1	0.77%			3	1.74%
Total	**130**	100.00%	**126**	100.00%	**172**	100.00%

Note: CN Subs – overseas subsidiaries located in China
DV Subs – overseas subsidiaries located in some developed countries

Table 3.2 Technological Complexities
Chinese Subsidiaries vs. Peer Subsidiaries in Developed Countries

Technological Complexity in Patent Citations	CN Subs Patent Citations		DV Subs Patent Citations	
	Freq	Percent	Freq	Percent
Intra-Class	782	82.75%	1255	69.76%
Inter-Class (Intra-Tech)	25	2.65%	147	8.17%
Inter-Tech (Intra-CEMT)	68	7.20%	219	12.17%
Inter-CEMT	70	7.41%	178	9.89%
Total	945	100.00%	1799	100.00%

Note: CN Subs – overseas subsidiaries located in China
DV Subs – overseas subsidiaries located in some developed countries

Table 3.3 Knowledge Accumulation Across Geographical, Organizational and Technological Boundaries
Chinese Subsidiaries vs. Peer Subsidiaries in Developed Countries

Geographical Boundary	Organizational Boundary	Tech-Field Boundary	CN Subs Patent Citations		DV Subs Patent Citations	
			Freq	Percent	Freq	Percent
International	Intra-Firm	Intra-Field	349	36.93%	416	23.12%
	Intra-Firm	Inter-Field	28	2.96%	80	4.45%
	Inter-Firm	Intra-Field	406	42.96%	471	26.18%
	Inter-Firm	Inter-Field	110	11.64%	264	14.67%
Local	Intra-Firm	Intra-Field	49	5.19%	148	8.23%
	Intra-Firm	Inter-Field	0	0.00%	3	0.17%
	Inter-Firm	Intra-Field	3	0.32%	367	20.40%
	Inter-Firm	Inter-Field	0	0.00%	50	2.78%
Total			945	100.00%	1799	100.00%

Note: CN Subs – overseas subsidiaries located in China
DV Subs – overseas subsidiaries located in some developed countries

Table 3.4: Two-Tailed Pearson Correlation Matrix – Study 3

	Variable	N	Mean	Std Dev	Min	Max	1	2	3	4	5	6	7	8
1	**Foreign-owned Subsidiary in China (CN=1)**	454	0.4670	0.4995	0.0000	1.0000	1.0000							
2	**Firm Technological Expertise (FMRTA)**	454	10.8155	4.0621	0.0132	16.8832	0.1446	1.0000						
							0.0020							
3	**Firm Technological Expertise (FMSHARE)**	454	0.0482	0.0215	0.0001	0.1404	0.0463	**0.4988**	1.0000					
							0.3254	<.0001						
4	**Knowledge Scope**	454	15.5511	4.3693	13.3631	39.6158	-0.1031	-0.4182	-0.0438	1.0000				
							0.0281	<.0001	0.3522					
5	**Knowledge Distance**	454	1.1033	2.1805	0.0000	13.7000	-0.1212	**-0.5350**	-0.1784	0.8175	1.0000			
							0.0097	<.0001	0.0001	<.0001				
6	**Year (year-1996)**	454	6.9626	1.3749	1.0000	9.0000	0.0448	0.0409	0.0910	-0.0559	-0.0368	1.0000		
							0.3408	0.3843	0.0528	0.2342	0.4341			
7	**Patent Share of Host Country**	454	18.1195	21.5485	0.0055	48.7505	-0.7624	0.2164	-0.0288	-0.2270	-0.1961	-0.0317	1.0000	
							<.0001	<.0001	0.5406	<.0001	<.0001	0.5008		
8	**Average Citation Year Lag**	454	1.1580	1.0629	0.0000	4.6000	-0.0287	-0.0414	-0.0823	0.1294	0.0927	**-0.8067**	0.0054	1.0000
							0.5419	0.3794	0.0797	0.0058	0.0483	<.0001	0.9089	

