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Subsidiary Development of New Technologies: Managing Technological Changes in Multinational and Geographic Space

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Abstract

This study explores the co-evolution of the subsidiaries of the multinational firm with their global organizations and geographic locations. We examine when and how subsidiaries respond to technological changes in these environments to expand their scope and develop new technologies. Using the concepts of local search and communities of practice, we propose that increased technology creation by the subsidiary's parent firm and host country, in areas specific to the subsidiary's expertise and at the broad industry level, has differential effects on the types of new technologies – competence exploiting and competence creating - developed by the subsidiary. We further propose that subsidiary embeddedness in the organization and location moderates the relationship between technological increases and the nature of subsidiary new technology development.

Keywords: Subsidiary, new technology development, multinational firm, geography

INTRODUCTION

The economic geography literature has primarily focused on relationships between location and spatial patterns or structures, while the international business literature explores the relationship between the organization of economic activity by the multinational firm and location (Beugelsdijk, McCann and Mudambi, 2010). Organizational or multinational firm perspectives have considered the subsidiary and its mandates (Cantwell and Mudambi, 2005; Kuemmerle, 1999), its capabilities in enhancing innovation (Phene and Almeida, 2008), and its role in introducing new technologies to the firm (Blomkvist, Kappen and Zander, 2010). From an economic geography perspective, location is the focus, with an exploration of regional differences and their implications for economic development (Fagerberg and Verspagen, 1996; Breschi and Malerba, 1997). In the context of knowledge and innovation, researchers have considered the agglomeration of innovative and technological activity (Feldman, 2000) and the consequences of localized knowledge spillovers for firm productivity and innovation of firms (Henderson, 1986; Glaeser, Kallal, Scheinkmann and Shleifer, 1992; Audretsch and Feldman, 1996), but with an increasing interest in trans-local and inter-regional influences (Amin and Cohendet, 2004; Gertler and Levitte, 2005). That participants in a cluster often build channels of communication to others outside their milieu, but mostly limited by the nation state's boundaries, is widely recognized but under-theorized (Bathelt, Malmberg and Maskell, 2004). We integrate these ideas and theorize about them by considering the effects of a geographic context represented by the host country and the organizational context reflected by the multinational firm on the subsidiary's technological transformation.

Subsidiary technological capabilities are central to the competitive advantage of the MNC but not all subsidiaries develop complex R&D abilities and they differ in the extent to which they pursue competence exploiting or competence creating activities (Cantwell, 2009; 1987; Cantwell and Mudambi, 2010). As subsidiaries increase the scale and scope of their innovative activities, they create technological links with other firms in their geographic location and with other parts of their parent multinational firm (Cantwell and Iammarino, 2001; Almeida and Phene, 2004), resulting in a co-evolutionary process that is influenced by location and organization. Because this process is heavily influenced by local search, new technology development by subsidiaries occurs at the margins of existing technologies, resulting in competence exploitation. Only some subsidiaries evolve to mandates that are competence creating in nature. Using insights from both international and economic geography perspectives that highlight the influence of these contexts on innovation (Cantwell, 2009; Malmberg, Solvell and Zander, 1996), we examine the conditions under which subsidiaries develop new competence exploiting and competence creating technologies. We explore the effects of technological changes, particularly activity increases, in the MNC and host country on two dimensions - in areas of subsidiary specific expertise and in the broader industry spectrum – on the nature of subsidiary development of new technologies.

Considering local search from an evolutionary perspective, the search for new knowledge is mostly constrained to proximate neighborhoods, whether organizational, technological, or geographic (March and Simon, 1958; Nelson and Winter, 1982). This resonates with the differences between related and unrelated variety in the economic geography context (Castaldi, Frenken and Los, 2015; Frenken, Oort and Verberg, 2007) and ideas related to communities of practice (Tallman and Chacar, 2011; Lowe, George and Alexy, 2012) that suggest there are differential implications for firm learning (Boschma and Frenken, 2011). We hypothesize that because of these concepts, increases in technology creation by the MNC and host country in subsidiary specific areas have consequences for firm ability to engage in the development of competence exploiting technologies.

