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Headquarter Involvement and Innovation in Multinational Corporations

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College of Business Administration

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Headquarter Involvement and Innovation in Multinational Corporations

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이 논문을 경영학 박사학위논문으로 제출함

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ABSTRACT

Headquarter Involvement and Innovation in Multinational Corporations

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This dissertation aims to study how headquarters (HQs) of multinational corporations (MNCs) actively involved in overseas R&D subsidiaries' innovation activities to achieve knowledge creation and integration within MNCs. In this dissertation, MNCs are viewed as a collaboration network, which is formed by collaborative innovation activities among globally dispersed R&D units. Based on this network-based view of MNC, headquarter involvement in both subsidiary-dyad and subsidiary level innovation activities are examined. I conducted two separate but related empirical studies, using patent data of 23 MNCs in the global semiconductor industry, observed over the 1989-2008 period.

Study1 investigated the phenomenon of headquarter involvement in inter-

subsidiary collaborative innovation. Drawing upon resource allocation perspective, I proposed three subsidiary-dyad level factors as determinants of headquarter involvement. I found that an HQ is more likely to involve in inter-subsidiary collaborative innovation when a subsidiary-dyad exhibits a stronger combined technological capability. I also found that prior collaborative innovation (both horizontal and vertical) of a subsidiary-dyad positively affect the likelihood of headquarter involvement in the focal dyad's collaborative innovation. The findings imply that HQs of MNCs actively search for new opportunities of knowledge integration and recombination by linking globally dispersed R&D subsidiaries to collaborate with each other and also by investing resources in most promising collaboration projects.

Study2 investigated the phenomenon of headquarter involvement in each overseas R&D subsidiary's innovation activities. I proposed that HQs will adjust their level of involvement in each subsidiary's innovation activity according to the subsidiary's capability development and subsidiary's dual (external and internal) embeddedness. I found that as an overseas R&D subsidiary's technological capability gets stronger, the HQ decreases its level of involvement, but above a certain level of subsidiary technological capability, the HQ increases its level of involvement. I also found that an HQ will increase its level of involvement in a subsidiary innovation as the subsidiary's external embeddedness increases, whereas it will decrease the level of involvement when the subsidiary's internal embeddedness increases. The findings imply that the HQ may react to each overseas R&D subsidiary's evolving capability and the level of embeddedness in external and internal collaboration networks by exerting hierarchical control when it is necessary,

that is, when greater autonomy may harm MNC-wide knowledge integration.

This dissertation both theoretically and empirically contributes to the current literature on R&D globalization of MNCs by showing how technological innovation is developed at subsidiary and subsidiary-dyad level and the importance of headquarter involvement in these processes. This dissertation also enriches our understanding of the value-adding roles of HQs under the network-based view of MNCs, since the results show that HQs can integrate knowledge that resides in overseas R&D subsidiaries via direct involvement in subsidiary dyadic collaborative innovation project and also can facilitate each subsidiary to contribute to MNC-wide knowledge integration via adjustment of involvement level in each subsidiary's innovation activities.

Keywords: Headquarter involvement, Overseas R&D subsidiary, MNC innovation, Subsidiary Innovation, Collaborative innovation, Subsidiary technological capability, Embeddedness

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CHAPTER I. OVERALL INTRODUCTION

I. RESEARCH BACKGROUND

Multinational corporations (MNCs) are becoming increasingly knowledge-driven. An ever-increasing competition forces them to seek and develop knowledge advantages wherever they can find them (Meyer, Mudambi, & Narula, 2011). This is especially true in technology-intensive industries, where a growing number of MNCs have increased investment in overseas R&D (OECD, 2015) by establishing global networks of R&D subsidiaries in foreign countries (Frost, 2001). Such globally dispersed knowledge activities enable MNCs to tap into location-specific knowledge from diverse knowledge clusters and the ability to recombine these diverse knowledge assets has been viewed as an important source of competitive advantage of the MNC (Bartlett & Ghoshal, 1989; Cantwell, 1989; Nobel & Birkinshaw, 1998). The role of HQs become particularly important in order to successfully achieve knowledge recombination and integration among these globally dispersed units.

In the past decades, MNCs have increasingly come to be seen as differentiated networks where the roles of overseas subsidiaries vary according to their specific capabilities and the internal and external networks they are embedded in (Ghoshal & Bartlett, 1990; Nohria & Ghoshal, 1997). Such network-based view of MNCs is fundamentally different from the traditional hierarchical view of MNCs with respect to the role of headquarters(HQs). The hierarchy perspective, the conventional view of an MNC, regards the HQ of an MNC as an entity with ultimate decision rights, emphasizing the role of headquarters with ultimate decision rights. While network-based view describes headquarters as just one "player amongst others" in the MNC federative arena (Ciabuschi, Dellestrand, & Holm, 2012). Accordingly, within this network-based view, much of the focus has been on subsidiaries and their contributory roles to the entire MNC, the role of HQ who still occupies a hierarchical position is rather neglected(Egelhoff, 2010). It is not until recent years that a few studies began to recognize the important roles of HQs by studying how HQs add value to the entire MNC via active involvement in subsidiary level activities under the network-based view (Bouquet & Birkinshaw, 2008; Ciabuschi, Dellestrand, & Martín, 2011; Nell & Ambos, 2013). My dissertation is in line with this research stream, focusing on the role of HQs by investigating headquarter involvement in subsidiary level innovation activities within the network-based view of MNCs.

II. KEY CONCEPTS

2.1. Innovation within MNCs

In the field of international business, innovation was traditionally viewed as an exclusive knowledge creation activity of HQs, whereas overseas subsidiaries have been regarded as mere passive recipients of parent firm's knowledge(Hymer, 1976; Vernon, 1966). However, there has been a growing emphasis on the important role that overseas subsidiaries play in the knowledge creation process(Almeida, 1996). A great number of studies have evidenced that some overseas subsidiaries have evolved from "competence-exploiting subsidiaries " to "competence-creating subsidiaries " (Cantwell & Mudambi, 2005), "global innovators" (Gupta & Govindarajan, 1991;

Nobel & Birkinshaw, 1998), “centers of excellence”(Frost, Birkinshaw, & Ensign, 2002) and “advanced subsidiaries”(Blomkvist, Kappen, & Zander, 2010). The main driver for the increased contribution of overseas subsidiaries to MNC innovation is their accumulation of knowledge in local contexts and the development of their own distinctive capabilities.

Some scholars have focused on technological innovation of MNCs and thus the role of overseas R&D subsidiaries(Almeida & Phene, 2004; Frost & Zhou, 2005; Phene & Almeida, 2008; Song, Asakawa, & Chu, 2011; Song & Shin, 2008). Similar to the general pattern mentioned above, R&D activities also become geographically distributed (Frost, 2001; Lahiri, 2010). The role of overseas R&D subsidiaries no longer limited to home-based exploiting, some are able to conduct home-based augmenting R&D that brings distinctive technological expertise embedded in a local context that is not available in the home country(Kuemmerle, 1999). In this dissertation, following this line of literature, I focused on the technological innovation of MNCs and I will use the term of innovation and technological innovation interchangeably. Accordingly, overseas subsidiaries refer to those who conduct R&D activities in local countries and HQs refers to R&D HQs.

2.2. MNC as a collaboration network

Overseas subsidiaries develop innovation not only by their own but also by collaborating with internal partners, including the HQ and peer subsidiaries in other countries (Berry, 2014). Frost & Zhou (2005) called such collaborative innovation activities as R&D co-practice, referring to the technical activities undertaken jointly by R&D personnel from two or more subunits in different geographic locations. These collaborative innovation activities among internal units result in the formation of collaborative ties among them and eventually the emergence of internal MNC collaboration network.

On the other hand, overseas subsidiaries also engage in collaborative innovation with external partners such as local firms, research institutions and universities that located in host countries(Asakawa, Nakamura, & Sawada, 2010). Therefore, from a subsidiary perspective, subsidiaries' collaboration network could be extended to include external partners beyond the firm boundary. In other words, an overseas subsidiary can be viewed as an entity that embedded in two different collaboration networks-internal collaboration network and external collaboration network.

2.3. Headquarter involvement

Since innovation can be developed through inter-subsidiary collaboration and also by the subsidiary itself, therefore headquarter involvement in subsidiary innovation development activities may occur at both subsidiary-dyad level and subsidiary level. On the one hand, an HQ can involve in an inter-subsidiary collaborative innovation by participating itself in an innovation development project together with personnel from two overseas subsidiaries, which accompanies with HQs' resource allocation (Ciabuschi et al., 2011). On the other hand, headquarter involvement may occur in the decision-making process of each subsidiary's innovation activities via a hierarchical control (Andersson, Buckley, & Dellestrand, 2015).

Despite the fact that the definitions and the theoretical lens to view headquarter involvement in subsidiary-dyad level and subsidiary level are different, the purpose of headquarter involvement is almost the same. That is, the HQ intends to add value to the entire MNC either by integrating knowledge that resides in overseas subsidiaries via direct involvement in subsidiary dyadic collaborative innovation project or by facilitating each subsidiary to contribute to MNC-wide knowledge integration via adjustment of involvement level in each subsidiary's innovation activities.

III. SUMMARY OF TWO EMPIRICAL STUDIES

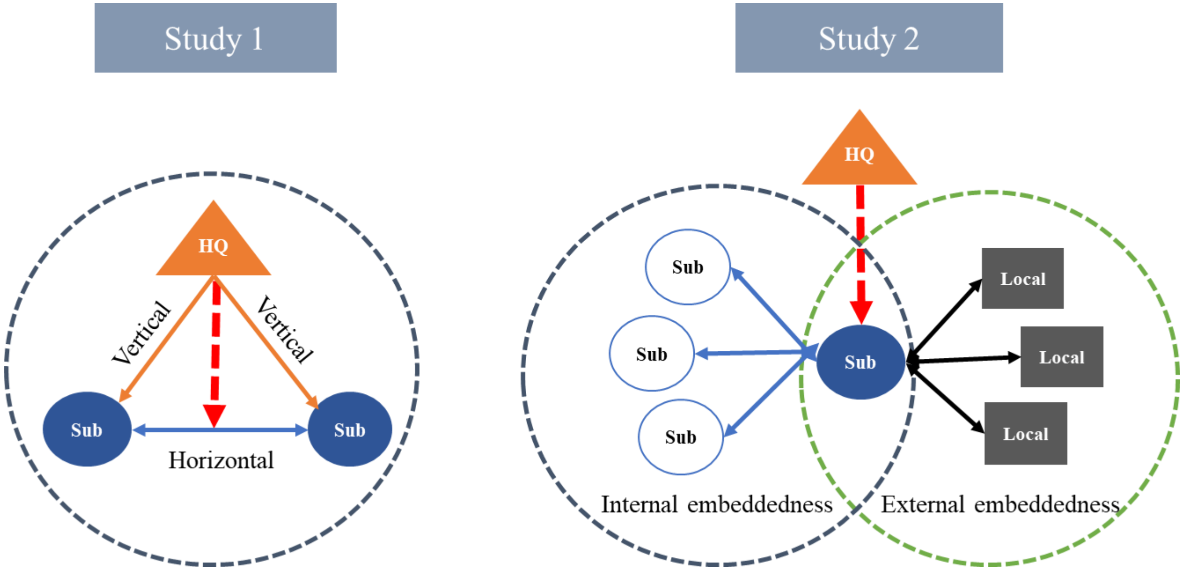
This dissertation aims to study how MNC-HQs to actively involved in subsidiary innovation activities to achieve knowledge integration within MNCs. I conducted two separate but related empirical studies. Figure 1 depicts the research models of Study1 and Study2.

Insert Figure 1-1 about here

Study1 investigated the phenomenon of headquarter involvement in inter-subsidiary collaborative innovation. Drawing upon resource allocation perspective, I proposed three subsidiary-dyad level factors as determinants of headquarter involvement. I found that an HQ is more likely to involve in inter-subsidiary collaborative innovation when a subsidiary-dyad exhibits a stronger combined technological capability. I also found that prior collaborative innovation (both horizontal and vertical) of a subsidiary-dyad positively affect the likelihood of headquarter involvement in the focal dyad's collaborative innovation. The findings imply that HQs of MNCs actively search for new opportunities of knowledge integration and recombination by linking globally dispersed subsidiaries to collaborate with each other and also by investing resources in most promising collaboration projects.

Study2 investigated the phenomenon of headquarter involvement in each subsidiary's innovation activities. I proposed that HQs will adjust their level of involvement in each subsidiary's innovation activity according to the subsidiary's capability development and subsidiary's dual (external and internal) embeddedness. I found that as an overseas subsidiary's technological capability gets stronger, the HQ decreases its level of involvement, but above a certain level of subsidiary technological capability, the HQ increases its level of involvement. I also found that an HQ will increase its level of involvement in a subsidiary innovation as the subsidiary's external embeddedness increases, whereas it will decrease the level of involvement when the subsidiary's internal embeddedness increases. The findings imply that the HQ may react to each subsidiary's evolving capability and embeddedness in external and internal collaboration networks by exerting hierarchical control when it is necessary, that is, when greater autonomy may harm MNC-wide knowledge integration.

[Figure 1-1] Research model for Study1 & Study2



CHAPTER II: STUDY 1

HEADQUARTER INVOLVEMENT IN INTER-SUBSIDIARY COLLABORATIVE INNOVATION

STUDY 1.

HEADQUARTER INVOLVEMENT IN INTER-SUBSIDIARY COLLABORATIVE INNOVATION

ABSTRACT

Study1 investigates subsidiary-dyad level factors that determine HQs' decision to get involved in inter-subsidiary collaborative innovation. Based on patents data of global semiconductor multinational corporations, I find that an HQ is more likely to involve in inter-subsidiary collaborative innovation when a subsidiary-dyad exhibits a stronger combined technological capability. I also find that prior collaboration experience of a subsidiary-dyad, both horizontal and vertical, positively affect the likelihood of headquarter involvement in the focal dyad's collaborative innovation. The findings imply that HQs of MNCs actively search for new opportunities of knowledge integration and recombination by linking globally dispersed subsidiaries to collaborate with each other and invest resources in most promising collaboration projects.

I. INTRODUCTION

MNCs gain competitive advantages from knowledge recombination that integrates diverse streams of knowledge across geographically dispersed units (Bartlett & Ghoshal, 1989; Cantwell, 1992; Frost, 2001; Nobel & Birkinshaw, 1998). Collaborative innovation among these R&D units may highly beneficial to the firm since it can improve innovation capability and competitive advantage of the entire MNC. Inter-subsidiary collaborative innovation also creates a foundation for future knowledge integration among them independent of any ongoing joint technical activities (Frost & Zhou, 2005). Moreover, inter-subsidiary ties that result from successful collaboration can act as an effective mechanism to share and transfer knowledge among subsidiaries (Gupta & Govindarajan, 2000; Hansen, 2002). Despite the potential benefit of collaborative innovation among globally dispersed R&D subsidiaries, there exit the difficulties in realizing the benefit by subsidiaries themselves. For example, they may not know each other's expertise or even existence. Geographic and cultural distance (Ambos & Ambos, 2009; van Wijk, Jansen, & Lyles, 2008) or incongruence in goals might hinder inter-subsidiary initiation of a collaborative project. Thus, HQ's active involvement is needed to realize inter-subsidiary collaborative innovation.

Some studies have investigated active headquarter involvement in subsidiary-dyad level innovation activities, but they only focused on headquarter involvement in inter-subsidiary innovation transfer, emphasizing the coordination role of the HQ in the transfer process (Ciabuschi et al., 2011; Ciabuschi, Forsgren, & Martín Martín, 2012; Dellestrand & Kappen, 2011; Holmström Lind & Kang, 2017; Yamin, Tsai, & Holm, 2011). These studies have adopted a so-called "sender-receiver model", which implicitly assume that knowledge is created by one unit and can be effectively transferred to other units based on various organizational mechanisms(Gupta & Govindarajan, 2000). This assumption, however, is problematic because knowledge integration can be achieved not only by unilateral knowledge transfer but also by knowledge co-development through inter-unit collaboration. Nevertheless, less is known about headquarter involvement in inter-subsidiary innovation development. Moreover, prior studies only focused on the performance effect of headquarter involvement by examining whether headquarter involvement adds value to the specific innovation transfer project, but they showed mixed findings. Such inconsistent findings might result from lack of understanding of rationales behind the HQ's decision on involvement in subsidiary-dyad level activities, implying that more research on the determinant factors that influence headquarter involvement is needed.

Study1 aims to investigate subsidiary-dyad level factors that determine HQs' decision to get involved in inter-subsidiary collaborative innovation. Based on patents data of global semiconductor multinational corporations, I found that an HQ is more likely to involve in inter-subsidiary collaborative innovation when a subsidiary-dyad exhibits a stronger combined technological capability. I also found that prior collaboration experience (both horizontal and vertical) of a subsidiary-dyad positively affect the likelihood of headquarter involvement in the focal dyad's collaborative innovation.

This paper is one of the few studies that investigate the phenomenon of inter-subsidiary collaborative innovation within MNCs. The findings showed that HQs of MNCs actively search for new opportunities of knowledge integration and recombination by linking globally dispersed subsidiaries to collaborate with each other and invest resources in most promising collaboration projects. This study also responds to the recent call for research on the value-adding role of HQs in the differentiated network of MNC.

II. THEORY & HYPOTHESES

2.1. Headquarter involvement as resource allocation

Headquarter involvement in inter-subsidiary collaborative innovation in this study refers to an occasion when R&D personnel from HQ and two overseas subsidiaries participated in a joint innovation development project. Headquarter involvement always accompanies with resource investment (including financial/ human/ physical /organization resources) (Dellestrand & Kappen, 2011). For example, HQs can provide financial resources and talented personnel to test ideas of a collaborative project includes two or more subsidiaries (Birkinshaw & Hood, 2001). However, resources possessed by HQs are often limited, therefore not all collaborative innovation project receive equal attention, resource allocation, and investment from the parent(Bouquet & Birkinshaw, 2008).

Network-based view of MNC implies that inter-subsidiary collaboration projects can be either initiated by HQs (HQ invites two subsidiaries to join in a project) or by subsidiary-dyad (two subsidiaries ask for HQ 's participation in their project). Nevertheless, they all become candidate projects. Based upon a set of alternative collaborative innovation projects, HQs need to allocate limited resources to collaboration projects that are most promising (Dellestrand & Kappen, 2011). However, it is less clear which collaborative projects (i.e. which subsidiary-dyad) actually receive resources from HQs. In the following session, I will propose that technological capability and prior collaborative innovation experience of a subsidiary-dyad will decide whether it is a promising collaborative project so that will lead to headquarter involvement.

2.2. Subsidiary's technological capability

It is commonly believed that MNCs are in a unique position to gain a competitive advantage from knowledge recombination that integrates diverse streams of knowledge across their geographically dispersed subsidiaries (Cantwell, 1989). Knowledge recombination occurs when different types of expertise are synthesized into novel ideas or when competencies are reconfigured due to new insights from new sources of knowledge (Galunic & Rodan, 1998). Overseas subsidiaries become important contributors to MNCs' knowledge recombination since they can tap into location-specific knowledge in host countries that may not exist elsewhere in the internal MNC network (Almeida & Phene, 2004; Singh, 2008). When R&D personnel from different subsidiaries jointly develop an innovation, they are likely to draw on distinctive knowledge that they hold and bring together different ideas from their local country contexts (Berry, 2014).

It has long been argued that innovation arises from a new combination of existing knowledge (Schumpeter, 1934). Higher subsidiary technological capability represents that the subsidiary has accumulated a richer knowledge stock. The richer the combined knowledge stock of a subsidiary-dyad, the higher the potential for recombination of each other's technological knowledge to generate novel innovations (Kogut & Zander, 1992; Rodan, 1998). Therefore, among all possible subsidiary dyads within an MNC, the potential to successfully develop a collaborative innovation will be higher for those with higher combined technological capabilities.

Moreover, absorptive capacity view suggests subsidiaries with strong technological capability enables them to understand and assimilate knowledge from partners (Cohen & Levinthal, 1990; Lane & Lubatkin, 1998; Zahra & George, 2002). Such ability is important in the context of inter-subsidiary collaborative innovation project since overseas subsidiaries often exhibit distinctive(location-specific) knowledge bases so that it is challenging to understand the value and relevance of partner's knowledge (Phene & Almeida, 2008). Consequently, all else being equal, a subsidiary dyad with a stronger combined level of technological capability has a higher chance to successfully develop a collaborative innovation. Thus, I hypothesize that:

Hypothesis1: Headquarter involvement in inter-subsidiary collaborative innovation will be more likely to occur when a subsidiary dyad has a stronger combined technological capability.

2.3. Subsidiary's prior collaborative innovation

"Collaborate to innovate" often requires more than just technological capability. Collaborative innovation can be viewed as a successful outcome of a knowledge co-development activity, which often requires intensive interaction and cooperation between people from different subsidiaries. It also requires subsidiaries to mutually commit their resources and knowledge to the same project (Gnyawali, Singal, & Mu, 2009). Drawing on subsidiaries' successful collaboration experience, therefore, HQs are able to evaluate whether the subsidiary has the ability to conduct a collaborative innovation project or whether the subsidiary is reliable as a partner.

An overseas subsidiary may have collaborative innovation experience with peer subsidiaries or the HQ (Berry, 2014). First, two subsidiaries might have participated in a collaboration project (without HQ's involvement) and successfully developed an innovation. I will call such dyadic collaborative innovation as "horizontal collaborative innovation". Second, a subsidiary might have participated in a collaboration project with HQ. If the subsidiary and the HQ successfully developed innovation, I will call it "vertical collaborative innovation". Figure 2-1 illustrates two types of collaborative innovation. Both horizontal collaborative innovation and vertical collaborative innovation result in the formation of collaborative ties among subsidiaries and between subsidiaries and the HQ eventually creates the internal MNC collaboration network.

Insert Figure 2-1 about here

Prior horizontal collaborative innovation

Network-based view of MNC suggests that a subsidiary dyad's horizontal collaborative innovation could result from one or both subsidiaries' initiative-taking, which is essentially an entrepreneurial process (Birkinshaw, 1997). Subsidiaries may identify an opportunity by seeking for internal partners to conduct a collaborative innovation project and commit its own resources to such a project. Prior studies have found that such subsidiary initiative taking can attract more headquarter attention(Ambos, Andersson, & Birkinshaw, 2010; Bouquet & Birkinshaw, 2008). Once recognized, the HQ may want to utilize the innovation output of such horizontal collaboration or attempt to absorb tacit knowledge that has been developed during the joint knowledge creation process (Nonaka, 1994), by inviting the dyad in its own innovation project.

Furthermore, prior horizontal collaborative innovation develops dyadic partner-specific knowledge which might create new opportunities for future collaboration, and it also develops partner-specific routines which can reduce coordination cost in a new project (Zollo, Reuer, & Singh, 2003). Moreover, inter-subsidiary trust can also be developed during prior horizontal collaborative innovation, which has been viewed as a necessary condition of cooperative behavior such as exchange and combination of resources and knowledge (Gulati, 1995). Therefore, compared to a subsidiary dyad without prior horizontal collaborative innovation, it is easier for the HQ to coordinate an inter-subsidiary collaboration project for a subsidiary dyad who has prior experience of horizontal collaborative innovation. Base on the above arguments, I hypothesize that:

> *Hypothesis2: Headquarter involvement in inter-subsidiary collaborative innovation will be more likely to occur when a subsidiary dyad has more prior horizontal collaborative innovation.*

Prior vertical collaborative innovation

Extant literature reveals that the HQ also collaborate with overseas subsidiaries to develop vertical collaborative innovation. Such joint R&D projects may aim for the adaptation of products and process in local market conditions (Håkanson & Nobel, 1993). The HQ also collaborate with subsidiaries to stimulate reverse knowledge transfer to get access to local technology and integrate it with home-based knowledge (Frost & Zhou, 2005). In Kuemmerle's (1999) words, vertical collaborative innovation can be an outcome of either home-base exploiting R&D or home-base-augmenting R&D. However, not all overseas subsidiaries have such vertical collaborative innovation experiences. At a subsidiary dyad level, three scenarios are possible: (1) both subsidiaries in a dyad have prior vertical collaborative innovation, (2) one of them has prior vertical collaborative innovation, or (3) both of them have no prior vertical collaborative innovation.

Social network theory suggests that if both subsidiaries have vertical ties with HQ, the HQ occupies a bridging position which allows HQ to enjoy brokering advantage (Burt, 1992). However, the HQ may close the open triad once it discovered a potential value to link two subsidiaries. The HQ may prefer to get involved in collaboration projects with subsidiaries, whom with they have prior vertical collaboration ties because prior vertical collaboration can help the HQ better evaluate each subsidiary's capability and expertise (Frost & Zhou, 2005). Vertical collaborative innovation also improves the HQ's understanding of each subsidiary's culture and cooperation style that may be taken into account when the HQ evaluate the feasibility of a potential collaboration project. Without knowledge of both subsidiaries, headquarter involvement may cause intervention hazard (Foss, Foss, & Nell, 2012; Holmström Lind & Kang, 2017), because the HQ could misjudge the capabilities of each subsidiary and falsely evaluate potential synergies of the dyad (Goold & Campbell, 1998; Nell & Ambos, 2013).

By carrying out an innovation project jointly, R&D personnel from a subsidiary and the HQ not only engage in knowledge exchange but also create reservoirs of trust and mutual obligation in the collaboration process that can be called upon in the future (Tsai & Ghoshal, 1998; Uzzi, 1997). Vertical collaborative innovation also facilitates the establishment of common values and collective goals within a globally dispersed organizational setting(Frost & Zhou, 2005). Therefore, if both subsidiaries of a subsidiary dyad have prior vertical collaborative innovation experience with HQ, it implies that the subsidiary dyad indirectly shares common knowledge and values through the common third party-the HQ. In such cases, therefore, it makes easier for the HQ to coordinate the inter-subsidiary collaborative innovation.

To sum up, when two subsidiaries both have prior vertical ties with HQ, the potential benefit of a collaboration project is higher and the coordination cost is lower, compared to the cases that one or both subsidiaries have no prior vertical ties. Thus, I hypothesize that:

Hypothesis3: Headquarter involvement in inter-subsidiary collaborative innovation will be more likely to occur when the headquarter has prior vertical collaborative innovation with each subsidiary in the dyad.

Figure2-2 summarizes the research model of study 1.

Insert Figure 2-1 about here

III. METHOD

3.1. Data & Sample

I used patent data of global semiconductor firms from the United States Patent and Trademark Office (USPTO) to test hypotheses. Patents data provides detailed information on inventor location, based on which researchers can identify who and who have participated in a collaborative innovation (Berry, 2014; Lahiri, 2010; Singh, 2008). The global semiconductor industry was chosen because R&D globalization in this industry has a relatively long history and exhibits a higher propensity of patenting than other high-tech industries, which enables researchers to observe more inter-subsidiary collaborative innovations (Almeida & Phene, 2004).

Patents data were crawled from USPTO website at the end of 2012, so I could access to patents which have been issued by late 2012. Generally, there are 4-6 years of the time lag between patent filing and patent issuance. To reduce the potential right truncation issue due to patent evaluation time, I advanced the end year of the observation period toward 2008.

Since only large multinational companies establish overseas R&D subsidiaries, I collected data of annual sales rankings in the global semiconductor industry from industry reports issued by market research companies (e.g. Gartner Dataquest Corporation; iSuppli Corporation). I also obtained company information from COMPUSTAT and annual reports. I collected the top 20 semiconductor firms every year from 1989 to 2008. I then made a full list of companies who have listed at least once in the rankings. 47 companies were originally identified. To be conservative, 15 companies who experienced major restructuring (e.g. merger and acquisition, spin-offs, divestment, and bankruptcy) in the observation period were excluded, since I lack subsidiary-level information to ensure the ownership change of subsidiaries in these cases. Four companies that lack information of subsidiary ownership were also excluded. Additionally, two companies that have less than five years' observation period and one company that has two HQs were excluded.

Patents issued by the remaining 25 companies were collected from USPTO by searching assignee names. Each patent was classified into two categories- single country patent and multi-country co-patent by verifying inventor city and country information. If all of the inventors of a patent were located in one country, it was coded as a single country patent which could be issued by an overseas subsidiary or a parent. If the inventors were located in more than one country, it was coded as multi-country co-patent, and then classified further into parent-subsidiary co-patent, subsidiary-subsidiary co-patent, and parent-subsidiary-subsidiary co-patent. Co-patenting can be seen as an indicator of inter-subsidiary collaborative innovation since it represents a successful outcome of collaboration among different units (Berry, 2014; Lahiri, 2010).

I identified every overseas subsidiary who has patented at least once during the observation period. To be more conservative, subsidiaries who have an only one-year record of patenting was not regarded as overseas subsidiaries. And I crosschecked with firm annual reports and other documents (e.g. 10k report for US firms) to confirm that the company actually has an overseas facility in that country. Two companies who owned only one overseas subsidiary was excluded from my sample because it is impossible for a subsidiary embedded in an internal network when only one subsidiary exits. I finally constructed a sample of 319 overseas subsidiaries, from 23 MNCs, observed over the 1989-2008 period. For each firm, all possible subsidiary-dyads given a year have been identified. This led to a sample of 2813 subsidiary dyads, and 20926 subsidiary dyad-year observations.

3.2. Variables

Dependent variable

Headquarter involvement in inter-subsidiary collaborative innovation. The dependent variable measures whether an MNC-HQ involved in a collaborative innovation between two overseas subsidiaries. To operationalize it, I followed Frost & Zhou(2005), using the records of co-patents to identify joint technical activities between two or more units. I discovered that a number of co-patents listed inventors residing in its home country (HQ) and inventors residing in two different foreign locations (two overseas subsidiaries). I interpret such three-party co-patents as instances of joint technical collaborative innovation activity between two subsidiaries with the involvement of HQ. Thus, I dichotomously coded the dependent variable as 1 if a focal subsidiary dyad was filed a co-patent with the parent in $Year_t$ and 0 otherwise.

Independent variables

Combined subsidiary technological capability is measured as the sum of the number of patents filed by each subsidiary in the focal subsidiary dyad in $Year_{t-1.}$ Following Almeida & Phene (2004), Berry (2014), and Phene & Almeida (2008), each subsidiary's technological capability is operationalized as the number of patents that filed by only subsidiary inventors in $Year_{t-1}$. At dyadic level, the combined level of technological capability of two subsidiaries is measured as the sum of each subsidiary technological capability, i.e. the total number of patents filed by both firms independently in *Year*$_{t-1}$ (Wang & Zajac, 2007).

Prior horizontal collaborative innovation is measured as the number of co-patent that filed only by two subsidiaries in the focal dyad in *Year*$_{t-1.}$ Such co-patent indicates joint R&D activity that voluntarily conducted by inventors from two overseas R&D subsidiaries, that is, without HQ's direct involvement in the focal project.

Prior vertical collaborative innovation is dichotomously coded as 1 if the HQ has filed co-patent with each subsidiary in the focal dyad respectively in *Year*$_{t-1}$, and 0 otherwise. If this variable is 1, it indicates that two overseas R&D subsidiaries have formed common collaborative ties with HQ. In other words, the HQ acts as a common third-party (Gulati, 1995).

Control variables

I included a number of control variables expected to affect inter-subsidiary collaborative innovation. First, several MNC-level controls were added in the model. As the number of subsidiaries in an MNC increase, a subsidiary has more potential partners to collaborate. Thus, I controlled for *Total number of subsidiaries* in *Year*$_t$. I also controlled the *Average subsidiary technological capability* in given *Year*$_t$, since as the subsidiary capability increase on average may lead to a lower probability of direct involvement of parent to initiate collaboration projects. The abundance of knowledge in the home country may influence HQs' perceptions on their technological capability possibly leading more involvement in subsidiary innovation activities, therefore I controlled for *Home technology advantage* measured by the proportion of home country semiconductor patents in $Year_{t-1.}$ Country-level patent data were downloaded from WIPO (World Intellectual Property Organization), where provides country-level patent data by technology. Technological capability of HQ may also influence headquarter involvement in inter-subsidiary collaborative innovation since HQ needs to possess a certain level of technological competence to understand subsidiaries' technical expertise. Thus, I controlled for *HQ technological capability*, measured as the number of patents (divided by 100) that filed by inventors only from the HQ in $Year_{t-1.}$

Firm heterogeneity in involvement propensity may exist so that some firms on average may be more likely to involve in subsidiary related activities than others. Thus, I controlled for *Headquarter involvement propensity (inter-sub level),* measured as the total number of HQ involved inter-subsidiary co-patent $Year_{t-1}$ divided by the number of subsidiaries; and also *Headquarter involvement propensity (sub level)* measured as the total number of HQ-subsidiary co-patents $Year_{t-1}$ divided by the number of subsidiaries. The need for inter-subsidiary collaborative innovation may vary with a firm's development stage and the scale of its business. Therefore, I controlled for both *Firm age* and *Firm size*. Headquarter involvement requires considerable financial resources, hence lagged *Firm ROA* in $Year_{t-1}$ was included in the model.

Second, some subsidiary-dyad level variables were also included as controls. *Geographic distance* and *Cultural distance* between two host countries of each subsidiary dyad were controlled because there are potential barriers to inter-subsidiary collaboration when two subsidiaries locate in geographically and culturally distant countries. I calculated the air miles between two host countries in a website (http://www.distancefromto.net) which provides distance calculation between any two places in the world. Following previous studies, I logged the absolute number of air miles to measure *Geographic distance* (Hansen & Løvås, 2004). I used Kogut & Singh (1988)'s formula to measure *Cultural distance,* based on Hofstede's six dimensions of culture that can be obtained from http://www.geerthofstede.nl/. I also controlled for *Duration* that the time of each subsidiary dyad exposed to potential dyadic collaboration. *Relative technological capability* between two subsidiaries in a dyad is calculated by the ratio of the absolute value of the difference between the numbers of patents filed by two subsidiaries and the sum of the two numbers. (i.e. $|Patent(Sub_i)-Patent(Sub_j)|$ / $[(Patent(Sub_i) + Patent(Sub_j)]$ The denominator acts as the weighting scheme so that the same difference between the two subsidiaries in their technological capabilities accounts for less difference if the two subsidiaries have higher combined technological capabilities than lower ones (Wang & Zajac, 2007). If both subsidiaries filed no single unit patents in $Year_{t-1}$ the ratio set to 0. An HQ may be more likely to involve in inter-subsidiary collaborative innovation when it has prior involvement experience in the same subsidiary dyad. So I controlled for *Prior headquarter involvement (lagged dependent variable)* in the focal dyad.

Finally, some subsidiary level controls were also added. Abundant knowledge stock in host countries may draw more attention from HQs, thus I added *Host technology advantage*, measured as the proportion of semiconductor patents registered by assignees from the host country. *External embeddedness* and *Internal embeddedness* were also controlled since they can influence HQ's decision to involve in a single subsidiary's innovation activities as demonstrated in Study2. Three subsidiary-level control variables mentioned above were created for each subsidiary in the dyad. I used the elder of the two subsidiaries in a dyad to represent Sub1, and the younger in the dyad to represent Sub2. *Firm fixed effects* and *Year fixed effects* were also included to control for the possible firm- and year- fixed effects.

3.3. Analytical approach

In this present study, the dependent variable takes a value of 1 if the HQ has involved in collaborative innovation of a subsidiary dyad at focal year and 0 otherwise. It turns out that out of 20926 dyad-year observation, 210 (1%) cases have resulted in headquarter involvement. Thus, the dependent variable remains zero in the majority of cases. In such case, fixed effects panel logistic regression will not function since the observations will be omitted when there is no change in the value of the dependent variable for each dyad. Therefore, I employed the random effects panel logistic regression to test my hypotheses. I reported results from the random effects panel logit model with robust standard errors adjusted for clustering at the subsidiary-dyad level to allow for nonindependence of observations referring to the same pair of subsidiaries and correct for heteroskedasticity(Greene, 2003).

Although a logit or probit model is commonly used for a binary dependent variable, Angrist & Pischke (2009) suggested that linear regression is still a good way to model on such occasion. Such special case is called linear probability model, which allows for fixed effects without loss of any observations and also provides consistent estimates of parameters by adjusting heteroscedasticity using robust standard errors(Forman & Zeebroeck, 2012). Therefore, I employed the linear probability model with fixed effects to check the robustness of the results.

IV. RESULTS

Table2-1 and Table2-2 depict summary statistics and pairwise correlations of all variables. Model (1) and Model (2) of Table 2-3 shows the results of the random effects panel logit model predicting the probability of headquarter involvement in inter-subsidiary collaborative innovation. Model (1) tests the baseline model with control variables only. Model (2) included all independent variables, based on which I will explain the results.

Insert Table 2-1 about here

Insert Table 2-2 about here

Insert Table 2-3 about here

Hypothesis1 predicts a positive relationship between the combined subsidiary technological capability and the likelihood of headquarter involvement in the focal subsidiary-dyad. Model (2) shows that the coefficient of *Subsidiary technological capability* is positive and significant ($\beta = 0.0298, p < 0.001$), supporting Hypothesis1.

Hypothesis2 predicts a positive relationship between prior horizontal collaborative innovation and the likelihood of headquarter involvement in the focal subsidiary-dyad. Model (2) shows that the coefficient of *Prior horizontal collaborative innovation* is positive and significant ($\beta = 0.3846, p < 0.01$), supporting Hypothesis2.

Hypothesis3 predicts that headquarter involvement in inter-subsidiary collaborative innovation will be more likely to occur when the HQ has prior vertical collaborative innovation with each subsidiary in the focal dyad. Model (2) shows that the coefficient of *Prior vertical collaborative innovation* is positive and significant ($\beta = 0.6745, p < 0.001$), supporting Hypothesis3.

Robustness checks

I conducted several additional analyses to check for the robustness of the results. First, I tested fixed effects linear probability model with robust standard errors. Time constant control variables were dropped during the estimating process. Table 2-4 shows that the coefficients for all three independent variables in Model (2) were positive and significant. This shows the robustness of the results based on random effects panel logit model.

Insert Table 2-4 about here

Second, I operationalized combined subsidiary technological capability in a different way. I classified each subsidiary dyad in to three categories based on each subsidiary's technological capability, namely 1) *High-High* when technological capability of two subsidiaries are both high, 2) *High-Low* when technological capability of one subsidiary is high and the other is low, 3) *Low-Low* when technological capability of two subsidiaries are both low. I identified whether a subsidiary's technological capability is high or low by comparing with the average technological capability of each MNC in a given $Year_{t-1}$. Then I classified subsidiaries that filed patents more than the average level as those with high technological capabilities, otherwise as with low technological capabilities. I coded a dyad of which both technological capabilities are high as 0 (*High-High*), one is high and the other is low as 1(*High-Low*), and both low as 2(*Low-Low*). The group of dyads in *Low-Low* category was set as a base group. Table 2-5 shows the results of both random effects panel logit model and fixed effects linear probability model, verifying that the headquarter involvement is more likely to occur when both subsidiaries of a dyad have high technological capabilities.

Insert Table 2-5 about here

Post-hoc analysis

I conducted two additional analyses to check whether my aforementioned results differ due to some specific conditions.

First, the network model of MNCs has been originally developed by studying European MNCs, especially those who are headquartered in northern European countries (e.g. Andersson & Forsgren, 1996). For example, Gates & Egelhoff (1986) found that European MNCs were more decentralized than American MNCs. Therefore, there might be a possibility that MNCs headquartered in European countries are less likely to involve in inter-subsidiary collaborative innovation activities, delegating a great level of autonomy to subsidiaries themselves to conduct innovation-related activities.

To check whether headquarter involvement in inter-subsidiary collaborative innovation occurs differently for European and non-European MNCs, I sub-sampled the original dataset by dividing MNCs as European and non-European MNCs and ran the same model. The results of the random effects panel logit model in Table 2-6 reveal that one out of three independent variables lost the statistical significance in the model of European MNCs. However, I acknowledge that only one firm in my sample was a European MNC. Thus, the loss of statistical significance for the variable of *Prior horizontal collaborative innovation* may be due to the relatively small sample size of European MNCs. Accordingly, I cannot guarantee that the proposed research model for the headquarter involvement in inter-subsidiary collaborative innovation only works for non-European MNCs.

Insert Table 2-6 about here

Second, there are three types of semiconductor firms that exhibit different characteristics. The first type is an integrated device manufacturer (IDM), which designs, manufactures, and sells integrated circuit (IC) products. Firms such as Intel or Samsung Electronics are the representative IDMs. The second type is a fabless firm that designs and sells semiconductor chips while outsourcing fabrication to a specialized manufacturer. The examples in this type are Qualcomm, Broadcomm, and AMD. The third type is a foundry firm, also called as a fab, which specialized in manufacturing under contract for other semiconductor firms (e.g., fabless semiconductor firms), without designing IC products. The typical dedicated foundry firms are TSMC and UMC. These three types of semiconductor firms are mainly different in their value chain activities. That is, an IDM is involved in both the design and the manufacturing of IC products, while the other two only focus on either design or manufacturing. Therefore, there might be a higher possibility for inter-subsidiary collaborative innovation for IDMs rather than fabless or foundry types, since a design subsidiary and a manufacturing subsidiary need to work closely on a collaborative basis. Thus, I subsampled my dataset by dividing it into IDMs and fabless/foundry firms. It turns out that there are 13 IDMs, 7 fabless firms, and 3 foundry firms in my sample. I reran the random effects panel logit model for two sub-samples.

The results of Table 2-7 indicate that all three independent variables exhibit a positive sign with statistical significance for the IDM sample. However, it turns out that two network-related independent variables, *Prior horizontal collaborative innovation* and *Prior vertical collaborative innovation* have no longer exerted positive influence for the fabless/foundry sample. Therefore, the research model presented in study 1 may be only effective for IDM type of semiconductor firms.

Insert Table 2-7 about here

V. DISCUSSION

5.1. Contributions & Implications

Drawing on resource allocation perspective, Study1 investigated the phenomenon of headquarter involvement in inter-subsidiary collaborative innovation. Three subsidiary-dyad level determinants have been identified. Specifically, I found that an HQ is more likely to involve in inter-subsidiary collaborative innovation when a subsidiary-dyad exhibits a stronger combined technological capability. I also found that prior collaborative innovations (both horizontal and vertical) of a subsidiary-dyad positively affect the likelihood of HQ's involvement in the focal dyad's collaborative innovation. These findings demonstrate that HQs of MNCs actively search for new opportunities of knowledge integration and recombination by linking globally dispersed R&D subsidiaries to collaborate with each other and allocate its resources in most promising collaboration projects. This study also responds to the recent call for research on the value-adding role of HQs in the differentiated network of MNCs(Ciabuschi et al., 2012).

Moreover, this study complements headquarter involvement literature in two aspects. First, the literature on headquarter involvement has been conducted exclusively on the issue of inter-subsidiary “innovation transfer”, which was believed to be an effective mechanism of knowledge integration among overseas subsidiaries(Ciabuschi et al., 2011; Ciabuschi, Forsgren, et al., 2012; Dellestrand & Kappen, 2011; Holmström Lind & Kang, 2017). This study suggested another type of knowledge integration mechanism by shedding light on the phenomenon of headquarter involvement in inter-subsidiary “innovation co-development”. Second, this study focused on the HQ’s rationale for its involvement in subsidiary-dyad level innovation activities and found several subsidiary-dyad level determinant factors. I believe that the findings may help to understand why headquarter involvement may not result in a positive outcome(Andersson et al., 2015; Yamin et al., 2011). For instance, one of the findings of the present study reveals that an HQ is more likely to involve in a collaborative project when a subsidiary dyad has prior horizontal collaborative innovation, because the HQ assumes that prior dyadic collaboration between two subsidiaries will decrease the potential coordination cost between them since partner-specific routines have been developed during prior collaboration. However, such an approach may not consider how the subsidiary dyad perceives headquarter involvement. For example, HQ’s direct involvement could reduce autonomous motivation (Foss et al., 2012) or harm established dyadic routines which may hinder successful innovation development. Such unintended involvement alerts HQ managers that subsidiaries' perspective should be taken into account in the HQ's evaluation criteria when they decide whether to directly involve in inter-subsidiary collaborative innovation projects.

5.2. Limitation & Future research

This paper is not without limitations. In this study, I only examined headquarter involvement in collaborative innovation among overseas R&D subsidiaries. Thus, the results may not generalizable in other types of functional subsidiaries. Nevertheless, future research can further investigate collaboration among subsidiaries in diverse functional domains such as sales, marketing, manufacturing, and R&D to improve our understating of the HQ's diverse roles in managing the complex internal MNC's collaboration network.

Furthermore, collaborative innovation was measured based on co-patenting data. Accordingly, when two subsidiaries did collaborate but failed to or strategically decided not to file co-patents, such collaboration may not be reflected in our measures. However, I still believe that co-patents data provides a huge opportunity for scholars who study subsidiary or inter-subsidiary level innovation activities. The majority of previous subsidiary-level research has been dominated by survey-based method because the secondary data of subsidiary level information is too limited. But survey-based research also faces a criticism, for example, it is always a cross-sectional data which cannot capture the dynamics among variables. Fortunately, patent records make it possible to construct a panel dataset at multi-level. Future research could combine patent data and survey-based method to overcome the disadvantage of using a single method(Asakawa, Park, Song, & Kim, 2018).

Recently, studies on regional HQs has emerged as a hot topic in MNC literature (Decreton, Dellestrand, Kappen, & Nell, 2017; Mahnke, Ambos, Nell, & Hobdari, 2012). This study did not consider the existence of the regional HQs and their involvement in intra-regional collaborative innovation. More correctly, I could not identify whether an overseas R&D subsidiary is controlled by a regional HQ if it exists. In reality, R&D subsidiaries may directly be controlled by the R&D HQ, or by both of the R&D HQ and the regional HQ. Unfortunately, such information may be only available through surveys or interviews. Nevertheless, it is a promising research area so that future studies can examine the involvement of HQs at different levels (regional/functional/divisional).

[Table 2-1] Summary statistics

	Variable	Obs	Mean	S.D.	Min	Max
(1)	Headquarter involvement in inter-subsidiary collaborative innovation	20926	0.01	0.10	0.00	1.00
(2)	Total number of subsidiaries	20926	19.05	6.54	2.00	29.00
(3)	Average subsidiary technological capability	20926	4.15	2.76	0.00	14.44
(4)	Home technology advantage	20926	33.54	14.52	0.00	55.92
(5)	HQ technological capability	20926	8.49	8.78	0.00	46.20
(6)	Headquarter involvement propensity(inter-sub level)	20926	0.25	0.44	0.00	6.67
(7)	Headquarter involvement propensity(sub level)	20926	2.18	1.53	0.00	6.44
(8)	Firm age	20926	38.85	24.57	2.00	110.00
(9)	Firm size	20926	9.33	1.14	2.66	11.66
(10)	Firm ROA	20926	0.06	0.18	-1.01	5.79
(11)	Geographic distance	20926	7.97	0.95	4.48	9.42
(12)	Cultural distance	20926	2.28	1.43	0.02	11.17
(13)	Duration	20906	5.62	4.08	1.00	20.00
(14)	Relative technological capability	20926	0.57	0.46	0.00	1.00
(15)	Prior headquarter involvement (lagged DV)	20926	0.01	0.10	0.00	1.00
(16)	Host technology advantage(Sub1)	20926	4.39	10.44	0.00	54.47
(17)	Host technology advantage(Sub2)	20926	1.84	6.12	0.00	54.47
(18)	External embeddedness(Sub1)	20926	0.14	1.21	0.00	30.00
(19)	External embeddedness(Sub2)	20926	0.04	0.66	0.00	30.00
(20)	Internal embeddedness(Sub1)	20926	0.40	1.41	0.00	22.00
(21)	Internal embeddedness(Sub2)	20926	0.20	0.93	0.00	22.00
(22)	Combined subsidiary technological capability	20926	8.29	18.93	0.00	226.00
(23)	Prior horizontal collaborative innovation	20926	0.02	0.26	0.00	22.00
(24)	Prior vertical collaborative innovation(dummy)	20926	0.20	0.40	0.00	1.00

[Table 2-2] Pairwise correlations

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
(1)	1.00																							
(2)	-0.01	1.00																						
(3)	0.03*	0.43*	1.00																					
(4)	-0.05*	0.01	-0.56*	1.00																				
(5)	-0.02	0.26*	0.54*	-0.33*	1.00																			
(6)	0.09*	0.08*	0.32*	-0.38*	-0.03*	1.00																		
(7)	0.07*	0.49*	0.69*	-0.47*	0.47*	0.48*	1.00																	
(8)	-0.04*	0.20*	-0.02*	0.35*	0.09*	-0.25*	-0.18*	1.00																
(9)	-0.00	0.55*	0.59*	-0.28*	0.72*	0.12*	0.55*	0.21*	1.00															
(10)	-0.00	0.14*	-0.19*	0.05*	-0.07*	-0.06*	-0.03*	0.16*	0.02*	1.00														
(11)	0.00	0.02*	-0.01	0.02	-0.03*	0.02*	0.02*	-0.01	0.02*	0.02*	1.00													
(12)	-0.02	0.07*	0.03*	0.00	0.04*	-0.03*	-0.01	0.05*	-0.00	0.01	0.26*	1.00												
(13)	0.01	0.27*	-0.02*	0.08*	-0.08*	-0.13*	-0.08*	0.36*	0.04*	0.13*	0.00	0.01	1.00											
(14)	0.02*	0.10*	0.12*	0.02*	0.01	0.01	0.06*	0.03*	0.06*	-0.01	0.01	-0.01	0.09*	1.00										
(15)	0.22*	-0.01	0.03*	-0.06*	-0.02	0.15*	0.07*	-0.03*	-0.00	-0.01	0.00	-0.02*	0.02*	0.01	1.00									
(16)	0.05*	-0.15*	0.03*	-0.18*	0.05*	0.05*	-0.00	-0.02*	0.02*	0.04*	0.14*	0.09*	0.04*	0.10*	0.05*	1.00								
(17)	0.09*	-0.15*	-0.06*	-0.02*	-0.10*	-0.00	-0.06*	-0.07*	-0.14*	0.03*	0.10*	0.00	0.11*	0.03*	0.09*	-0.01	1.00							
(18)	0.10*	0.02	0.17*	-0.19*	0.03*	0.12*	0.16*	-0.09*	0.03*	-0.04*	0.04*	-0.00	-0.03*	0.09*	0.09*	0.29*	0.01	1.00						
(19)	0.14*	0.00	0.07*	-0.08*	-0.01	0.07*	0.08*	-0.04*	-0.00	-0.02	0.04*	-0.02	0.00	0.03*	0.13*	-0.01	0.28*	0.01	1.00					
(20)	0.09*	0.09*	0.23*	-0.22*	0.14*	0.12*	0.17*	-0.07*	0.15*	-0.03*	0.02*	-0.01	0.01	0.14*	0.09*	0.22*	0.02	0.30*	0.04*	1.00				
(21)	0.06*	0.07*	0.15*	-0.15*	0.11*	0.07*	0.11*	-0.05*	0.12*	-0.01	-0.03*	-0.03*	0.00	0.03*	0.07*	0.00	0.06*	0.02	0.21*	0.07*	1.00			
(22)	0.08*	0.14*	0.10*	-0.00	0.06*	0.09*	0.19*	-0.05*	0.12*	0.00	0.02	-0.02*	0.09*	0.10*	0.09*	0.04*	0.04*	0.06*	0.07*	0.10*	0.05*	1.00		
(23)	0.15*	0.13*	0.29*	-0.16*	0.16*	0.09*	0.20*	-0.01	0.17*	-0.05*	0.07*	0.02	0.13*	0.28*	0.15*	0.35*	0.12*	0.42*	0.21*	0.60*	0.12*	0.22*	1.00	
(24)	0.11*	-0.01	0.04*	-0.05*	0.03*	0.02*	0.02*	-0.01	0.02*	-0.01	-0.01	-0.02	0.01	0.03*	0.11*	0.08*	0.04*	0.06*	0.11*	0.24*	0.30*	0.03*	0.19*	1.00

* shows significance at the .01 level

[Table 2-3] Result of random effects panel logit model

	(1)	(2)
Total number of subsidiaries	0.1110	0.1049
	(0.0695)	(0.0680)
Average subsidiary technological capability	-0.0373	-0.1889^{+}
	(0.1081)	(0.1084)
Home technology advantage	0.0248	-0.0901
	(0.1109)	(0.1040)
HQ technological capability	0.0116	0.0023
	(0.0509)	(0.0485)
Headquarter involvement propensity(inter-sub level)	-0.1700	-0.1202
	(0.1914)	(0.1969)
Headquarter involvement propensity(sub level)	0.3369**	0.2669*
	(0.1308)	(0.1290)
Firm age	-0.4583^{+}	-0.1897
	(0.2340)	(0.2218)
Firm size	0.6903	0.6660
	(0.4276)	(0.4062)
Firm ROA	0.2201	0.2917
	(0.2151)	(0.2227)
Geographic distance	-0.1870	-0.1948
	(0.1322)	(0.1374)
Cultural distance	-0.0960	-0.0962
	(0.0918)	(0.0936)
Duration	0.0884*	0.0384
	(0.0431)	(0.0422)
Relative technological capability	0.1827	0.1018
	(0.2053)	(0.2155)
Prior headquarter involvement	0.5935*	0.4069
	(0.2970)	(0.2974)
Host technology advantage(Sub1)	0.0252*	0.0063
	(0.0112)	(0.0123)
Host technology advantage(Sub2)	0.0425**	0.0300*
	(0.0141)	(0.0149)
External embeddedness(Sub1)	0.0623^{+}	0.0135
	(0.0352)	(0.0409)
External embeddedness(Sub2)	0.1234*	0.0684
	(0.0521)	(0.0557)
Internal embeddedness(Sub1)	0.1567***	-0.0623
	(0.0382)	(0.0597)
Internal embeddedness(Sub2)	0.1491**	-0.0548
	(0.0465)	(0.1008)
(H1)Combined subsidiary technological capability		0.0298***
		(0.0058)
(H2)Prior horizontal collaborative innovation		0.3846**
		(0.1358)
(H3)Prior vertical collaborative innovation		0.6745***
		(0.1936)
Firm fixed effects	Included	Included
Year fixed effects	Included	Included
Constant	-2.6645	-1.2547
	(3.2674)	(3.1764)
Observations	19517	19517
No. of dyads	2637	2637
Wald chi2	690.59***	642.41***
Log pseudolikelihood	-855.6784	-829.1847

Clustered standard errors in parentheses. $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

[Table 2-4] Result of fixed effects linear probability model

	(1)	(2)
Total number of subsidiaries	0.0017*	0.0013
	(0.0008)	(0.0008)
Average subsidiary technological capability	0.0002	-0.0009
	(0.0006)	(0.0006)
Home technology advantage	-0.0003	-0.0007
	(0.0007)	(0.0007)
HQ technological capability	-0.0005	-0.0004
	(0.0003)	(0.0003)
Headquarter involvement propensity(inter-sub level)	0.0074	0.0081
	(0.0057)	(0.0058)
Headquarter involvement propensity(sub level)	0.0038**	0.0035*
	(0.0014)	(0.0014)
Firm age	-0.0021+	-0.0024*
	(0.0012)	(0.0012)
Firm size	0.0022	0.0018
	(0.0036)	(0.0035)
Firm ROA	0.0052+	0.0057+
	(0.0030)	(0.0030)
Geographic distance	N/A	N/A
Cultural distance	N/A	N/A
Duration	N/A	N/A
Relative technological capability	-0.0024+	-0.0027*
	(0.0013)	(0.0013)
Prior headquarter involvement	-0.0331	-0.0383
	(0.0306)	(0.0306)
Host technology advantage(Sub1)	0.0010	0.0012
	(0.0009)	(0.0009)
Host technology advantage(Sub2)	-0.0010	-0.0009
	(0.0015)	(0.0015)
External embeddedness(Sub1)	0.0031	0.0021
	(0.0028)	(0.0029)
External embeddedness(Sub2)	0.0148*	0.0138*
	(0.0058)	(0.0057)
Internal embeddedness(Sub1)	0.0010	-0.0011
	(0.0010)	(0.0008)
Internal embeddedness(Sub2)	0.0025+	0.0006
	(0.0015)	(0.0007)
(H1)Combined subsidiary technological capability		0.0005**
		(0.0002)
(H2)Prior horizontal collaborative innovation		0.0214**
		(0.0074)
(H3)Prior vertical collaborative innovation		0.0063**
		(0.0022)
Firm fixed effects	N/A	N/A
Year fixed effects	Included	Included
Constant	0.0405	0.0718
	(0.0723)	(0.0724)
Observations	20906	20906
No. of dyads	2812	2812
R-squared	0.0053	2.16***
F statistic	0.0089	2.41***

Robust standard errors in parentheses. $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

[Table 2-5] Combined subsidiary technological capability as a categorical variable

	Random effects	Fixed effects
Total number of subsidiaries	0.1201^{+}	0.0015^{+}
	(0.0649)	(0.0008)
Average subsidiary technological capability	-0.0294	0.0001
	(0.1056)	(0.0006)
Home technology advantage	0.0112	-0.0003
	(0.1060)	(0.0007)
HQ technological capability	0.0058	-0.0004
	(0.0476)	(0.0003)
Headquarter involvement propensity(inter-sub level)	-0.1342	0.0076
	(0.1964)	(0.0058)
Headquarter involvement propensity(sub level)	0.2868*	0.0035*
	(0.1301)	(0.0014)
Firm age	-0.4289^{+}	-0.0020^{+}
	(0.2225)	(0.0012)
Firm size	0.4929	0.0014
	(0.4171)	(0.0034)
Firm ROA	0.1498	0.0046
	(0.2302)	(0.0031)
Geographic distance	-0.1523	N/A
	(0.1359)	
Cultural distance	-0.1241	N/A
	(0.0909)	
Duration	0.0223	N/A
	(0.0407)	
Relative technological capability	-0.0283	-0.0013
	(0.2989)	(0.0014)
Prior headquarter involvement	0.4467	-0.0378
	(0.3005)	(0.0305)
Host technology advantage(Sub1)	0.0188^{+}	0.0010
	(0.0109)	(0.0009)
Host technology advantage(Sub2)	0.0368**	-0.0009
	(0.0138)	(0.0015)
External embeddedness(Sub1)	0.0563	0.0031
	(0.0343)	(0.0028)
External embeddedness(Sub2)	0.1034^{+}	0.0143*
	(0.0583)	(0.0057)
Internal embeddedness(Sub1)	0.0815*	0.0001
	(0.0413)	(0.0008)
Internal embeddedness(Sub2)	0.0090	0.0007
	(0.0848)	(0.0007)
(H1) Combined subsidiary tech capability		
High-High	1.9589***	0.0184*
	(0.3365)	(0.0073)
High-Low	1.0032***	0.0019
	(0.2641)	(0.0020)
(H2) Prior horizontal collaborative innovation	0.2754*	0.0211**
	(0.1186)	(0.0075)
(H3) Prior vertical collaborative innovation	0.5325**	0.0061**
	(0.1901)	(0.0021)
Firm fixed effects	Included	N/A
Year fixed effects	Included	Included
Constant	1.1014***	0.0459
	(0.2177)	(0.0721)
Observations	19517	20906
No. of dyads	2637	2812
Wald chi2	747.83***	
Log pseudolikelihood	-830.5261	
R-squared		0.0073
F statistic		2.27***

Clustered/Robust standard errors in parentheses. $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

[Table 2-6] European vs. non-European MNCs (random effects panel logit)

	European	Non-European
Total number of subsidiaries	1.6438^{+}	0.1639^{+}
	(0.9635)	(0.0895)
Average subsidiary technological capability	2.8406^{+}	-0.2362^{+}
	(1.4927)	(0.1402)
Home technology advantage	-13.7038*	0.0037
	(5.8017)	(0.1291)
HQ technological capability	0.1451	-0.0054
	(0.8586)	(0.0540)
Headquarter involvement propensity(inter-sub level)	-4.1412**	-0.0418
	(1.5487)	(0.1980)
Headquarter involvement propensity(sub level)	-2.3772*	0.2814^{+}
	(1.1145)	(0.1661)
Firm age	2.6204*	-0.4455
	(1.1428)	(0.2970)
Firm size	-29.4594*	0.8950*
	(11.9096)	(0.4450)
Firm ROA	0.0000	0.3082
	(.)	(0.2733)
Geographic distance	-0.2684	-0.1493
	(0.3267)	(0.1550)
Cultural distance	-0.0930	-0.1292
	(0.2225)	(0.1055)
Duration	-0.4576**	0.0637
	(0.1528)	(0.0438)
Relative technological capability	0.8485	0.0355
	(0.6701)	(0.2335)
Prior headquarter involvement	-0.4250	0.7786*
	(0.7461)	(0.3474)
Host technology advantage(Sub1)	-0.0050	0.0133
	(0.0308)	(0.0128)
Host technology advantage(Sub2)	0.0643^{+}	0.0271
	(0.0343)	(0.0168)
External embeddedness(Sub1)	-0.0192	-0.0856
	(0.0551)	(0.1656)
External embeddedness(Sub2)	0.0185	0.0554
	(0.0599)	(0.1464)
Internal embeddedness(Sub1)	0.1770	-0.1392
	(0.1771)	(0.0902)
Internal embeddedness(Sub2)	0.2755	-0.0650
	(0.2511)	(0.1744)
(H1)Combined subsidiary technological capability	0.0259^{+}	0.0315***
	(0.0139)	(0.0073)
(H2)Prior horizontal collaborative innovation	-0.2442	0.5190*
	(0.2744)	(0.2284)
(H3)Prior vertical collaborative innovation	1.1073*	0.7489***
	(0.4406)	(0.2196)
Firm fixed effects	Included	Included
Year fixed effects	Included	Included
Constant	260.5909*	-3.4737
	(105.0102)	(3.5143)
Observations	1897	17620
No. of dyads	300	2337
Wald chi2	190.51***	525.05***
Log pseudolikelihood	-168.6055	-636.8332

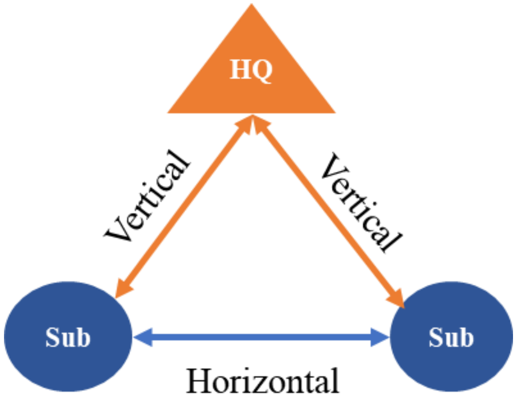
Clustered standard errors in parentheses. $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

[Table 2-7] IDM vs. fabless/foundry MNCs (random effects panel logit)

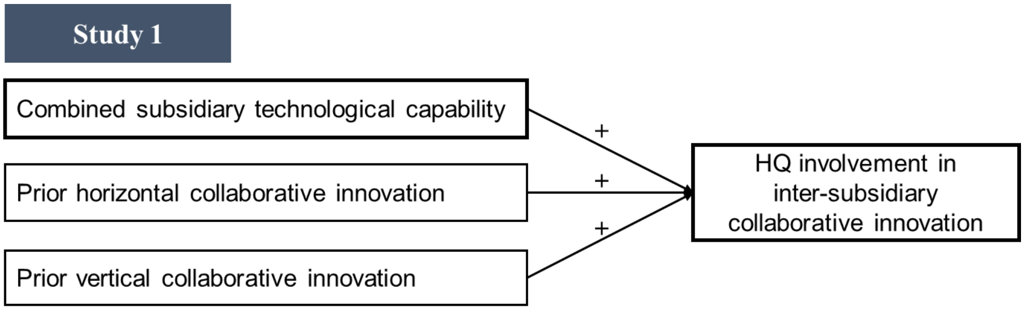
	IDM	Fabless/Foundry
Total number of subsidiaries	0.0498	-0.1225
	(0.0945)	(0.1657)
Average subsidiary technological capability	-0.0580	-0.5666
	(0.1227)	(0.3927)
Home technology advantage	-0.2527	-0.8475
	(0.1936)	(0.6091)
HQ technological capability	0.0539	0.8092**
	(0.0747)	(0.2800)
Headquarter involvement propensity(inter-sub level)	-0.3247	-0.2760
	(0.4839)	(0.2693)
Headquarter involvement propensity(sub level)	0.2477	0.4196*
	(0.2241)	(0.2033)
Firm age	0.2985	14.2716
	(0.2020)	(12.6791)
Firm size	1.3374*	-0.2071
	(0.6423)	(1.5972)
Firm ROA	2.9065	0.6894*
	(2.5661)	(0.3346)
Geographic distance	-0.2109	-0.1876
	(0.1489)	(0.3401)
Cultural distance	-0.0337	-0.3305
	(0.0963)	(0.3253)
Duration	0.0621	-0.2023
	(0.0464)	(0.1309)
Relative technological capability	0.2526	-0.5071
	(0.2656)	(0.4631)
Prior headquarter involvement	0.2158	0.6698
	(0.3736)	(0.5011)
Host technology advantage(Sub1)	0.0021	0.0176
	(0.0159)	(0.0206)
Host technology advantage(Sub2)	0.0329*	0.0713
	(0.0161)	(0.0471)
External embeddedness(Sub1)	0.0233	0.0000
	(0.0399)	(.)
External embeddedness(Sub2)	0.0687	0.0000
	(0.0565)	(.)
Internal embeddedness(Sub1)	-0.0384	0.5252
	(0.0585)	(0.4394)
Internal embeddedness(Sub2)	-0.0127	0.6681
	(0.1124)	(0.5156)
(H1)Combined subsidiary technological capability	0.0274***	0.0819*
	(0.0059)	(0.0380)
(H2)Prior horizontal collaborative innovation	0.3504*	-0.0988
	(0.1362)	(1.0064)
(H3)Prior vertical collaborative innovation	0.6724***	0.7447
	(0.1968)	(0.5244)
Firm fixed effects	Included	Included
Year fixed effects	Included	Included
Constant	-9.5412	-314.3229
	(12.9627)	(275.5945)
Observations	14903	4351
No. of dyads	1832	805
Wald chi2	595.57***	419.22***
Log pseudolikelihood	-619.3199	-184.7597

Clustered standard errors in parentheses. $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

[Figure 2-1] Horizontal and vertical collaborative innovation



[Figure 2-2] Research model (Study 1)



CHAPTER III. STUDY 2

HEADQUARTER INVOLVEMENT IN OVERSEAS R&D SUBSIDIARY INNOVATION OF MULTINATIONAL CORPORATIONS

STUDY 2.
HEADQUARTER INVOLVEMENT IN OVERSEAS R&D SUBSIDIARY INNOVATION OF MULTINATIONAL CORPORATIONS

ABSTRACT

Study2 investigates how MNC-HQs adjust their level of involvement in each subsidiary's innovation activity according to the subsidiary's capability development and subsidiary's dual (external and internal) embeddedness. I find that as an overseas R&D subsidiary's technological capability gets stronger, the HQ decreases its level of involvement, but above a certain level of subsidiary technological capability, the HQ increases its level of involvement. I also find that an HQ will increase its level of involvement in an overseas R&D subsidiary's innovation activity as the subsidiary's external embeddedness in host country increases, whereas the HQ will decrease its level of involvement as the subsidiary's internal embeddedness increases. The findings imply that HQs of MNCs react to each subsidiary's evolving capability and the level of embeddedness in external and internal collaboration networks by exerting hierarchical control when it is necessary, that is, when greater autonomy may harm MNC-wide knowledge integration.

I. INTRODUCTION

MNCs are becoming increasingly knowledge-driven. An ever-increasing competition forces them to seek and develop knowledge advantages wherever they can find them (Meyer et al., 2011). This is especially true in technology-intensive industries, where a growing number of MNCs have increased investment in overseas R&D (OECD, 2015) by establishing global networks of R&D subsidiaries in foreign countries (Frost, 2001). Such globally dispersed knowledge activities enable MNCs to tap into location-specific knowledge from diverse knowledge clusters and the ability to recombine these diverse knowledge assets has been viewed as an important source of competitive advantage of the MNC (Bartlett & Ghoshal, 1989; Cantwell, 1989; Nobel & Birkinshaw, 1998).

Numerous studies have investigated subsidiary level knowledge creation activities with respect to whether and how these overseas subsidiaries actually access technological knowledge within local contexts. One stream of literature has emphasized that overseas R&D units need to develop their own technological capabilities which enable them to assimilate and to source host locations' scientific and technological endowments(Frost, 2001; Phene & Almeida, 2008; Song et al., 2011). Another but related stream of literature has highlighted that subsidiaries need to deeply embedded in local knowledge network, since external embeddedness enables subsidiaries to better get access to local knowledge via close interaction and collaboration with local partners (Andersson, Forsgren, & Holm, 2002; Ciabuschi, Holm, & Martín Martín, 2014; Song et al., 2011).

As subsidiaries successfully develop their own technological capabilities and increase their external embeddedness in host locations, they became enjoy higher autonomy to conduct innovation projects (see Cavanagh, Freeman, Kalfadellis, & Herbert, 2017 for literature review on subsidiary autonomy). Prior literature often explains such phenomenon drawing upon resource dependence theory (Pfeffer & Salancik, 1978), that is, subsidiaries who hold more location-specific knowledge that cannot be easily accessed by HQs could bargain for more autonomy and thus less control from HQs (Ambos, Asakawa, & Ambos, 2011; Ambos & Schlegelmilch, 2007; Andersson & Forsgren, 1996; Asakawa, 2001a). However, greater subsidiary autonomy may not always lead to better results. For instance, Mudambi & Navarra (2004) argued that subsidiary autonomy enhances a subsidiary's ability to appropriate rents for its own good. In other words, too much autonomy can cause inconsistencies of subsidiary decision with firm's goal and strategy, leading to difficulties in knowledge integration with other units within MNCs.

Study2 aims to investigate how MNC-HQs adjust their level of involvement in each subsidiary's innovation activity according to the stages of the subsidiary's capability development and subsidiaries' dual (external and internal) embeddedness. I found that as an overseas R&D subsidiary's technological capability gets stronger, the HQ decreases its level of involvement, but above a certain level, the HQ increases its level of involvement. I also find that an HQ will increase its level of involvement in an overseas R&D subsidiary's innovation activity as the subsidiary's external embeddedness in host country increases, whereas the HQ will decrease its level of involvement as the subsidiary's internal embeddedness increases.

II. THEORY & HYPOTHESES

2.1. Subsidiary's capability development

MNCs establish overseas subsidiaries globally to tap into location-specific knowledge that is not available at home country(Bartlett & Ghoshal, 1989; Cantwell, 1989; Nobel & Birkinshaw, 1998). In such cases, subsidiaries need to possess a considerable level of technological capability to assimilate local knowledge (Song et al., 2011). In the early stage of a subsidiary's capability development, subsidiaries often lack their own technological capabilities, thus highly dependent on knowledge transferred from the parent (Hymer, 1976; Vernon, 1966). As subsidiaries improve their own technological capabilities by conducting own R&D activities and cumulating experiences in a specified technological area in host countries, they become generate entirely new technologies and capabilities for the parent MNCs (Cantwell & Mudambi, 2005; Michailova & Mustaffa, 2012) and augment their parents' knowledge bases (Kuemmerle, 1999). Such capability development of overseas subsidiaries may evolve over time toward a more autonomous set of activities that are less closely aligned to the existing knowledge base of the parent firms (Håkanson & Nobel, 1993).

Previous studies have suggested some rationales for why HQs grant more autonomy to subsidiaries. These research generally suggested that greater subsidiary autonomy is conducive to subsidiary performance. For example, greater autonomy may stimulate subsidiaries' knowledge creation (Asakawa, 2001a; Cantwell & Mudambi, 2005; Young & Tavares, 2004), facilitate organizational learning(Luo, 2003), and promote subsidiary initiatives (Birkinshaw, 1997; Birkinshaw, Hood, & Jonsson, 1998) to enhance their capabilities. Accordingly, a common consensus is that “as subsidiary technological capability increase, the degree of headquarter involvement in subsidiary innovation should be decreased”.

However, HQs may face an “innovation-integration” dilemma especially for highly innovative subsidiaries (Mudambi, 2011). That is, the greater the integration of a subsidiary into the MNC innovation system, the lower its focus on truly new competences; the greater the innovativeness of the subsidiary’s activities, the more likely it is that the capabilities that are developed cannot be leveraged by the MNC. In other words, even if greater autonomy may benefit a subsidiary by developing its own technological capability, but it does not guarantee MNC-wide knowledge integration which may harm the competitive advantage of the MNC as a whole. Thus, above a certain threshold level of subsidiary technological capability, the cost of disintegration may exceed the benefit of autonomy, therefore the HQ needs to increase its level of control to facilitate the subsidiary’s knowledge integration with other MNC units.

Some evidence for HQ’s control back can be found in the literature of subsidiary role and evolution. For example, highly capable subsidiaries are more likely to become “centers of excellence”(Frost et al., 2002) - an organizational unit that embodies a set of capabilities that has been explicitly recognized by the firm as an important source of value creation, with the intention that these capabilities be leveraged by and/or disseminated to other parts of the firm. They originally assumed that these centers of excellence would be associated with a higher level of autonomy, but actually found that once a subsidiary is formally recognized as a center of value creation for the corporation as a whole, the subsidiary may be forced to give up some of its autonomy because the firm seeks to integrate the unit into its global network of innovation.

Moreover, Asakawa (2001b) studied the evolution of overseas R&D subsidiaries of Japanese MNCs and proposed a three-stage model of subsidiary role evolution. He suggested that the role of overseas R&D subsidiary evolves from “starter” to “innovator”, and then “contributor”. As a “starter”, the role of the local subsidiary is to manage the start-up operation with strong support and protection by the parent. As an “innovator”, the role of the local subsidiary is to develop its superior capability and to maximize innovation output within the subsidiary. As a “contributor”, the role of subsidiary shifts to become a contributor of knowledge and technology developed within the local unit to the rest of the company. The shift from “starter” to “innovator” was depicted as the “dis-integration stage”, during which the parent grants autonomy to the local subsidiaries and both the parent and the local subsidiaries are mostly in agreement that substantial autonomy is necessary for the local units. While the shift from “innovator” to “contributor” is described as the “re-integration” process. During this process, the local subsidiary often takes the current level of autonomy for granted and even looks for more, but the parent wishes to have local subsidiaries more integrated in order to utilize them more strategically. Thus the autonomy-control tension becomes intensified, especially when the subsidiary’s technological capability outstands.

Taken above arguments together, I predict that MNC HQs will decrease its involvement in subsidiary innovation in order for the subsidiary to develop its technological capability with substantial autonomy, but when the subsidiary's technological capability reaches a certain level, the benefit of integration might exceed the benefit of autonomy, so that HQs may take back the autonomy from the subsidiary by increasing its involvement in subsidiary innovation and control their knowledge creation activities.

> *Hypothesis1: There is a U-shaped relationship between an overseas R&D subsidiary's technological capability and the degree of headquarter involvement in the subsidiary innovation, that is, the effect of the subsidiary technological capability is initially negative and turns positive after a threshold.*

2.2. Subsidiary's dual embeddedness

Embeddedness perspective suggests that the social relations that an actor creates with other actors in their social environment can influence its behavior(Granovetter, 1985) and performance(Uzzi, 1996). The level of embeddedness often refers to the closeness in the relationship that reflects the intensity of information exchange. Such a relationship is usually based on cooperative actions and trust that can facilitate learning and innovation. Indeed, social relations are important to innovation development since valuable knowledge is often embedded in social relations and structures and acquisition and utilization of such knowledge is also a complex social process (Kogut & Zander, 1992).

It has been argued that overseas subsidiaries of MNCs are distinctively positioned in that they are dually embedded: on the one hand, they are embedded in the host countries where they are located; on the other hand, they are part of the internal MNC network. (Almeida & Phene, 2004; Ciabuschi et al., 2014; Michailova & Mustaffa, 2012; Song et al., 2011). In this sense, an overseas subsidiary can draw upon knowledge that resides in both internal and external collaboration network to generate innovation. This means that the degree of embeddedness, irrespective of whether it is external or internal, will influence a subsidiary's innovation-related behavior. Thus, the task of the HQ such as control and coordination can be challenged by the subsidiary's embeddedness (Andersson & Forsgren, 1996). Nevertheless, the HQ may react to the changes in a subsidiary's dual embeddedness by adjusting its level of control (Ambos et al., 2011).

This study will examine the effects of both external and internal embeddedness on the degree of headquarter involvement in subsidiary innovation activities. Previous studies have defined embeddedness in various ways based on the types of relationships, for example, some focused on the business networks (Andersson et al., 2002; Nell & Andersson, 2012), some focused on technology and knowledge network (Song et al., 2011). In this study, I will investigate both external and internal embeddedness in a subsidiary's collaboration network for developing technological innovation. Specifically, I define external embeddedness as a subsidiary's interactions (via collaboration for innovation) with local partners, including firms, research institutes, and universities in host countries; internal embeddedness is defined as interactions (via collaboration for innovation) with peer subsidiaries in other foreign countries.

External embeddedness

Previous literature has highlighted the importance of local embeddedness since overseas subsidiaries need to deeply embedded in local knowledge network to get access to and further assimilate knowledge from local partners (Andersson et al., 2002; Song et al., 2011). As subsidiaries become successfully embedded in local knowledge network by collaborating with local partners, they could bargain for more autonomy from HQs, because overseas subsidiaries hold location-specific knowledge that could not easily be accessed by HQs (Ambos & Schlegelmilch, 2007; Andersson & Forsgren, 1996; Chiao & Ying, 2013)

However, these studies only focused on the benefit side of external embeddedness, neglecting the potential cost that could result from. Andersson, Forsgren, & Holm (2007) argued that if a subsidiary is heavily involved in local linkages, it is highly possible that issues external to the MNC are prioritized, thus less time and resources may be invested in maintaining relationships within the MNC. Moreover, the more a subsidiary is engaged in deep and intensive interactions with specific counterparts in its local context, the higher the context specificity of its knowledge so that could not easily be used in other MNC units' contexts (Andersson et al., 2002). Finally, a subsidiary is deeply embedded in local knowledge network not only facilitates knowledge inflows from local partners but also increases the risk of knowledge outflows (Perri & Andersson, 2014). These paradoxical effects of local embeddedness might eventually harm the overall competence of the MNC, thus the need for control and monitoring arises. Therefore, the HQ may be more likely to react to a subsidiary's increased external embeddedness by increasing its level of involvement. Thus, I hypothesize that:

Hypothesis2: An overseas R&D subsidiary's external embeddedness positively affects the degree of headquarter involvement in the subsidiary innovation.

Internal embeddedness

The concept of internal embeddedness has been developed as a theoretical construct contrary to external embeddedness and also called as corporate embeddedness in earlier days(Asakawa et al., 2018; Song et al., 2011). Compared to studies on external embeddedness, less research has focused on internal embeddedness and its relationship with headquarter involvement. Most notably, Andersson & Forsgren (1996) has defined internal embeddedness as relationships between a focal subsidiary and its peer subsidiaries in other countries, that is, relationships that go beyond administrative links because of adherence to a common organizational entity. They argued that a higher degree of internal embeddedness positively relates to a higher level of headquarter control because the HQ has a better knowledge of its internal units than external counterparts in the network so that makes it easier for the HQ to exert hierarchical control inside.

Moreover, Andersson et al. (2007) argued that internal embeddedness might indirectly influence headquarter involvement, mediated by the subsidiary's strategic importance. The key logic is that internal embeddedness is positively related to the subsidiary's strategic importance since the subsidiary is able to influence other peer subsidiaries' knowledge activities and to provide new technologies and competencies to them, which eventually may affect the competitive advantage of the entire MNC. Thus the HQ is more likely to get involved in innovation activities of such strategically important subsidiaries.

However, Andersson et al., (2007)'s argument has overlooked some possibilities that may lead to less headquarter involvement. Firstly, a high level of subsidiary internal embeddedness is an evidence of the subsidiary's current contribution to the knowledge integration within the MNC; HQ's direct involvement might destroy the subsidiary's existing motivation to actively collaborate with peer subsidiaries or discourage the subsidiary's initiative taking (Birkinshaw et al., 1998). Moreover, a high level of internal embeddedness also implies that subsidiary knowledge developed in local contexts has already been shared with other peer subsidiaries. This means that the HQ can gain access to the subsidiary knowledge via other peer subsidiaries that they have linkages with. Consequently, the need for access to subsidiary knowledge through direct control diminishes. Furthermore, more linkages with other subsidiaries can also act as an indirect control mechanism, since the HQ can control the subsidiary's knowledge activity by influencing the focal subsidiary's internal partners. Such indirect control also decreases the necessity of HQ's direct involvement in the innovation activities of overseas R&D subsidiaries. Thus, I hypothesize that:

> *Hypothesis3: An overseas R&D subsidiary's internal embeddedness negatively affects the degree of headquarter involvement in the subsidiary innovation.*

Figure 3-1 summarizes the research model of study 2.

Insert Figure 3-1 about here

III. METHOD

3.1. Data & Sample

Patent data of global semiconductor firms from the USPTO were used to test hypotheses. The global semiconductor industry was chosen because R&D globalization in this industry has a relatively long history and exhibits a higher propensity of patenting than other high-tech industries. Based on the same dataset of Study1, I constructed a subsidiary-year panel. This led to a final sample of 319 overseas subsidiaries of 23 MNCs and 1680 subsidiary-year observations.

3.2. Variables

Dependent variable

Degree of headquarter involvement in subsidiary innovation. The dependent variable is the degree of headquarter involvement in subsidiary innovation, measured as the proportion of patents which are co-patented by both HQ and subsidiary inventors in a subsidiary's focal year's total patent counts. It is operationalized as follows:

$$\text{Degree of headquarter involvement in subsidiary innovation}_{it} = \frac{\text{HQ} - \text{subsidiary co} - \text{patents}_{it}}{(\text{HQ} - \text{subsidiary co} - \text{patents}_{it} + \text{subsidiary} - \text{only patents}_{it})}$$

Independent variables

Subsidiary technological capability. Following Almeida & Phene (2004), Berry (2014), and Phene & Almeida (2008), subsidiary technological capability is measured as the number of patents that filed by subsidiary inventors only in $Year_{t-1}$.

External embeddedness. A subsidiary's *external embeddedness* is operationalized as the number of co-patents that filed by inventors in a focal subsidiary and local assignees where the subsidiary locates in $Year_{t-1}$. Co-patent data provides detailed information of who and who have collaborated. For example, Yamin and Otto (2004) used co-patent data in order to evaluate the degree of joint research and collaborative knowledge-sharing among inventors from different institutions. Therefore, co-authorship in a patent can be utilized as a good proxy of relational embeddedness.

Internal embeddedness. Similar to *external embeddedness, internal embeddedness* of a subsidiary is operationalized as the number of co-patents that filed by inventors in a focal subsidiary and other subsidiaries in different host countries in $Year_{t-1}$.

Control variables

I included a number of control variables expected to affect headquarter involvement in subsidiary innovation. Two subsidiary-level variables were included as controls. The experience of a subsidiary in the host location may affect the strategic decision of its headquarter to involve in its innovation activities (Yamin & Andersson, 2011). Thus, I controlled for *Subsidiary age*, measured by the number of years since the first patent application of the subsidiary on a yearly basis. Moreover, if a subsidiary is relatively competent than other sister subsidiaries, it may draw more attention from the HQ, thus can lead to more headquarter involvement (Bouquet & Birkinshaw, 2008). Thus, I controlled for *Subsidiary's relative competence,* operationalized as the proportion of patents filed by each subsidiary in $Year_{t-1}$.

Country-level factors may also affect HQs' motivation to involve in subsidiary innovation. On the one hand, overseas subsidiaries were established in host countries with different levels of knowledge stock. To gain knowledge from technologically advanced countries, HQs may be more likely to involve in subsidiary innovation activities to get access to host country knowledge. Therefore, I added *Host technology advantage*, measured as the total number of semiconductor patents of a subsidiary's host country as the percentage of all semiconductor patents in all countries in my sample in $Year_{t-1}$ (Zhang, Jiang, & Cantwell, 2015). On the other hand, HQs may be less likely to involve in innovation activities in host countries when their home countries are technologically more advanced (Song & Shin, 2008). Thus, *Home technology advantage* was also controlled for, measured as the total number of semiconductor patents of an MNC's home country as the percentage of all semiconductor patents in all countries in my sample in $Year_{t-1}$. Country-level patent data were downloaded from WIPO, where provides country-level patent data by technology.

Technological capability of HQs may influence the ability and also motivation to involve in subsidiary level innovation activities (Song & Shin, 2008). Therefore, *HQ technological capability*, measured as the number of patents (divided by 100) filed by HQ inventors in *Year*$_{t-1}$ was also controlled. HQs may exhibit heterogeneity in their propensity to involve in subsidiary activities regardless of the individual subsidiary situation. Thus, I included *Headquarter involvement propensity* as a control variable, which was measured by the average number of HQ-subsidiary co-patents in *Year*$_{t-1.}$ Previous studies also found that HQ's knowledge about the local context where a subsidiary located in will increase the value-added by headquarter involvement (Nell & Ambos, 2013). Thus, I controlled for *HQ's local embeddedness*, operationalized as the number of co-patents filed by HQ inventors and inventors from local assignees in *Year*$_{t-1}$. Moreover, headquarter involvement in subsidiary innovation requires resource investment. Accordingly, as the number of subsidiaries in an MNC increase, each subsidiary will have fewer resources to be invested in and less attention from the HQ. Thus, I controlled for *Total number of subsidiaries* in the focal year. *Firm size* was also controlled and measured by firm asset with log transformation in *Year*$_{t-1}$. Financial support from the firm may be needed for headquarter involvement in subsidiary innovation activities, hence lagged *Firm ROA* was included in the model.

Geographic distance and *Cultural distance* between HQ and subsidiary were controlled since they can act as potential barriers for HQs to involve in innovation activities of overseas subsidiaries in distant countries. I calculated the air miles between two host countries in a website (http://www.distancefromto.net) which provides distance calculation between any two places in the world. Following previous studies, I logged the absolute number of air miles to measure *Geographic* *distance* (Hansen & Løvås, 2004). I used Kogut & Singh (1988)'s formula to measure *Cultural distance,* based on Hofstede's six dimensions of culture that can be obtained from http://www.geerthofstede.nl/. *Firm fixed effects* and *Year fixed effects* were also included to control for the possible firm- and year- fixed effects.

3.3. Analytical approach

I employed a generalized linear model(GLM) with a logit link and the binomial family to test the hypotheses since the dependent variable in this study was a proportion that bounded between 0 and 1. Moreover, the data includes multiple observations for each subsidiary, thus I clustered standard errors by subsidiaries.

IV. RESULTS

Table 3-1 and Table 3-2 depict summary statistics and pairwise correlations of all variables. Table 3-3 presents statistical findings from the generalized linear model with a logit link and the binomial family and the clustering option by a subsidiary. Model (1) tests the baseline model with control variables only. Model (2) included all three independent variables, based on which I will explain the results.

Several control variables are worth noting. The results show that the HQ increases the degree of its involvement in subsidiary innovation as its own technological capability gets stronger, which is consistent with the parenting advantage view (Nell & Ambos, 2013). The results also showed that the HQ decreases the degree of involvement in subsidiary innovation as it establishes more overseas subsidiaries in foreign countries. This implies that the parent has limited resources to involve in each subsidiary's innovation activity. Moreover, the degree of headquarter involvement decreases as the relative competence of a subsidiary gets stronger. This result confirms that within an MNC, a subsidiary will enjoy more autonomy when it possesses more technological capability relative to peer subsidiaries.

Insert Table 3-1 about here

Insert Table 3-2 about here

Insert Table 3-3 about here

Hypothesis1 predicts a U-shaped relationship between the subsidiary technological capability and the degree of headquarter involvement. The results of Model (2) show that the coefficient of *Subsidiary technological capability* is negative and significant (β = -0.0476, p < 0.001), and the coefficient of the squared term of *Subsidiary technological capability* is positive and significant (β = 0.0004, p < 0.001), supporting Hypothesis1. Both the scatter plot and the margins plot of subsidiary technological capability were shown in Figure 3-2 and Figure 3-3. It turns out that the vertex point for subsidiary technological capability is estimated to appears at 66 (when other variables are at mean value).

Insert Figure 3-2 about here

Insert Figure 3-3 about here

Hypothesis 2 predicts a positive relationship between external embeddedness and the degree of headquarter involvement. Model (2) shows that the coefficient of *External embeddedness* is positive and significant ($\beta = 0.0952$, $p < 0.01$), supporting Hypothesis 2.

Hypothesis 3 predicts a negative relationship between internal embeddedness and the degree of headquarter involvement. Model (2) shows that the coefficient of *Internal embeddedness* is negative and significant ($\beta = -0.0977$, $p < 0.05$), supporting Hypothesis 3.

Robustness checks

I operationalized internal embeddedness in the same way as the operationalization of external embeddedness by calculating the number of co-patents filed by a focal subsidiary with other peer subsidiaries. Such a measure was operationalized based on the relational perspective of embeddedness. But it may not clearly exhibit the level of internal embeddedness of a subsidiary because the subsidiary may have filed a considerable number of co-patents but only with one peer subsidiary. To take account of a structural perspective of a subsidiary internal network (e.g. internal linkages in the whole collaboration network), I used two alternative measures to operationalize the internal embeddedness. One is measured as the number of subsidiaries that the focal subsidiary has co-patented with. The other measure was operationalized as the percentage of co-patented subsidiaries to the total number of subsidiaries. Model (2) and Model (3) in Table 3-4 show that the coefficient of both alternative measures is negative but marginally significant, confirming the robustness of Hypothesis 3.

Insert Table 3-4 about here

Post-hoc analysis

Similar to Study 1, I conducted two additional analyses to check whether my aforementioned results differ due to some specific conditions.

First, Gates & Egelhoff (1986) found that European MNCs were more decentralized than American MNCs. Therefore, there might be a possibility that MNCs headquartered in European countries are less likely to exert headquarter control in each overseas subsidiary's innovation activities, delegating a great level of autonomy to subsidiaries themselves. To check whether the degree of headquarter involvement in overseas subsidiary innovation varies for European and non-European MNCs, I sub-sampled the original dataset by dividing MNCs as European and non-European MNCs and ran the same model. The results of the generalized linear model in Table 3-5 reveal that two out of three independent variables lost the statistical significance in the model of European MNCs. But at the same time, one out of three independent variables in the non-European model also lost the statistical significance. The loss of statistical significance in key variables in both sub-samples may be due to the decreased sample size. Therefore, I could not find strong evidence that the proposed hypotheses only work for non-European MNCs.

Insert Table 3-5 about here

Second, I also tested whether my research model fit for different types of semiconductor firms. Generally, there are three types of semiconductor firms (IDMs, fabless, and foundry) that exhibit different characteristics. As I mentioned in Study 1, there might be a higher possibility for a greater level of headquarter involvement for IDMs rather than fabless or foundry types, since IDM type of semiconductor firms involved in both design and manufacturing of IC products that may need for more parent's coordination among different subunits. Thus, I subsampled my dataset by dividing it into IDM and fabless/foundry firms. It turns out that there are 13 IDMs, 7 fabless firms, and 3 foundry firms in my sample. I reran the generalized linear model for two sub-samples respectively. The results of Table 3-6 indicate that all three hypotheses are supported in the sub-sample of IDMs. For fabless/foundry sub-sample, however, only Hypothesis 1 is supported. Such results may imply that the research model presented in study 2 may be only effective for IDM type of semiconductor firms.

Insert Table 3-6 about here

V. DISCUSSION

5.1. Contributions & Implications

Study2 investigated how MNC-HQs adjust their level of involvement in each subsidiary's innovation activity according to the subsidiary's capability development and subsidiary's dual (external and internal) embeddedness. The findings showed that as an overseas subsidiary's technological capability gets stronger, the HQ decreases its level of involvement, but above a certain level of subsidiary technological capability, the HQ increases its level of involvement. The findings also demonstrated that an HQ will increase its level of involvement in a subsidiary innovation as the subsidiary's external embeddedness increases, whereas it will decrease the level of involvement when the subsidiary's internal embeddedness increases.

The findings contradict the prediction based on resource dependency theory prior studies have drawn upon (Ambos & Schlegelmilch, 2007; Andersson & Forsgren, 1996). Rather, the findings are in line with Ambos et al. (2011)'s study, in which a dynamic perspective on autonomy-control tension was highlighted. The findings of the present study imply that an HQ may react to each subsidiary's evolving capability and the level of embeddedness in external and internal collaboration networks by exerting hierarchical control when it is necessary, that is, when greater autonomy may harm MNC-wide knowledge integration. Therefore, this study underlines the role of HQs as an entity with hierarchical power even in a differentiated network of MNCs.

5.2. Limitation & Future research

I found a U-shaped relationship between the overseas R&D subsidiary's technological capability and the degree of headquarter involvement in the subsidiary's innovation activities. This finding implies that the HQ is more likely to involve in the early stage and the later stage of a subsidiary's technological capability development, however, the purposes of headquarter involvement in two stages were assumed to be different. My data did not show whether headquarter involvement in these two stages does occur by different mechanisms. Nevertheless, I believe this is an interesting research area for further research.

The development of the theoretical arguments in this study was under the assumption of greenfield overseas R&D subsidiaries. I tried as best as I can to tease out subsidiaries that could be acquired through cross-border M&A in the sampling process. However, this may lead to a limitation of this study in which acquired overseas subsidiaries were neither included in the theory and hypothesis development nor in data analysis. Indeed, prior literature has suggested that foreign acquisitions have become a major contributor to the expansion of technological capabilities, through which the HQ can access to “instant local embeddedness” (Blomkvist et al., 2010; Zander, 1999). But we still lack understanding whether the degree of headquarter involvement varies in different entry modes, thus further research is needed.

Since the majority of subsidiary-level variables are constructed based on patent data, I could not control for some seemingly important factors, such as subsidiary mandate, subsidiary level R&D investment, and etc. Moreover, I operationalized key variables such as external embeddedness and internal embeddedness based on the data of co-patents. Therefore, when two parties did collaborate but failed to or strategically decided not to file co-patents, such collaboration may not be reflected in my measures. But a co-patent can be seen as a more conservative measure for a collaboration tie since it only counts cooperative and trustful tie that have resulted from a successful innovation outcome (i.e. co-patents). I believe patents data, especially co-patents data, will provide a huge opportunity for scholars who study subsidiary level or inter-subsidiary level innovation activities. Future research could combine co-patents data and patent citation data and even surveys or interviews to enrich our understanding of the multi-level structure of MNC innovation(Asakawa et al., 2018).

[Table 3-1] Summary statistics

Variable	Obs	Mean	S.D.	Min	Max
Degree of headquarter involvement in subsidiary innovation	1680	0.44	0.40	0.00	1.00
Subsidiary age	1680	9.07	7.83	1.00	37.00
Subsidiary's relative competence	1680	0.14	0.26	0.00	1.00
Host technology advantage	1680	4.79	11.39	0.00	54.47
Home technology advantage	1680	33.89	15.22	0.00	55.92
HQ technological capability	1680	7.25	7.70	0.00	46.20
Headquarter involvement propensity	1680	1.75	1.40	0.00	6.28
HQ's local embeddedness	1680	0.14	0.95	0.00	19.00
Total number of subsidiaries	1680	16.07	7.22	2.00	29.00
Firm size	1680	9.03	1.24	2.66	11.66
Firm ROA	1680	0.07	0.25	-1.01	2.62
Geographic distance	1680	8.43	0.73	5.45	9.16
Cultural distance	1680	2.00	1.25	0.02	7.03
Subsidiary technological capability	1680	5.91	15.27	0.00	163.00
External embeddedness	1680	0.12	1.15	0.00	30.00
Internal embeddedness	1680	0.35	1.34	0.00	22.00

[Table 3-2] Pairwise correlations

	Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
(1)	Degree of headquarter involvement in subsidiary innovation	1.00															
(2)	Subsidiary age	-0.18*	1.00														
(3)	Subsidiary's relative competence	-0.25*	0.29*	1.00													
(4)	Host technology advantage	-0.10*	0.20*	0.37*	1.00												
(5)	Home technology advantage	-0.04	0.14*	-0.05	-0.21*	1.00											
(6)	HQ technological capability	0.06*	-0.01	-0.11*	0.04	-0.25*	1.00										
(7)	Headquarter involvement propensity	0.15*	-0.02	-0.20*	-0.07*	-0.37*	0.42*	1.00									
(8)	HQ's local embeddedness	-0.03	0.11*	0.21*	0.33*	-0.17*	0.22*	0.16*	1.00								
(9)	Total number of subsidiaries	0.05	0.20*	-0.36*	-0.20*	-0.01	0.35*	0.58*	0.04	1.00							
(10)	Firm size	0.06	0.10*	-0.19*	-0.02	-0.18*	0.69*	0.51*	0.13*	0.60*	1.00						
(11)	Firm ROA	0.03	0.06*	0.08*	0.16*	-0.14*	-0.08*	-0.08*	-0.02	-0.06	-0.15*	1.00					
(12)	Geographic distance	-0.09*	0.12*	0.09*	0.07*	0.49*	-0.04	-0.26*	-0.01	-0.05	-0.06	-0.01	1.00				
(13)	Cultural distance	-0.02	-0.06	0.04	0.31*	-0.01	0.14*	-0.02	0.11*	0.00	0.09*	0.01	0.42*	1.00			
(14)	Subsidiary technological capability	-0.19*	0.30*	0.47*	0.36*	-0.14*	0.18*	0.16*	0.63*	0.11*	0.18*	-0.06	0.02	0.11*	1.00		
(15)	External embeddedness	-0.04	0.04	0.17*	0.26*	-0.15*	0.03	0.12*	0.57*	0.03	0.04	-0.02	-0.02	-0.01	0.47*	1.00	
(16)	Internal embeddedness	-0.11*	0.12*	0.18*	0.17*	-0.19*	0.17*	0.16*	0.34*	0.12*	0.16*	-0.02	-0.05	0.02	0.53*	0.27*	1.00

* shows significance at the .01 level

[Table 3-3] Results of generalized linear model(GLM)

	(1)	(2)
Subsidiary age	-0.0137	-0.0020
	(0.0109)	(0.0107)
Subsidiary's relative competence	-2.0290***	-1.2907***
	(0.2788)	(0.3405)
Host technology advantage	-0.0051	-0.0036
	(0.0066)	(0.0064)
Home technology advantage	0.0231	0.0228
	(0.0370)	(0.0372)
HQ technological capability	0.0387*	0.0356+
	(0.0186)	(0.0195)
Headquarter involvement propensity	-0.0104	0.0070
	(0.0597)	(0.0591)
HQ’s local embeddedness	0.0546	-0.0486
	(0.0419)	(0.0564)
Total number of subsidiaries	-0.0745**	-0.0639*
	(0.0247)	(0.0255)
Firm size	0.1168	0.1516
	(0.1357)	(0.1336)
Firm ROA	-0.0700	-0.1027
	(0.2630)	(0.2709)
Geographic distance	-0.2019	-0.2268+
	(0.1258)	(0.1208)
Cultural distance	0.0559	0.0650
	(0.0647)	(0.0624)
(H1) Subsidiary technological capability		-0.0476***
		(0.0120)
(H1) Subsidiary technological capability^2		0.0004***
		(0.0001)
(H2) External embeddedness		0.0952**
		(0.0309)
(H3) Internal embeddedness		-0.0977*
		(0.0466)
Firm fixed effects	Included	Included
Year fixed effects	Included	Included
Constant	0.1403	-0.1247
	(2.4246)	(2.4356)
Observations	1680	1680
AIC	1.1250	1.1168
BIC	-10849.80	-10841.91
Log pseudolikelihood	-892.0134	-881.1042

Cluster-robust standard errors in parentheses.

$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

[Table 3-4] Internal embeddedness using different measures (GLM)

	(1)	(2)	(3)
Subsidiary age	-0.0020	-0.0013	-0.0014
	(0.0107)	(0.0108)	(0.0108)
Subsidiary's relative competence	-1.2907***	-1.3093***	-1.2683***
	(0.3405)	(0.3438)	(0.3427)
Host technology advantage	-0.0036	-0.0038	-0.0035
	(0.0064)	(0.0064)	(0.0065)
Home technology advantage	0.0228	0.0242	0.0206
	(0.0372)	(0.0371)	(0.0368)
HQ technological capability	0.0356^{+}	0.0339^{+}	0.0343^{+}
	(0.0195)	(0.0194)	(0.0195)
Headquarter involvement propensity	0.0070	0.0134	0.0131
	(0.0591)	(0.0588)	(0.0589)
HQ’s local embeddedness	-0.0486	-0.0411	-0.0349
	(0.0564)	(0.0524)	(0.0519)
Total number of subsidiaries	-0.0639*	-0.0622*	-0.0648*
	(0.0255)	(0.0255)	(0.0256)
Firm size	0.1516	0.1475	0.1559
	(0.1336)	(0.1335)	(0.1338)
Firm ROA	-0.1027	-0.1026	-0.0978
	(0.2709)	(0.2707)	(0.2718)
Geographic distance	-0.2268^{+}	-0.2322^{+}	-0.2308^{+}
	(0.1208)	(0.1209)	(0.1209)
Cultural distance	0.0650	0.0667	0.0659
	(0.0624)	(0.0624)	(0.0625)
(H1) Subsidiary technological capability	-0.0476***	-0.0458***	-0.0471***
	(0.0120)	(0.0121)	(0.0122)
(H1) Subsidiary technological capability^2	0.0004***	0.0003***	0.0003***
	(0.0001)	(0.0001)	(0.0001)
(H2) External embeddedness	0.0952**	0.1062***	0.1102**
	(0.0309)	(0.0321)	(0.0342)
(H3) Internal embeddedness			
NO. of co-patents with other subs	-0.0977*		
	(0.0466)		
NO. of co-patented subsidiaries (degree centrality)		-0.1659^{+}	
		(0.0877)	
% of co-patented subsidiaries (network density)			-2.2907^{+}
			(1.2787)
Firm fixed effects	Included	Included	Included
Year fixed effects	Included	Included	Included
Constant	-0.1247	-0.1245	-0.0104
	(2.4356)	(2.4248)	(2.4212)
Observations	1680	1680	1680
AIC	1.1168	1.1176	1.1177
BIC	-10841.91	-10840.57	-10840.38
Log pseudolikelihood	-881.1042	-881.7729	-881.8694

Cluster-robust standard errors in parentheses.
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

[Table 3-5] Results of European vs. non-European MNCs

	European	Non-European
Subsidiary age	0.0507	-0.0001
	(0.1057)	(0.0108)
Subsidiary's relative competence	2.1311	-1.2186***
	(2.4517)	(0.3550)
Host technology advantage	-0.0268	-0.0049
	(0.0242)	(0.0066)
Home technology advantage	-0.8272	0.0514
	(0.8641)	(0.0387)
HQ technological capability	0.6813+	0.0292
	(0.3762)	(0.0198)
Headquarter involvement propensity	-0.9814	-0.0010
	(0.7315)	(0.0726)
HQ’s local embeddedness	-0.0433	-0.0328
	(0.0850)	(0.0792)
Total number of subsidiaries	-1.0510+	-0.0497+
	(0.5610)	(0.0267)
Firm size	15.2095	0.1323
	(9.6716)	(0.1350)
Firm ROA	-15.9124	-0.1683
	(15.4207)	(0.2747)
Geographic distance	-0.0232	-0.2993
	(0.1740)	(0.1827)
Cultural distance	-0.4111	0.1062
	(0.3141)	(0.0682)
(H1) Subsidiary technological capability	-0.0603*	-0.0522***
	(0.0237)	(0.0140)
(H1) Subsidiary technological capability^2	0.0004**	0.0004***
	(0.0001)	(0.0001)
(H2) External embeddedness	0.0120	0.0670
	(0.0507)	(0.1706)
(H3) Internal embeddedness	-0.0745	-0.1089*
	(0.1132)	(0.0540)
Firm fixed effects	Included	Included
Year fixed effects	Included	Included
Constant	-116.2801	-1.0417
	(78.0273)	(2.7058)
Observations	136	1544
AIC	1.3467	1.1100
BIC	-478.3848	-9825.301
Log pseudolikelihood	-72.5725	-800.9345

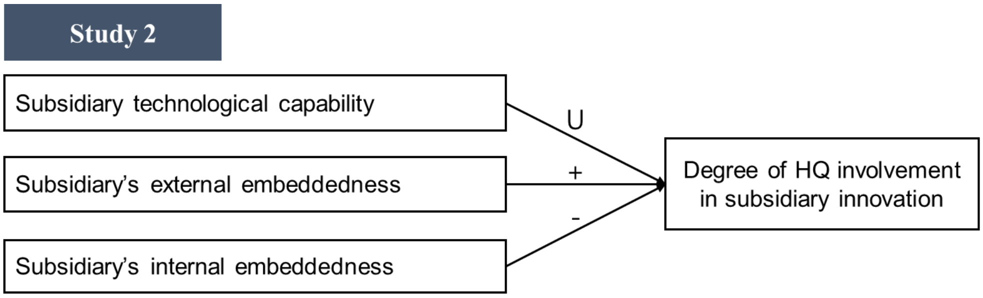
Cluster-robust standard errors in parentheses.
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

[Table 3-6] Results of IDM vs. fabless/foundry MNCs

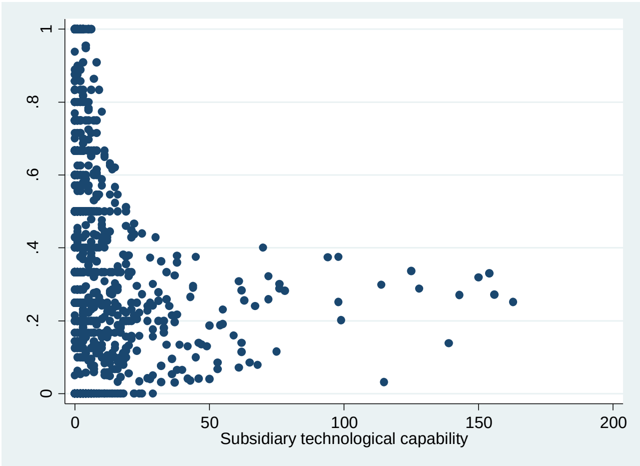
	IDM	Fabless/Foundry
Subsidiary age	0.0040	-0.0579^{+}
	(0.0116)	(0.0337)
Subsidiary's relative competence	-1.5729**	-0.8429^{+}
	(0.5720)	(0.4722)
Host technology advantage	-0.0148^{+}	0.0279*
	(0.0077)	(0.0120)
Home technology advantage	0.0208	0.1658
	(0.0458)	(0.1141)
HQ technological capability	0.0229	0.1955**
	(0.0232)	(0.0680)
Headquarter involvement propensity	0.0459	-0.1290
	(0.0730)	(0.1346)
HQ’s local embeddedness	-0.0905	0.3543
	(0.0560)	(0.2694)
Total number of subsidiaries	-0.0825**	-0.1240*
	(0.0312)	(0.0538)
Firm size	0.3951	-0.1170
	(0.2505)	(0.1881)
Firm ROA	-0.1074	-0.4754
	(0.8340)	(0.3318)
Geographic distance	-0.2105	-0.4126^{+}
	(0.1381)	(0.2168)
Cultural distance	0.0947	-0.0060
	(0.0740)	(0.1204)
(H1) Subsidiary technological capability	-0.0424**	-0.0938**
	(0.0143)	(0.0333)
(H1) Subsidiary technological capability^2	0.0004***	0.0012*
	(0.0001)	(0.0005)
(H2) External embeddedness	0.1235***	-0.1573
	(0.0320)	(0.8981)
(H3) Internal embeddedness	-0.1131*	-0.0823
	(0.0497)	(0.1933)
Firm fixed effects	Included	Included
Year fixed effects	Included	Included
Constant	-2.1482	11.4601^{+}
	(3.3279)	(6.7360)
Observations	1167	513
AIC	1.1089	1.1541
BIC	-7104.888	-2637.52
Log pseudolikelihood	-600.0313	-266.0322

Cluster-robust standard errors in parentheses.
$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

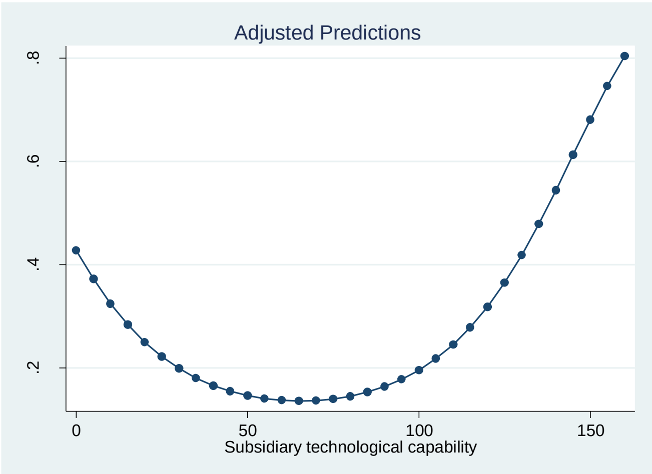
[Figure 3-1] Research model (Study 2)



[Figure 3-2] Scatter plot of subsidiary technological capability



[Figure 3-3] Margins plot of subsidiary technological capability



CHAPTER IV. OVERALL CONCLUSION

This dissertation aims to investigate the phenomenon of headquarter involvement during the globalization of MNCs' R&D activities. This is an important research topic in the fields of international business and strategic management. A recent trend in R&D globalization of MNCs have led to a globally dispersed technological competence and knowledge, thus a rise in importance of overseas R&D subsidiaries to MNC innovation (Frost, 2001; Phene & Almeida, 2008). How to develop the technological and innovative capabilities of these overseas R&D subsidiaries has become an important issue for management. Enhanced technological capability of overseas subsidiaries often accompanies with an increased level of subsidiary autonomy in innovation-related activities. Such increased autonomy paradoxically may hinder knowledge integration among these dispersed R&D units. This is why subsidiary-level innovation activities necessitate a certain level of headquarter involvement, which can directly or indirectly foster MNC-wide knowledge integration. To better understand the headquarter involvement in subsidiary innovation activities, I conducted two separate but related empirical studies, using patent data of 23 MNCs in the global semiconductor industry, observed over the 1989-2008 period.

In the first empirical study, I focused on the phenomenon of headquarter involvement in inter-subsidiary collaborative innovation. Drawing upon resource allocation perspective, I proposed three subsidiary-dyad level factors as determinants of headquarter involvement. I found that an HQ is more likely to involve in inter-subsidiary collaborative innovation when a subsidiary-dyad exhibits a stronger combined technological capability. I also found that prior collaborative innovation of a subsidiary-dyad, both horizontal and vertical, positively affect the likelihood of headquarter involvement in the focal dyad's collaborative innovation.

In the second empirical study, I focused on the phenomenon of headquarter involvement in each overseas R&D subsidiary's innovation activities. I proposed that HQs will adjust their level of involvement in each subsidiary's innovation activity according to the different stages in the subsidiary's capability development and the level of the subsidiary's external and internal embeddedness. I found that as an overseas R&D subsidiary's technological capability gets stronger, the HQ decreases its level of involvement, but above a certain level, the HQ increases its level of involvement. I also found that an HQ will increase its level of involvement in a subsidiary innovation as the subsidiary's external embeddedness increases, whereas it will decrease the level of involvement when the subsidiary's internal embeddedness increases.

The findings from two empirical studies showed that HQs of MNCs do actively involved in overseas R&D subsidiaries' innovation activities to pursue knowledge integration within MNCs. Specifically, HQs of MNCs search for new opportunities of knowledge integration and recombination by linking globally dispersed R&D subsidiaries to collaborate with each other and also by investing resources in most promising collaboration projects. Moreover, HQs also react to each overseas R&D subsidiary's evolving capability and the level of embeddedness in external and internal collaboration networks, by exerting hierarchical control when greater subsidiary autonomy may impede MNC-wide knowledge integration.

This dissertation theoretically contributes to the current literature on R&D globalization of MNCs by showing how technological innovation is developed at the subsidiary and subsidiary-dyad level and the importance of headquarter involvement in these processes. Moreover, it enriches our understanding of the roles played by HQs with respect to MNC innovation, responding to the recent call for research on the value-adding role of HQs in the differentiated network of MNCs (Ciabuschi et al., 2012). Two empirical studies focused on the determinant factors for headquarter involvement, rather than the performance effect of headquarter involvement. Therefore, this dissertation also has managerial implication for both HQ and subsidiary managers, by showing the purposes of headquarter involvement and its underlying mechanisms to help both parties to understand each other's considerations and thus can better contribute to MNC-wide innovation.

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국문 초록

본사의 관여와 다국적기업의 혁신

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경영학과 경영학 전공

본 박사학위 논문은 다국적기업의 본사가 기업 내 지식 창출과 통합을 이루어 내기 위해 해외 연구개발 자회사의 혁신 활동에 어떻게 관여하는지 탐구하는 것을 목표로 하였다. 본 학위논문에서는 다국적기업을 세계 각 국에 분산된 연구개발 조직간의 협력적 혁신의 결과로 형성된 협업 네트워크로 보았고 이러한 네트워크 관점에서 자회사 간의 협력적 혁신 활동과 개별 자회사 수준의 혁신 활동에 대해 본사가 어떻게 관여하는지 연구하였다. 연구가설 검증을 위해 두 편의 실증연구를 진행하였는데, 글로벌 반도체 산업의 23 개 다국적기업을 연구대상으로 하였고 20 년간(1989-2008)의 특허 데이터를 활용하였다.

첫 번째 실증 연구는 다국적기업의 자회사 간의 협력적 혁신에 본사가

관여하는 현상에 대해 탐구하였다. 자원의 분배 관점에 초점을 맞추어, 자회사간 협력적 혁신의 본사 관여 여부에 대해 자회사 다이애드 수준(subsidiary-dyad level)에서 세 가지 결정요인을 제시하였고 연구 가설을 설정하였다. 분석 결과, 다국적기업의 본사는 두 자회사의 통합된 기술 역량이 높을수록 양자간의 협력적 혁신에 관여할 확률이 더 높아지는 것으로 나타났다. 또한, 두 자회사의 이전 협력적 혁신 경험 (수평적과 수직적)이 많을수록 본사가 양자간의 협력적 혁신에 관여할 확률이 더 높아지는 것으로 나타났다. 이러한 연구 결과는 다국적기업의 본사가 전 세계에 분산된 연구개발 자회사들이 서로 협업을 할 수 있게 연결시켜주며 성공가능성이 가장 높다고 판단되는 자회사간 협업 프로젝트에 본사의 자원을 투자하는 방식으로 기업 내부적으로 지식의 통합과 재조합을 통한 지식 창출을 할 수 있는 새로운 기회를 적극적으로 탐색하고 있음을 시사한다.

두 번째 실증 연구는 다국적기업의 본사가 각각의 해외 연구개발 자회사의 혁신활동에 관여하는 현상에 대해 탐구하였다. 본 연구에서는 본사가 개별 자회사의 역량 개발 단계와 이중(외부적 및 내부적) 배태성에 따라 자회사의 혁신 활동에 관여하는 정도를 조절할 것이라고 주장하였다. 실증 분석 결과, 해외 자회사의 기술 역량이 증가 할수록 본사가 자회사의 혁신 활동에 관여하는 정도가 낮아지지만, 자회사의 기술 역량이 일정 수준을 넘으면 본사의 관여 정도가 다시 높아지는 것으로 나타났다. 또한, 자회사가 외부 협업 네트워크에 배태된 정도가 커질수록 본사의 관여 정도가 높아지며 반대로 내부 협업 네트워크에 배태된 정도가 커질수록 본사의 관여 정도가

낮아짐을 발견하였다. 이러한 연구 결과는 다국적기업의 본사가 해외 연구개발 자회사의 역량의 진화와 외부 및 내부 협업 네트워크에 배태된 정도에 대응하여 필요한 경우, 즉 보다 강화된 자회사의 혁신 활동 자율성이 다국적기업 내부적인 지식 통합에 해가 될 가능성이 커질 경우, 위계적인 통제를 행사하고 있음을 시사한다.

본 박사학위 논문은 다국적기업의 기술 혁신이 자회사 수준과 자회사 다이애드 수준에서 어떻게 일어나는지 보여주었고 그 과정에서의 본사 관여의 중요성을 부각시킴으로써 다국적기업의 연구개발 활동의 글로벌화를 이해하는데 있어 이론적 및 실증적 차원에서 모두 기여한다. 두 편의 실증연구를 통해 본 학위논문은 다국적기업의 본사가 자회사 간의 협력적 혁신 프로젝트에 직접적으로 관여하여 자회사 간의 지식 통합을 촉진시키며 개별 자회사의 혁신활동에 관여하는 정도를 적절하게 조절하는 방식으로 자회사 스스로 다국적기업 전반의 지식 통합에 기여하도록 한다는 연구 결론을 도출함으로써 네트워크 기반 관점하에 다국적기업의 본사가 어떻게 가치를 부가하는 역할을 수행하는지를 보여주었다.

주요어: 본사 관여, 해외 연구개발 자회사, 다국적기업 혁신, 자회사 혁신, 협력적 혁신, 자회사 기술 역량, 배태성

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