Table 3.5: T-Test Between Patents Invented by Subsidiaries in China and by Peer Subsidiaries in Developed Countries

	Variable	Knowledge Inflow					Knowledge Outflow				
		Mean Difference Group (1-2)	Method	DF	t-Value	p-Value	Mean Difference Group (1-2)	Method	DF	t-Value	p-Value
Internal	**Parent**	11.34	Pooled	452	**5.89**	**<.0001**	-6.975	Pooled	452	**-2.09**	**0.0372**
	Peer Subsidiary	3.514	Satterthwaite	376	**3.72**	**0.0002**	3.158	Satterthwaite	417	1.58	0.1138
	Self Accumulation	-3.123	Satterthwaite	448	**-2.79**	**0.0054**	9.362	Satterthwaite	405	**3.08**	**0.0022**
External	**Local External Knowledge**	-25.062	Satterthwaite	242	**-16.65**	**<.0001**					
	International External Knowledge	13.33	Satterthwaite	452	**5.27**	**<.0001**					
	External Kowledge Outflow						-0.1389	Pooled	452	-0.06	0.9503

Table 3.6: Multivariate Regression for Knowledge Inflow Dependent Variables

Multivariate Test	**1**			**2**		**3**			**4**	
Dependent Variables	**Knowledge Inflow from Parent (%)**	**Knowledge Inflow from Peer Subsidiary (%)**	**Knowledge Inflow from Focal Subsidiary (%)**	**Local External Knowledge Inflow (%)**	**International External Knowledge Inflow (%)**	**Knowledge Inflow from Parent (%)**	**Knowledge Inflow from Peer Subsidiary (%)**	**Knowledge Inflow from Focal Subsidiary (%)**	**Local External Knowledge Inflow (%)**	**International External Knowledge Inflow (%)**
Intercept	29.5160***	3.1993***	8.2283***	25.1600***	33.8965***	32.5636***	-3.7797	6.7683*	-2.5090	70.3501***
Independent Variable										
Foreign-owned Subsidiaries in China	**11.3381*** **	**3.5144*** **	**-3.1230** **	**-25.0617*** **	**13.3322*** **	**10.5831*** **	**3.1954*** **	**-3.9217*** **	0.4482	**-13.2236*** **
Controls										
Firm Technological Expertise (FMSHARE)						41.9334	-6.6140	-1.5239	-6.7830	-30.8726
Knowledge Distance						**-1.3761** **	**-0.3650+**	**-1.3995*** **	0.1133	**2.7749*** **
Year of Knowledge Generation						-0.4592	**1.1274*** **	0.4956	0.2769	**-1.4445+**
Patent Share of Host Country									**0.7743*** **	**-0.8593*** **
p-Value	<.0001	0.0002	0.0061	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
R2	7.13	3.11	1.65	34.94	5.68	9.53	6.17	8.25	60.47	37.87
Adj R2	6.93	2.89	1.43	34.80	5.47	8.73	6.17	7.43	60.02	37.17
Sample Size (CN=1)	454(212)	454(212)	454(212)	454(212)	454(212)	454(212)	454(212)	454(212)	454(212)	454(212)
Multivariate Test of 'Foreign-owned Subsidiaries in China' (CN)										
F Value		19.96		116.17			21.1		9.49	
p-value		<.0001		<.0001			<.0001		0.0022	