The subsidiary itself may drive the evolutionary process and enable pursuit of competence creating technologies. As the MNC invests in overseas R&D, it does so with the purpose of tapping into new knowledge from foreign markets (Cantwell and Mudambi, 2005). To achieve this objective, the subsidiary may proactively build pipelines to sources of knowledge outside local search boundaries. Of course such connections are still likely to be circumscribed by the broad contours of the industry resulting in communities of practice that are particularly conducive to knowledge sharing and diffusion. At the same time, they are likely to be broader than the narrow confines of its own specific areas of expertise within the industry as the subsidiary seeks to build its profile. As a result, we propose that increased technology creation by the MNC and by the host country in broad areas of the industry that are outside subsidiary specific expertise enable the subsidiary to develop competence creating technologies.

The embeddedness of the subsidiary reflected in its efforts to integrate with the MNC or the local environment is expected to moderate the influence of technological increases on the nature of technologies developed. Greater embeddedness of the subsidiary should signal more complementarity with the rest of the MNC and an implicit understanding within the MNC of the specialization of each subsidiary. The highly embedded subsidiary can take advantage of complementarities to capitalize on both specific and broad spectrum changes and develop competence exploiting and competence creating technologies respectively. Just as higher knowledge embeddedness in the MNC is underlaid by complementarity of knowledge pursuits within the firm, embeddedness in the host country context signifies a similar complementarity with other firms in the local environment (Maskell, 2014). Consequently, in the face of increased technology creation in the host country's specific and broad spectra the more locally embedded subsidiary is likely to develop competence exploiting and competence creating technologies respectively.

THEORY AND HYPOTHESES

A multinational subsidiary can be viewed as a distinctive cluster of capabilities that evolves over time (Pitelis and Teece, 2010; Cantwell, 1989). However, the nature of this evolution differs across subsidiaries with the complexity and level of R&D function rising for some while others demonstrate atrophy or diminishing of their charters (Cantwell, 1987; Birkinshaw and Hood, 1998). There appears to be a consensus in the literature that dynamics related to the subsidiary, the MNC and the host country have important consequences for subsidiary development (Birkinshaw, Hood and Jonsson, 1998; Almeida and Phene, 2004; Cantwell and Mudambi, 2005). Therefore, we explore subsidiary evolution by considering the unique position and familiarity of the subsidiary with organizational and locational contexts as well as the subsidiary's embeddedness.

Innovations by subsidiaries, whether they are new technologies or new products, are created by combining existing components in a novel manner (Schumpeter, 1939) and are consequently influenced by factors that contribute to local search outcomes – bounded rationality, organizational routines and likelihood of success. Innovative search is associated with strong uncertainty, as there is often a lack of knowledge of the different alternatives, their outcomes, and their costs (Dosi, 1988). Faced with this uncertainty, firms (and subsidiaries) engage in new projects that share technological content with their established technological base by relying on local search (Cyert and March, 1963) or related variety (Castaldi et al., 2015), to increase the likelihood of success. Further, capabilities associated with information processing, computation, organization and utilization of memory impose limitations on the rationality of individuals involved in the search process as they engage in satisficing behavior and a narrow search process that makes sense within these constraints (Simon, 1956; March 1978). At the organizational or unit level, the development of organizational routines that can be leveraged to proximate or related areas increases incentives to engage in local search (Stuart and Podolny, 1996). Consequently, organizations become specialized to specific niches in the industry (Cyert and March, 1963), bounding their activities and technologies and even new explorations to familiar and proximate areas. New capability development therefore usually occurs at the margins of existing technologies, resulting in path dependent trajectories of capabilities that evolve gradually over time (Birkinshaw and Hood, 1998) in a generally evolutionary manner (Phelps and Fuller, 2016), resulting in competence exploiting technologies.

Dynamic and entrepreneurial subsidiaries may attempt to deviate from local search constraints by proactively investing in creating internal or external connections and pipelines (Jenkins and Tallman, 2010; Bathelt et al, 2004). Such connections afford them the opportunity to source knowledge that is outside the boundaries of local search and can support development of competence creating technologies. In order to understand the nature and extent to which such deviations are possible, we consider the concept of communities of practice. A community of practice refers to a group of people who share a passion or concern for some activity that they share and who collectively learn how to do it better, as they interact regularly (Wenger, 1998, 2004). An organization (or the multinational firm) is itself an aggregate of such agile, self-constituting communities of practice that are represented by technological boundaries, capturing the essence of common interests or focuses shared by different organizational members such as those working in a common technical area or on a specific technological problem (Brown and

Duguid, 2001; Henderson and Clark, 1990). Communities also emerge in the geographic context because of the social processes that drive interactions (Granovetter, 1985; Saxenian, 1996). While some conceptualizations of these communities emphasize spatial proximity (Amin and Roberts, 2008; Pinch et al., 2003), there is a growing acknowledgement of community based knowledge generation through relational ties or pipelines that enable trans-local and inter-regional reach within a country (Amin and Cohendet, 2004; Gertler and Levitte, 2005; Bathelt, Malmberg and Maskell, 2004). This literature resonates with work on national innovation systems (Nelson, 1993) and would appear to indicate that community based knowledge generation is viable in the national context because of a shared institutional profile across regions, on cognitive, regulatory and normative dimensions (Kostova, 1997; Jandhyala and Phene, 2015). Although there is some indication of global pipelines that have the potential to extend communities even further, the dominant influence appears to be at the nation-state level (Gertler, 2001).

The movement of valuable knowledge within communities of practice, whether inside the firm or across co-located firms, is tied to practice or the performance of actions related to value creation in a particular product or service (Brown and Duguid, 2001; Lowe et al, 2012). Without engagement in or experience of such practice, it is difficult to acquire a deep understanding of the knowledge associated with the practice (Pinch et al, 2003; Tallman and Chacar, 2011). The extent of a subsidiary's engagement in such a community of practice is of course likely to be strongest in areas specific to its expertise because of bounded rationality and existing routines. However, it is also likely to have some level of engagement in communities of practice within the broad spectrum of technologies that encompass the industry in which it operates. While this broad engagement may not be as strong as in the case of its areas of expertise, it exists nevertheless as some of its specific knowledge is likely to be relevant to broad industry practice allowing it to process information. Some routines could also be leveraged to knowledge development in other domains in the industry, allowing for success in engagement with such knowledge. However, such engagement is likely to be markedly lower for domains outside the industry. Consequently, when a subsidiary considers developing connections outside its areas of expertise, they are likely to be circumscribed by its broad industry domain. Even in the event that it is able to cultivate connections that are outside the broad domain, it is unlikely to be effective in accessing and utilizing new knowledge for innovation because of the aforementioned factors that inhibit deep understanding and experience of those areas. Next, we consider how these ideas influence the response of the subsidiary to changes that may occur in its organizational and geographic contexts, in specific and broad areas.

MNC Technological Changes

MNC technological change is manifested through increases or decreases in the firm's innovative activity in various technological subfields. For the purpose of this paper, we focus on increases in MNC technological activity. Such increases send signals of organizational transformation and development. They may convey a message of acceptability and indeed necessity of strategies involving technological change within the organizational context. They may also reflect an enabling organizational culture and norms that support the creation of new technologies. Alternatively, a subsidiary may perceive such changes as a threat due to greater competition in its space by other constituents in the MNC. Thus, the expected response by the subsidiary would be to increase its new technology development either as it is supported by the MNC strategy and culture or as it attempts to expand or consolidate its position in response to threats emanating from inside the firm.

We posit that the nature of new technology development, competence exploiting or competence creating, is contingent on the type of MNC technological increase, whether within the specific technological domain of subsidiary expertise or across the broader spectrum. First, we consider changes in subsidiary specific areas of expertise. Bounded rationality on the part of the scientists and inventors, in conjunction with the deep engagement and practice that the subsidiary has in areas of its expertise, narrows the subsidiary's response to cues from such MNC increases. The subsidiary fails to consider the universe of R&D applications indicated by the increases in specific areas and is instead more likely to rely on its experience with previous technology development decisions (Stuart and Podolny, 1996), creating an approach akin to using blinders and resulting in new competence exploiting technologies. The existence of smoothly functioning organizational routines (Cyert and March, 1963) and experience with such routines that can be easily leveraged to similar technologies further increase incentives for development of competence exploiting technologies that can be readily accommodated and supported. These ideas align with the notion that related variety increases opportunities for interaction and recombination of ideas, practices, and technologies (Castaldi et al, 2015; Frenken et al, 2007). Similarly, related specialization appears to be more conducive to absorption of knowledge for innovation (Blit, 2017). Since technology development represented by applied R&D is a cumulative process (Helfat, 1994), the likelihood of success in technology development increases with accumulated experience in that technological field (Cohen and Levinthal, 1990). Naturally, this will predispose managers and scientists to use the cues from technological increase in the MNC in subsidiary specific areas for development of competence exploiting technologies. Consequently, increases in the MNC in subsidiary specific areas of expertise are expected to lead to greater development of competence exploiting technologies by the subsidiary.

Technological increases in the broad industry domain are, in contrast, expected to engender a different response from the subsidiary. Because such increases are within the subsidiary's broad domain, they are likely to be perceived and recognized by its scientists, albeit to a lesser extent than increases in the specific domain. The nature of related variety is different in the case of increases in the broad domain, encompassing greater breadth, yet involving a measure of familiarity. For the subsidiary, it is this combination that creates flexibility to perceive the utility of these increases for a broader set of R&D applications outside the immediate domain, resulting in competence creating technologies. Similarly, the inability to leverage existing routines and experience *in toto* requires adjustments and changes, opening the possibility for undertaking riskier actions that are balanced by familiarity. Thus success in this case is not as assured as in the case of response to increases in specific areas, but may appear achievable as the subsidiary seeks to utilize related but less familiar knowledge. The recombinations that can result from such related variety and experimentation with new and riskier deployments would appear to have greater depth and richness to create competence creating technologies. Indeed, evidence that the MNC is engaging in broad changes may spur the subsidiary to extend its influence and position in those areas by competence creation. We therefore expect technological increases in the MNC at the broad industry level to have a positive effect on subsidiary development of competence creating technologies.

H1a: An increase in technology creation by the MNC in <u>areas specific to subsidiary expertise</u> has a positive influence on subsidiary development of <u>new competence exploiting technologies</u>

H1b: An increase in technology creation by the MNC at the <u>broad industry</u> level has a positive influence on subsidiary development of <u>new competence creating technologies</u>

Host Country Technological Changes

Just as subsidiaries respond to technological cues from their parent MNC, they also respond to similar cues from the host country – indeed, a major consideration for locating subsidiaries in at least some host markets is access to locally held knowledge (Phelps & Fuller, 2016; Maskell, 2014). Increased technological activity in the host country sends signals to the subsidiary of emerging opportunities and threats as technological fields become more crowded due to changes in the innovative activity of host country firms. They provide stimuli for upgrading capabilities as the subsidiary responds to moves by other firms in the environment (Birkinshaw and Hood, 1998). We therefore expect the subsidiary to respond to technological increases in the host country, but similarly to the MNC context, we predict that the nature of the subsidiary response will differ based on the type of increase.

Host country technological development in areas of subsidiary expertise provides a strong stimulus for subsidiary development of new technologies in the competence exploiting space. The bounded rationality of subsidiary managers narrows their response to such changes in the host country, biasing them towards new technologies within their existing expertise. In addition, supporting organizational routines, related knowledge, and prior practice that can be leveraged by the subsidiary in their entirety without noticeable modifications, further constrain these managers into competence exploiting paths. Increased technological activity in the host country in areas of subsidiary expertise points to competition and a potential threat to the subsidiary's market position as other firms in the host country pursue technological development in the subsidiary's niche. The chances of a subsidiary successfully developing new technologies in response to these threats are higher in the case of competence exploiting technologies that offer lower costs and risks. We therefore posit that increased host country technological activity in the subsidiary's areas of expertise is likely to result in new competence exploiting technology development by the subsidiary.

Host country technological increases in the broad industry area are also expected to influence technology development by the subsidiary, although of a competence creating kind. Because of related variety that is underlaid by lower bounded rationality and some familiarity, the subsidiary may be more open to the potential deployment of the technology outside its area of expertise. The variations needed in existing routines and practice may encourage greater experimentation and innovative competence creation. While countering the threat of local firms is still a key concern for the subsidiary, because the increases are in a domain in which it has an understanding but in which it does not specialize, the subsidiary may be more willing to pursue opportunities for competence creation to address such challenges. We therefore propose that host country technological increases at the broad industry level will result in the development of competence creating technologies by the subsidiary.

H2a: An increase in technology creation in the host country in areas specific to subsidiary expertise has a positive influence on subsidiary development of new competence exploiting technologies

H2b: An increase in technology creation in the host country at the broad industry level has a positive influence on subsidiary development of new competence creating technologies.

Moderating Effects of Subsidiary Embeddedness

The ability of the subsidiary to capitalize on technological changes in these contexts for the development of new technologies is contingent on the extent of its embeddedness in them. We propose that subsidiary embeddedness in the MNC and host country contexts creates complementarities between its innovative pursuits and those of the organizational and locational contexts, respectively, resulting in a moderating effect.

High subsidiary embeddedness in the MNC reflects a greater level of knowledge flows and exchanges with other units in the MNC, including other subsidiaries and the headquarters. It is likely to represent an interdependent set of relationships creating cognitive proximity, shared knowledge and practice, and therefore complementarity across innovative pursuits. Similarly, greater embeddedness of the subsidiary in the host country represents mutual knowledge exchanges with local firms, leading to a complementarity in innovation focus. These complementarities have implications for the subsidiary's response to technological changes.

For a subsidiary with greater embeddedness, the relationship between technological increases in the MNC, at the narrow or broad level, and new technology development is likely to be enhanced as a consequence of the complementarity. In the case of MNC technological changes in areas of subsidiary specific expertise, subsidiary managers and inventors will be more aware of and attuned to the increases, and also be more able to utilize the cues from such increases for pursuit of new competence exploiting technologies because of embeddedness and shared knowledge. Further, embeddedness is likely to have enhanced the identification of areas of overlap across complementary pursuits and the subsidiary is therefore likely to possess routines similar to the rest of the MNC, easing the development of new competence exploiting technologies. Thus the positive effect of MNC technological change in subsidiary areas of expertise is enhanced for subsidiaries with greater embeddedness in comparison to those with lower embeddedness.

In the face of broad MNC technological change, embeddedness can enhance the subsidiary's ability to respond to such changes by developing competence creating technologies. An important aspect of broad change is the limited engagement of the subsidiary with the area that is useful in considering larger applications and riskier options. Complementarity increases awareness of these areas, but does not necessarily involve greater engagement of the subsidiary with the broad area. This assists the subsidiary's receptiveness and recognition of changes in broad areas, but still retains the advantages of experimentation and risk taking that enable the ability to engage in competence creating technologies.

We expect similar effects to occur in the case of embeddedness in the host country. Again, embeddedness will moderate the influence of host country technological changes on subsidiary development of new technologies due to complementarity effects. Greater subsidiary embeddedness in the host country will make the subsidiary more attuned to and able to capitalize on changes in the narrow technological area and therefore better able to pursue competence exploiting technologies. It also makes the subsidiary more aware of increases in broad technological areas but is less likely to enhance engagement with the area. Consequently we propose that subsidiary embeddedness in the MNC and host country act as positive moderators of the effects of technological increases in subsidiary specific areas of expertise and also in the broader industry domain.

H3a: Subsidiary embeddedness in the MNC moderates the relationship in H1a, such that highly embedded subsidiaries are more likely to respond to MNC technological increases in areas specific to subsidiary by developing new competence exploiting technologies.

H3b: Subsidiary embeddedness in the MNC moderates the relationship in H1b, such that highly embedded subsidiaries are more likely to respond to MNC technological increases at the broad industry level by developing new competence creating technologies.

H4a: Subsidiary embeddedness in the host country moderates the relationship in H2a, such that highly embedded subsidiaries are more likely to respond to host country technological increases in areas specific to subsidiary expertise by developing new competence exploiting technologies.

H4b: Subsidiary embeddedness in the host country moderates the relationship in H2b, such that highly embedded subsidiaries are more likely to respond to host country technological increases at broad industry level by developing new competence creating technologies.

DATA AND METHODS

Our data setting is the semiconductor industry in which the ability to develop new technologies is important to competitive advantage. To construct our sample we adopt a process with several steps. First, we identify U.S. semiconductor companies listed in Compustat North America, by using SIC code 3674 or NAICS code 334413 (Dutta, Narasimhan and Rajiv, 2005). Next, we use data from the U.S. Patent Database on semiconductor patents[1] filed by our set of firms during the 1984 - 2008[2] time period from the Fleming Patent Dataverse Network. Then we identify those semiconductor patents with an inventor location other than the U.S and use them to determine overseas subsidiaries of semiconductor firms engaged in innovation (Phene and Almeida, 2008). Since we consider the development of new technologies by a subsidiary, only those subsidiaries that engaged in patenting for a minimum of two years during 1989 - 2008 are included in our sample. We collect information on the host country of the subsidiary from the World Development Indicators, on the MNC from Compustat and on measures of distance between the home and host countries from the Cross National Distance dataset (Berry, Guillen and Zhou, 2010). This results in a set of 215 subsidiaries of 50 U.S. MNCs located in 35 host countries. The average MNC has an asset base of $400 million, 5 overseas subsidiaries and a five year firm patent portfolio of about 1200 patents. The overseas subsidiaries have smaller patent portfolios of about 10 patents. Our unit of analysis is a subsidiary-year. We have two samples, one of 1463 observations for tests with the competence exploiting technologies as the dependent variables

[1] To identify semiconductor patents, we follow Jiang, Tan and Thursby (2010) and use 25 primary classes that cover patents related to semiconductor devices and manufacture, identified in the USPTO Technology Profile Report.

[2] Although we collect data from 1984-2008, our model includes independent variables and controls which are lagged and consider prior 5 year stocks, resulting in a sample of observations that are considered from 1989 to 2008.

and the other of 1296 observations for tests with competence creating technologies as the dependent variable[3].

Measures

To construct our dependent, independent, and control variables, we first create semiconductor patent portfolios for the subsidiary, MNC, and host country for each year and for the prior five years. Subsidiary patent portfolios are constructed by identifying all semiconductor patents filed by the subsidiary - i.e., where the MNC is the assignee on the patent and the inventor location is the host country where the subsidiary was located - with application dates in a particular year and over the prior five-year period, respectively. Patent portfolios for the same periods are constructed for the MNC and host country by identifying semiconductor patents on which the MNC is listed as the assignee and those on which the host country is listed as the inventor location, respectively.

The patent document provides us valuable information regarding the geographic location and technological domain of an innovation (Trajtenberg, 1990). Following prior research (Almeida and Phene, 2004) we use the country of the first inventor to identify the overseas subsidiary, assignee name to identify the MNC, and the date of application to determine timing of the innovation. We also use additional information on the primary class and subclass of the patent to determine its technological domain. The USPTO system organizes patents into collections or groups based on common subject matter. Each subject matter division includes a major component called a primary class and minor component called a subclass. The U.S. patent

[3] Not all subsidiaries in our sample contribute all years of observation, since some began patenting later and some did not patent in all years. Additionally, the samples differ in size from each other, because our fixed effects specification results in our statistical analysis package, Stata, dropping observations where the subsidiary had zero dependent variable outcomes across all years of observation. This may occur when a subsidiary does not file any new competence exploiting or competence creating patents during the period in which it is observed, but such a subsidiary may still patent in existing fields.

system classifies patents into more than 450 primary technology classes and more than 150,000 subclasses (USPTO, 2012). Several primary classes comprise an industry. The primary class serves as an umbrella for a major technological direction that groups together distinct technologies. However, the subclasses within the primary class represent considerable heterogeneity (Thompson and Fox-Kean, 2005), with each subclass representing a narrow knowledge area within the larger domain of the class. As an example, one of the primary classes in our study, