Track 5

Technological Knowledge Accumulation and Subsidiary Evolution in China

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Abstract

Subsidiary evolution in terms of innovative capability development has been intensively studies through MNC group-level and subsidiary-level characteristic, as well as host locational factors. However, little attention has been paid toward the capability developed. This study focuses on the structure and components of technological knowledge accumulated in foreign-owned subsidiaries in China during their evolution process. We found that strategically important technological knowledge is increasingly coming from external knowledge sources over time while internal knowledge sources continuously play important roles in the knowledge accumulation of foreign-owned subsidiaries in China. The findings support an overall proposition that the capabilities of foreign-owned subsidiaries in China have being developed over the studied period. Some theoretical and practical implications could be drawn from this study.

Keys: Knowledge Accumulation, Foreign-Owned Subsidiary, China

Introduction

The fact that overseas subsidiaries could play strategic roles in the competence development of multinational corporations (MNCs) has attracted considerable attentions from researchers in both strategic management and international business field in the past three decades. Correspondingly, asset-augmenting, also known as strategic asset seeking (Dunning, 1998; Kuemmerle, 1999), emerged as an alternative motivation for foreign direct investment.

Moreover, a large amount of effort has been given to subsidiary level analyses, generating revolutionary insights on the capability development of subsidiaries as well as that of MNCs. For instance, a decentralized control mechanism in some MNCs to encourage local initiatives of overseas subsidiaries has been documented since 1980s (Bartlett & Ghoshal, 1986) whereas host location conditions along with the formal and informal management mechanism within MNCs were later emphasized by many researches (Birkinshaw & Hood, 1998; Andersson, Forsgren & Holm, 2002; Almeida & Phene, 2004). On top of these factors, a well-received wisdom is that internal and external embeddedness of an overseas subsidiary is crucial, and sometimes decisive (Andersson, Bjorkman & Forsgren, 2005), for its performance and capability development. This argument has been put forward recently with the notion of *network MNCs* (Ghoshal & Nohria, 1989; Ghoshal & Bartlett, 1990; Andersson & Forsgren, 2000; Ernst & Kim, 2002); in other words, the subsidiary's capability is shaped by its embeddedness in both internal and external networks.

While the capability development of an overseas subsidiary may be represented by a better performance in any stage on supply chain (e.g. innovation, engineering, production, marketing, financing, and etc), most studies chose to focus on technological innovation (Pearce, 1999; Andersson, et al., 2002; Almeida & Phene, 2004; Cantwell & Mudambi, 2005). Among other reasons, this choice could be explained by the belief that technological knowledge generation capability is an important indicator of international competitiveness of firms and even countries. Technological innovation normally requires the complementary inputs from both internal and external knowledge resources. On one hand, firms specialize in the internal transfer of certain types of knowledge due to imperfect knowledge market (Buckley & Casson, 2002), the tacit nature of knowledge (Kogut & Zander, 1993), and/or strategic considerations; on the other hand, firms increasingly rely on external resources in knowledge generation in response to both demand side and supply side factors; the former may include, to name a few, the sharing of soaring research and development (R&D) costs, the accessing of scientific knowledge, and the search for technological opportunities while the latter denotes the capability improvements of host locations, for instance, the emergence of specialized/general locational clusters, and the capability upgrading of some developing locations. Consequently, the conditions of internal and external environments (Bartlett & Ghoshal, 1986; Birkinshaw & Hood, 1998; Schulz, 2003; Almeida & Phene, 2004; Andersson, *et al.*, 2005), as well as a subsidiary's embeddedness in internal and external networks (Andersson & Forsgren, 2000; Andersson, *et al.*, 2002; Cantwell & Mudambi, 2005), are normally preferred in explaining the technological innovation performance of the subsidiary. However, whereas the capability development of overseas subsidiaries is the focus of previous studies, little attention has been given to the capability per se. In particular, we still miss precise knowledge of which types of knowledge from each network contribute to the capabilities developed in the subsidiaries. This study represents an effort to fill this gap by looking at the structure and components of technological knowledge accumulated in overseas subsidiaries over their evolution process attributable to internal and external networks, respectively.

Two issues must be settled before empirical analyses. First of all, when decomposing a piece of technological knowledge, we should be able to incorporate the internal management mechanism of a firm and the external conditions of a host location. Meanwhile, all the measurements should remain at technological knowledge level. The technological, organizational, locational and geographical information provided by patents and patent citations allow us to meet these requirements. Consequently, in addition to break down technological knowledge by technological fields, age and origins, this study differentiates competence-creating from competence-exploiting type of technological knowledge by comparing the revealed technological advantages (RTAs) of host and home locations (Cantwell & Piscitello, 2007) as measured by patent citations. Technological categories, i.e.

core, niche, background and margin technologies (Granstrand, Patel & Pavitt, 1997), further still take into consideration the strategic decisions and internal control mechanism of firms.

The second issue is that the competence development of firms is a dynamic process, and therefore the technological knowledge components from internal and external resources are expected to change over the process. An ideal setting to investigate this process would be a host location with a significant upgrade of capabilities, in which the subsidiary strategy of investing firms is also evolved over time. China, as a long-standing strategic market with location advantages for production facilities for most MNCs around the world, has started to attract research and development (R&D) affiliates of those firms over the last decade. The accumulated R&D investment of MNCs in Mainland China (thereafter China) had reached approximately $4 billion by June 2004 (WIR, 2005). By 2005 there were reportedly as many as 750 foreign-invested R&D centers in China (China Daily, 2005). In other words, China could provide a fertile background for the purpose of this study. Finally, it's worth mentioning that this study is not interested in the mechanism of knowledge linkages within the internal and external networks of MNCs; rather our purpose is to reveal the pattern change of the technological knowledge accumulated during subsidiary evolution. While technological knowledge may embed in other activities such as design, engineering, and manufacturing, this study focuses on technological innovations.

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 were analyzed in this study. By empirically testing the structure and components of technological knowledge accumulated in foreign-owned subsidiaries in China over the 10-year period, we found that external sources significantly contribute to technological knowledge components that are not among the existing expertise of parent MNCs or of home countries, and that are more likely cross-discipline and well established. This finding is consistent with our overall assumption that the capabilities of foreign-owned subsidiaries in

China are developing. Moreover, the results of this study showed that specialized technological knowledge from peer subsidiaries has become increasingly important for the knowledge accumulation of subsidiaries over time. While this concurs with the findings of Jaffe and Trajtenberg (1999) in a study of international knowledge flows, namely a rise in the share of 'self-cites' since the 1960s or 1970s in major MNCs, the finding also provides opposite evidence of so-called ‘phantom’ MNCs by showing the increased interdependence between subunits of MNCs. However, contrary to our expectation given the above evidence of the capability development of foreign-owned subsidiaries in China, we found that technological knowledge of local origin is playing an insignificant role in the technological innovative capabilities developed by the subsidiaries. It echoes the motive of this study that the needs to source knowledge from host environment, namely the process of knowledge accumulation, may differ with the capability accumulated through the process, namely the results of knowledge accumulation. An important managerial implication is derived from this finding. Finally, the results of this study mirror the catching-up of China, as well as the space for further policy development in China.

The next section reviews theoretical backboard and develops hypotheses, followed by the setting and results of hypotheses testing using USPTO patent citation data. The final section discusses the results of the study and concludes.

Conceptual Development and Hypotheses

Studies have showed that a high proportion of technology for innovations is generated within innovating firms themselves, while the acquisition of technological knowledge from other firms and from public knowledge is always involved in the process (Pavitt, 1988). Evolutionary theory believes that firms exist because of their superior efficiency in knowledge creation, transfer and combination (Kogut & Zander, 1993); such an capability may be also relevant in explaining the heterogeneity of overseas subsidiaries. In the literature of subsidiary evolution, the profile of knowledge transferred from parent company and that sourced from host environment is generally an implicit criterion in defining the capability of a subsidiary. A number of established subsidiary typologies, for instance, classify subsidiaries based on their dependence on parent knowledge and local creative initiatives (White & Poynter, 1984; Bartlett & Ghoshal, 1989; Pearce, 1999). Under the notion of *network MNCs* (Ghoshal & Nohria, 1989; Ghoshal & Bartlett, 1990; Andersson & Forsgren, 2000; Ernst & Kim, 2002), subsidiaries are, more explicitly, differentiated based on each subsidiary's unique and idiosyncratic patterns of internal and external network linkages (McEvily & Zaheer, 1999; Phene & Almeida, 2003).

Correspondingly, internal management mechanism and the conditions in external environment have been extensively studied during the last three decades in explaining subsidiary capability development. The former include internal control mechanisms in terms of decision making, incentives and local initiatives (Bartlett & Ghoshal, 1986; Birkinshaw, Hood & Jonsson, 1998; Pearce, 1999), the co-evolution of subsidiary capability development and charter change (Birkinshaw & Hood, 1998), organizational structure (Bartlett & Ghoshal, 1989), strategic concerns (Schulz, 2003), corporate culture and informal employee networks, and etc. The latter, on the other hand, focuses on the supply side factors of host locations, for instance host country technology competencies, capacities and heritage (Pearce, 1999), the technological richness and diversity of local knowledge network (Almeida & Phene, 2004), and the presence of major competitors in host locations (Cantwell & Mudambi, 2005). Finally, the embeddedness of a subsidiary in its internal network (Pearce, 1999) and external network (Andersson, *et al.*, 2002) links the two categories of determinants sketched above, and therefore influences the capability development of the subsidiary. In other words, subsidiary evolution has been explained by MNC group-level and subsidiary-level characteristics as well as locational factors, interactively.

Whereas most of the previous studies use the scale or scope of technological innovation as a proxy for the level of subsidiary capability development, our knowledge is largely limited at the aggregated level of capability measurements, such as R&D expenditures (Cantwell & Mudambi, 2005), the number of patents (Almeida & Phene, 2004), the inflow of knowledge from parent and peer subsidiaries (Schulz, 2003), the possession of product development or international market development function (Andersson, *et al.*, 2002; Cantwell & Mudambi, 2005) and etc. Pearce's (1999) R&D laboratory typology indirectly provides a possible way to disaggregate the capability accumulated in a R&D subsidiary, i.e. technological, marketing, engineering, management, and scientific capabilities. Garcia-Pont and et al. (2009) suggest to disaggregate the embeddedness of a subsidiary into three categories, namely operational, capability and strategic embeddedness, in response to different capability and strategic considerations of firms. However, on one hand, it is well received that subsidiary evolution can be defined 'as the process of accumulation or depletion of resources/capabilities in the subsidiary over time' (Birkinshaw & Hood, 1998), and that the resources/capabilities per se could be complementarily acquired from internal and external sources; on the other hand, we still miss precise knowledge of which types of knowledge from each source contribute to the capabilities developed in the subsidiaries. This study aims to unfold this black box. Instead of interested in the mechanism of which firms accumulate skills and capability as previous studies did, we focus on the pattern change of the structure and components of the resources/capabilities that are accumulated from internal and external sources over time, with a particular interest in the disaggregation of the technological knowledge accumulated by foreign-owned subsidiaries in China. The remaining part of this section develops hypotheses at technological knowledge level.

Today, the number of technologies required per product is increasing in many industries, by for example, the shift from mechanical to electro-mechanical to electronic systems in the automobile industry (Miller, 1994; Granstrand, *et al.*, 1997; Howells, James & Malik, 2003); 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. Another important factor contribute to this process is the blurring of the boundary between science and technology. A great many examples antecedents can be found in the history of science and technology, including the cases of pharmaceutical, biotechnology, modern science of bacteriology. Yet with the limited resources and capability of a single company given the increasing costs of science-based research, as well as the persistence of the specific profile of specialization of firms due to the path dependence and tacit nature of technologies, such cross-boundary research issues encourage the seeking of outside support to overcome internal technical limitations.

Also due to the path-dependent nature of technology, firms will seek to improve and to diversify their technology by searching in areas that enable them to use and to build upon their existing technological base (Pavitt, 1988; Cantwell & Barrera, 1998). For instance, a niche application of external sourced technological knowledge has been widely employed, like ICT technologies for pharmaceutical firms. In other words, external technological knowledge is complementary to internal knowledge base and may be sourced largely for the purpose of application rather further development. In contrast, open innovation literature argues that an equal weight should be given to external knowledge, in comparison to internal knowledge (Chesbrough, 2006). However, for the time being, we follow the complementary argument and hypothesize that externally sourced technologies must be relatively established, which is ready for application and requires minimum further development. Finally, whereas the accumulation of internal knowledge, in general, becomes increasingly important for firms over time (Jaffe & Trajtenberg, 1999), local embeddedness has been emphasized by subsidiary evolution literature for over a decade (Birkinshaw, *et al.*, 1998; Andersson, *et al.*, 2002; Cantwell & Mudambi, 2005). The access to external knowledge of local origin turns out to be more strategically significant in the capability development of, as well as the internal charter competition of, a subsidiary. Consequently, we have:

Hypothesis 1: Knowledge crossing technological disciplines is more likely to come from external knowledge sources instead of internal knowledge sources.

Hypothesis 2: Mature technological knowledge is more likely to come from external knowledge sources instead of internal knowledge sources.

Hypothesis 3: The local portion of the technological knowledge of a subsidiary is more likely to come from external knowledge sources instead of internal knowledge sources.

FDI theory suggests that 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). *Network MNCs* literature further argues that the different exposure of subsidiaries to host environments could be one of the basic competitive advantages of parent MNCs (McEvily & Zaheer, 1999; Andersson, *et al.*, 2002). Indeed, according to subsidiary evolutionary theory (Pearce, 1989), not every subsidiary has the capability and autonomy to enjoy the critical knowledge-related assets from external environment. The distinction between competence-creating (CC) and competence-exploiting (CE) types of subsidiary R&D activity has been well documented in previous literature, in which CC activities create new lines of technology for the MNC group whereas CE activities adapt established lines of technology of the MNC group (Kuemmerle, 1999; Pearce, 1999; Cantwell & Mudambi, 2005). By directly associating the typology of subsidiary R&D with the overall mandates of subsidiaries, actively searching for strategic assets from external sources is normally exclusively enjoyed by CC type of subsidiary mandate.

However, rather than assuming an exclusive corresponding relationship between the typology of subsidiary R&D and the overall mandates of subsidiaries as a whole, recent studies argue that there may be elements of both types of R&D in many subsidiaries (Zander, 1999; Cantwell & Piscitello, 2007). Given that this study is interested in knowledge components, we follow evolutionary theory and expect that subsidiaries differ in their capabilities of sourcing and combining internal and external technological knowledge and of generating the CC elements for the knowledge base of their parent MNCs. As CC elements are not the forte of the parent group, they may encourage, and sometimes require, the searching beyond the boundary of an MNC.

Hypothesis 4: Competence-creating technological knowledge is more likely to come from external knowledge sources instead of internal knowledge sources.

While knowledge, especially technological knowledge, increasingly becomes strategically important for firms, the process of technological knowledge accumulation is unavoidably influencing and influenced by corporate strategies. Instead of 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). Background technologies enables a firm to coordinate and benefit from technical change in its supply chain but do not necessarily result in distinctive competencies, whereas core technologies command both high shares of corporate technological resources and expertise, and result distinctive competencies for firms; moreover, both niche and marginal technologies only take a small proportion of corporate technological resources, but niche technologies might generate a strong competitive position for firms (Granstrand, *et al.*, 1997). If the core technological knowledge of a firm could generate distinctive competencies, then the subsidiaries of the firm can only get the knowledge from internal sources since the knowledge should not be widely available in other firms. However, Zack (1999) argues that 'core knowledge tends to be commonly held by members of an industry and therefore provides little advantage …' In this case, there is no reason to limit a subsidiary's sourcing of core technological knowledge in internal network, given the difficulties of long distance knowledge transfer (Jaffe, Trajtenberg & Henderson, 1993) on one hand, and the superior role of firms in knowledge transfer as suggested by evolutionary and internalization theories on the other. For the time being, we hypothesize that a subsidiary's accumulation of the core technological knowledge of parent group tends to prefer sources within the boundary of a firm given that the firm should have already accumulated a high degree of technological expertise in core fields.

As knowledge is dynamic, core technological knowledge might be soon obsolete and today's niche technological knowledge may be providing distinctive competencies for the firm in the future. Locational cluster literature suggests that a niche application of inter-industry knowledge spillover is generally observed in either specialized or all-round 'centers of excellence' (Cantwell & Iammarino, 2000; Cantwell & Piscitello, 2002). Moreover, it has been argued that a competence-creating subsidiary is more likely to develop a higher proportion of technologies that are non-primary for the firm's industry than does the parent company at home (Cantwell & Mudambi, 2005). In other words, subsidiaries may enjoy a niche strategy focusing on combining external sourced niche technological knowledge with existing knowledge base.

Background technological knowledge is a largely ignored category in strategic and knowledge management literature. However, the increasingly geographically dispersed CC activities of today's MNCs is at least partly due to the management needs of firms to maintain the access to a broader set of technological competencies, which are crucial in coordinating continuous improvement and innovation in the corporate production system and supply chain (Granstrand, *et al.*, 1997). Therefore, we expect that background technological knowledge is becoming strategically important by helping to coordinate and benefit from the technical changes in supply chain. Moreover, while the supply chain of many MNCs has been broadened to include both internal and external networks, the organizational boundary of today's MNCs starts to blur (Cantwell, 2007). To coordinate the increasingly networked and complex supply chain internal resources might be insufficient. Consequently, firms have to search for background technological knowledge from external resources.

Hypothesis 5: Niche technological knowledge, in contrast to core technological knowledge, is more likely to come from external knowledge sources instead of internal knowledge sources.

Hypothesis 6: Background technological knowledge, in contrast to core technological knowledge, is more likely to come from external knowledge sources instead of internal knowledge sources.

Hypotheses 1-6 are summarized in Figure 1.

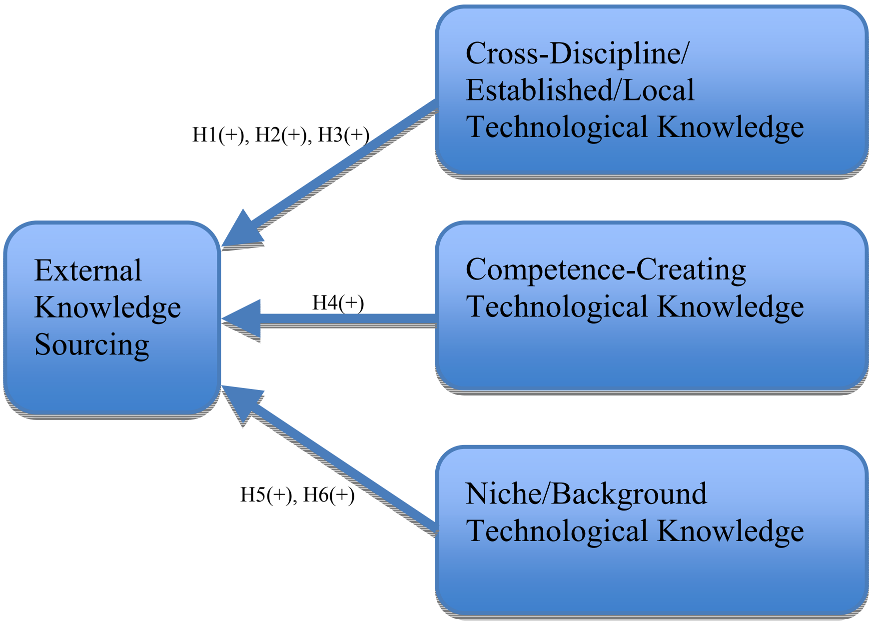

Figure 1. The Hypothesized Model

Data and Methodology

This study starts with 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 citation records, which allow us to calculate various measures of technological knowledge sources and components. There has been a historical discussion about the advantages and disadvantages of using patent and patent citation data (see Cantwell (2006) for a detailed review). A concern relevant to current study might be whether patent citations could represent real technological knowledge flows (Griliches, 1990; Alcacer &

Gittelman, 2006). Several studies have showed that patent citation is a reasonable measurement for knowledge flows (Jaffe, Trajtenberg & Fogarty, 2000; Duguet & Macgarvie, 2005); moreover, current study is interested in the types of internal and external technological knowledge that may contribute to the capability development of overseas subsidiaries (rather than knowledge flow). Even a citation added by patent examiners represents a legitimate component of the knowledge accumulated in the citing firm, and the origin of the cited technological knowledge represents a knowledge source available to the citing firm. More importantly, patent citation provides a relatively objective method to measure the knowledge structure and components of a citing patent.

Our dependent variable (EXT) is an indicator of whether a patent citation (a pairwise combination of citing and cited patents) is of an inter-organizational knowledge accumulation kind or not. In other words, EXT equals one if the citing patent cites a cited patent assigned to another firm/organization; and zero, otherwise.

By utilizing the 56 technological fields of Cantwell and Noonan (2004), we measure cross-discipline technological knowledge (CD) by pairwise matching the technology fields of citing and cited patents. CD equals one if a pair of citing and cited patents is in the same technological field; and zero, otherwise. Mature technological knowledge (M) is measured by the difference between the grant years of each pair of citing and cited patents. Finally, local technological knowledge (L) is measured by the inventor's location of a cited patent. L equals one if the inventor of a cited patent is located in China; and zero, otherwise. When L equals zero, it means that the knowledge is from international sources outside China, so we further divide this category into two sub-categories, namely home country ($L=0_a$) and a third country ($L=0_b$).

To operationalize competence-creating (CC), in contrast to competence-exploiting, technological knowledge, we follow Cantwell and Piscitello (2007) to define them in terms of the Revealed Technological Advantage (RTA) of home and host locations:

$$RTA_{ij} = (P_{ij} / \sum_i P_{ij}) / (\sum_j P_{ij} / \sum_{ij} P_{ij}) \qquad (1)$$

where P_{ij} is the number of patents of location i in field j. Independent variable CC equals one if host country RTA >=1 but home location RTA < 1; and zero, otherwise. While the 'host country' in this study is China, the 'home location' may vary depending on the origin of each foreign-owned subsidiary in China.

Following the definition of core, niche, marginal, and background technologies in Granstrand, and et al. (1997), we measure the type of technological knowledge using both the share of corporate technological resources (FMSHARE) and the level of expertise of the corporate (FMRTA) in a certain technological field. For the assignee of each citing patent, FMSHARE is the assignee's share of total world patenting in a given technological field, expressed as a percentage; FMRTA is the RTA index of the assignee in a given technological field. It's worth mentioning that we measure 'total world patenting' by the total number of USPTO patents granted to world largest firms between 1996 and 2005. Whereas Granstrand and et al. (1997) employed the average share per field, i.e. dividing 1 by the number of technological fields, in evaluating corporate technological resources devoted to a given field, we divide 1 by the number of firms that filed at least one patent in a given field to calculate the mean of FMSHARE. In doing so, we incorporate the potential difference across technological fields. Since 'RTA>=1' has been widely accepted as a criterion to differentiate specialized from unspecialized technological fields, the four technological knowledge categories are defined as:

I. Core: FMRTA >= 1 and FMSHARE >= mean (FMSHARE)

II. Niche: FMRTA >= 1 and FMSHARE < mean (FMSHARE)

III. Background: FMRTA < 1 and FMSHAE >= mean (FMSHARE)

IV. Marginal: FMRTA < 1 and FMSHARE < mean (FMSHARE)

Three dummy variables N, B, and M are created for the last three categories with core technological knowledge as the baseline category.

Finally, to capture changes over time, we control the grant year of citing patents (Y). Moreover, industry dummies (IND) and home country/region dummies (HM) are included to control the possible industrial and home country/region effects, in which food industry and Taiwan are the baseline categories.

As EXT is a dichotomous variable that takes values of 1 and 0, a logistic regression model is used. The model may be expressed formally as:

$$Y = f\,(X, C) \qquad (2)$$

where Y is the probability of knowledge coming from external sources, viz. the probability of EXT equaling one; X is a vector of independent variables, and C is a vector of control variables.

Results

Table 1 reports the two-tailed Pearson correlation matrix of most variables in this study. Give the number of dummies for control variables IND and HM, we didn't report their correlation coefficients in Table 1. (The full correlation matrix is available upon requests.) No significant correlation is observed among explanatory variables.

Insert Table 1 Here

The results of Logistic Regression are reported in Table 2, and all the models are statistically significant. In Model 1, the positive and significant coefficients of variables CD and M confirmed that cross-discipline and established technological knowledge is more likely to come from external sources. *Hypotheses 1* and *2* are confirmed. Whereas variable L is significant, the sign of its coefficient is opposite to what we predicted in *Hypothesis 3*. It seems that a foreign-owned subsidiary in China tends to rely on the technological knowledge generated by itself or its peer subsidiaries in China, rather than the knowledge from local external sources (we'll further discuss this finding in the next section). *Hypothesis 4* regarding competence creating technological knowledge is supported in Model 1. Finally, the coefficient of background technological knowledge (B) is positively significant, which supports that B is more likely than the baseline category, namely core technological knowledge, to come from external sources. However, the coefficient of niche technological knowledge (N) is not significant. Therefore, *Hypothesis 6* is supported whereas *Hypothesis 5* is rejected.

Insert Table 2 Here

We included all control variables, i.e. year (Y), industry (IND) and home country (HM), in Model 2, but only significant industries are reported in Table 1 to save space. The coefficient of competence-creating technological knowledge (CC) loses its significance after adding control variables while the coefficients of other independent variables are consistent with those in Model 1. As 'Non-Metallic Mineral Prod' industry is the only dummy that is negatively significant, we speculate that the change of CC's coefficient could be due to the highly professional technological knowledge required by firms in that industry, of which knowledge may not be widely available in external knowledge sources. Another possibility would be a tendency to rely on internal knowledge sources for competence-creating knowledge over time given that control variable Y is negatively significant. Moreover, Model 2 shows that firms from any other countries/regions are more likely to use external knowledge sources in China, than firms from Taiwan, i.e. the baseline category of home country/region (HM). Models 3 and 4 further investigate whether there is any difference between technological knowledge from the home locations of foreign-owned subsidiaries in China and that from a third-country. Local technological knowledge (L) equaling one becomes the baseline category in Models 3 and 4. Although no significant difference is observed, both models achieve a better model fit in comparison to Models 1 and 2.

Two issues are raised in Table 2. First, whereas the technological knowledge sourcing from local external environment is normally thought as an important ingredient of the capability development of an overseas subsidiary, the correlation coefficients of variables L and Y seem to suggest the opposite for foreign-owned subsidiaries in China. Second, while *Hypothesis 6* is supported, *Hypothesis 5* is rejected. The difference may be due to a lower level of FMRTA according to the definition of background technological knowledge in contrast to that of core technological knowledge; or by the same token, a lower level of FMSHARE according to the definition of niche technological knowledge in contrast to that of core technological knowledge doesn't significantly influence the dependent variable of interest.

Models 3 and 4 in Table 2 seem to suggest that a detailed geographical origin of technological knowledge may provide further explanation power to our model. To explore this possibility, especially in solving the first issue discussed above, we divide our dependent variable (EXT) in equation (2) by geographical origins, namely host country/local (i.e. China), home countries/regions, and third-countries. A response variable with six categories that have no natural ordering is generated, and therefore Multinomial Logistic Regression is employed. Time effect (Y) is also considered in the regression. Moreover, we replace technological knowledge categories (i.e. dummies variables N, B and M) by FMRTA to acknowledge the possibility discussed in the second issue. The higher a firm's RTA index (FMRTA) in a technological field, the more specialized the knowledge in that field for the firm. Finally, in subsidiary evolution literature, the dependence on the knowledge from parent companies is an important criterion in evaluating the capability of subsidiaries. Lately, in the debate about 'phantom' multinationals (Zander & Solvell, 2002), knowledge flow from peer subsidiaries in contrast to that from parents may become an important evidence of the organizational restructuring of multinationals. Therefore, we choose 'internal home country knowledge sources (parents)' as the baseline category in the Multinomial Logistic Regression, of which the results are reported in Table 3.

Insert Table 3 Here

The results of variables CD, M and CC in Table 3 are consistent with what we find in Table 2. In other words, *Hypotheses 1, 2,* and *4* are confirmed again. In the case of *Hypothesis 3*, the third column, namely ‘external local’, shows an increasing importance of local external knowledge sources in comparison to internal knowledge sources for subsidiaries accumulation of competence-creating technological knowledge (CC) over time (Y). Whereas ‘external local’ is the only external category that Y has a positively significant coefficient, the negatively significant Y observed in Table 2 could be explain by the first two columns in Table 3, namely a stronger tendency to rely on internal technological knowledge sources in general. The first three intercepts are negatively significant in Table 3, indicating a dominant role of parent companies in the technological knowledge accumulation of foreign-owned subsidiaries in China. However, in spite of this overall pattern, the coefficients of FMRTA show that foreign-owned subsidiaries in China and their peer subsidiaries, rather than parent companies, are more likely to be the sources of specialized technological knowledge. This finding has an important implication that the generation of technological expertise/competencies has being decentralized to overseas subsidiaries from headquarters, and that the exchange of technological expertise among subsidiaries has become significant over time, facilitating intra-firm interdependence.

Conclusion and Discussions

Subsidiary evolution in terms of innovative capability development has been intensively studies through MNC group-level and subsidiary-level characteristic, as well as host locational factors. However, little has been said about the capability developed. This study focuses on the structure and components of technological knowledge accumulated in foreign-owned subsidiaries in China during their evolution process. We found that cross-discipline and established technological knowledge, as well as background technological knowledge that is crucial in coordinating today's complex supply chain of MNCs, are more likely to come from external knowledge sources. A further investigation also showed that competence-creating technological knowledge is increasingly coming from local external knowledge sources over time. The results support our overall assumption that the capabilities of foreign-owned subsidiaries in China have being developed over the 10-year period.

This study uses patents granted by USPTO to inventions attributable to foreign-owned subsidiaries in China. It is reasonable to assume that the patents are strategically important for the parent MNCs of those subsidiaries given the costs of filing an international patent. In other words, foreign-owned subsidiaries in China should have already possessed capabilities to generate quality technological innovations. To develop such capabilities, an increasingly intensive knowledge flow from host environment to the subsidiary is expected. However, we observed a less important role of the technological knowledge from local external sources (see L in Table 2). This finding echoes the motive of this study, i.e. the importance to look into the capabilities developed in overseas subsidiaries. In particular, the need to source knowledge from host environment, namely the process of knowledge accumulation, is different from the capability accumulated through the process, namely the results of knowledge accumulation. Moreover, this finding has an important managerial implication. Given the numerous subunits of an MNC, it's essential to develop a proper method to coordinate the heterogeneity of subsidiaries and corporate strategies toward each subsidiary. While Garcia-Pont and et al. (2009) propose to identify different components of subsidiary embeddedness in order to develop proper subsidiary strategies, they couldn't provide a generalizable and quantized method. Although current study focuses on technological innovative capabilities only and is restricted to foreign-owned subsidiaries in a single host location, the result of this study suggests a promising future research that a comparison of capability components across subsidiaries may reveal interesting insights about the heterogeneity of subsidiaries and provide tailor made subsidiary strategies.

Indeed, another possibility would be that foreign-owned subsidiaries in this study are strategically avoiding the knowledge exchange with host environment, given their concerns on intellectual property right (IPR) conditions. As the organization of MNCs could provide an alternative institutional device for intellectual property protection (Zhao, 2006), the subsidiaries may limit the knowledge exchange within the boundary of individual parent MNCs on purpose. However, this argument might be more relevant for the outflow of technological knowledge, or it at least must be testified by looking at both inflow and outflow of technological knowledge of the subsidiaries. Therefore, another interesting future research would be to look at the antecedents and descendants of technological knowledge developed in different subsidiaries located across weak and strong IPR regions.

The coefficients of niche technological knowledge are insignificant across all models in Table 2. It may be due to the limited amount of niche technological knowledge accumulated in foreign-owned subsidiaries in China. Given that a niche application of external sourced technological knowledge is normally observed in 'centres of excellence', especially in all-round centres, the result might be implicating that the effective locational clusters for general purpose technological knowledge haven't been formed yet in China. Instead of setting up standardized industrial or scientific parks, China might be benefited through a strategic combination of different types of locational cluster. Finally, the interdependence between subsidiaries observed in Table 3 supports the argument of the restructuring of MNCs global innovation networks, and therefore contributes to the solution of the debate on 'phantom' multinationals.

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Table 1. Two-Tailed Pearson Correlation Matrix

Var	Mean	Std Dev	EXT	CD	M	L	CC	N	B	M	Y
EXT	0.7748	0.4178	1.0000								
CD	0.2039	0.4030	0.1539	1.0000							
			<.0001								
M	7.5813	10.0794	0.2330	0.0918	1.0000						
			<.0001	<.0001							
L	0.0434	0.2039	-0.3616	-0.0698	-0.1185	1.0000					
			<.0001	<.0001	<.0001						
CC	0.0975	0.2967	0.1185	0.1839	0.0645	-0.0356	1.0000				
			<.0001	<.0001	<.0001	0.0271					
N	0.0039	0.0624	0.0337	0.0512	0.0138	-0.0133	-0.0065	1.0000			
			0.0364	0.0015	0.3931	0.4084	0.6865				
B	0.0629	0.2429	0.0962	0.2649	0.0517	-0.0500	0.1278	-0.0162	1.0000		
			<.0001	<.0001	0.0013	0.0019	<.0001	0.3147			
M	0.0778	0.2678	0.1263	0.1664	0.0718	-0.0428	-0.0431	-0.0182	-0.0753	1.0000	
			<.0001	<.0001	<.0001	0.0079	0.0075	0.2599	<.0001		
Y	2003	1.5287	-0.0152	-0.0197	-0.0407	0.0534	-0.0903	-0.0716	-0.0085	0.0851	1.0000
			0.3462	0.2222	0.0117	0.0009	<.0001	<.0001	0.5992	<.0001	

Table 2. Logistic Regression Coefficients for Variables Predicting External Knowledge Accumulation

Variables	Model 1	Model 2	Model 3	Model 4
Intercept	0.2218**	183.000**	-3.4405***	232.3000**
Cross-Discipline Knowledge (CD)	0.5289***	0.4358***	0.7639***	0.5085**
Mature Knowledge (M)	0.1821***	0.1893***	0.1635***	0.1296***
Local Knowledge (L=1)	-3.6143***	-3.5968***		
International Knowledge (L=0)				
a. Home-Country			2.8246***	2.5809***
b. Third-Country			4.7696***	5.1094***
Competence-Creating Knowledge (CC)	1.1359***	0.1146	1.4776***	-0.0859
Niche (N)	12.7682	13.0826	11.9136	14.0863
Background (B)	1.0236***	1.0179***	1.0990***	1.2507***
Marginal (M)	1.9415***	1.7249***	1.9159***	1.2531***
Year (Y)		-0.0919**		-0.1186**
Industry (IND)				
Metals		2.1691**		2.1303*
Electrical Equipment		1.1216		1.4805*
Office Equipment		1.1794		1.7591*
Motor Vehicles		2.7348*		2.7370*
Non-Metallic Mineral Prod		-2.2126**		-1.8670*
...				
Home Country (HM)				
US		0.9836***		1.9939***
Japan		0.8907**		0.4646
Other Countries		1.0200**		1.1911**
Likelihood Ratio - Chi-Square(df)	924.1329(7)***	1086.2812(24)***	1337.3225(8)***	1630.9158(25)***
Pseudo R-Square	21.36	24.61	29.38	34.57

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

Table 3. Multinomial Logistic Regression

Variables	Baseline = Internal Home Country Knowledge Sources (Parent)				
	Internal Sources (EXT=0)		External Sources (EXT=1)		
	Internal Local	Internal Third Country	External Local	External Home Country	External Third Country
Intercept	-802.9***	-379.8**	-1162.9*	-83.7889	16.8581
Cross-Discipline Knowledge (CD)	-0.5257	-0.6697	0.5245	0.7623***	0.4103**
Mature Knowledge (M)	-0.5926***	-0.0580	0.0674	0.1718***	0.1699***
Competence-Creating Knowledge (CC)	0.0958	-0.8638	2.6202***	0.6477**	0.6852**
Specialized Knowledge (FMRTA)	0.0295***	0.0234***	0.0003	-0.0934***	-0.0034
Year (Y)	0.4007***	0.1890**	0.5780*	0.04190	-0.0083
Likelihood Ratio - Chi Square (df)	1039.7772 (25)***				

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