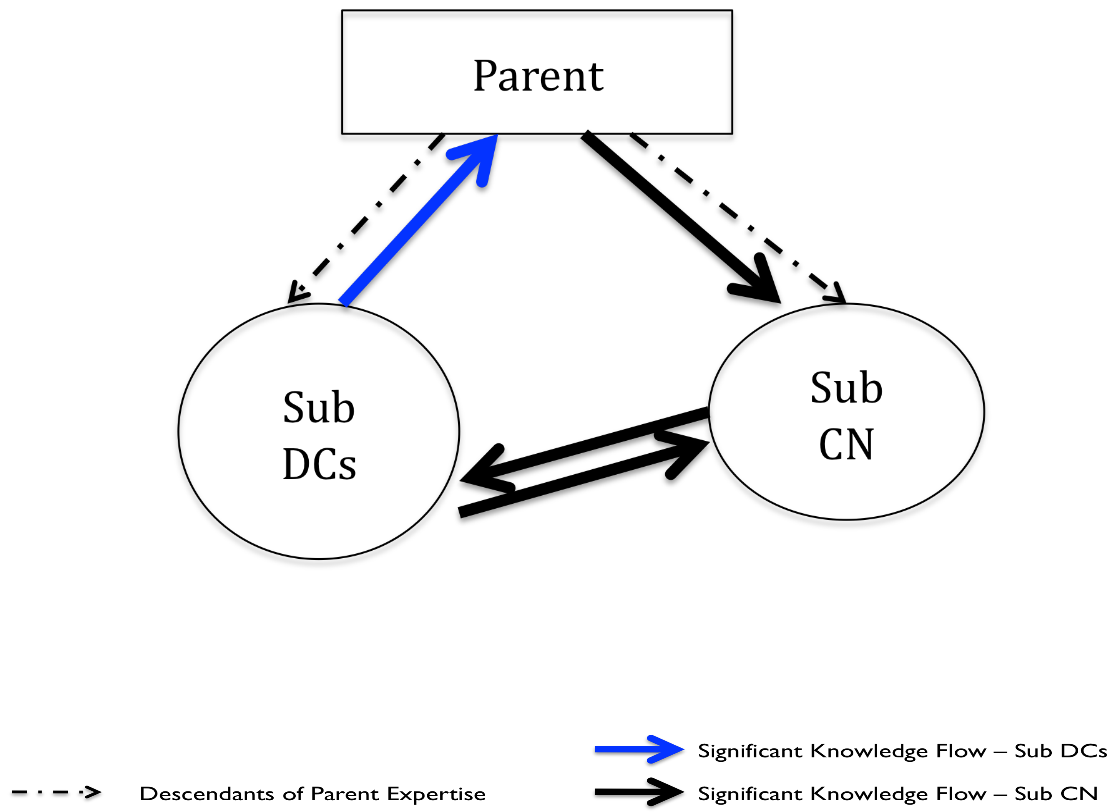
Notes: ***, $p < 0.001$; **, $p < 0.01$; *, $p < 0.05$; + $p < 0.10$

Table 3.7. Multivariate Regression for Knowledge Outflow Dependent Variables

Multivariate Test	**1**			**2**		
Dependent Variables	**Knowledge Outflow to Parent (%)**	**Knowledge Outflow to Peer Subsidiary (%)**	**Knowledge Outflow to Focal Subsidiary (%)**	**Knowledge Outflow to Parent (%)**	**Knowledge Outflow to Peer Subsidiary (%)**	**Knowledge Outflow to Focal Subsidiary (%)**
Intercept	31.3899***	6.4041***	15.2899***	91.9134***	17.3789***	49.5698***
Independent Variable						
Foreign-owned Subsidiaries in China	**-6.9750***	3.1584	**9.3625****	**-5.8939+**	**3.3545+**	**9.9748*****
Controls						
Year of Knowledge Generation				**-8.7652*****	**-1.5894***	**-4.9645*****
p-Value	0.0372	0.11	0.0019	<.0001	0.0238	<.0001
R2	0.96	0.56	2.12	12.39	1.64	6.62
Adj R2	0.74	0.34	1.90	12.00	1.21	6.21
Sample Size (CN=1)	454(212)	454(212)	454(212)	454(212)	454(212)	454(212)
Multivariate Test of 'Foreign-owned Subsidiaries in China' (CN)						
F Value		13.25			12.86	
p-value		0.0003			0.0004	

Notes: ***, p < 0.001; **, p < 0.01; *, p < 0.05; + p < 0.10

Figure 2: The Pattern of Knowledge Flows within MNCs



Curriculum Vita

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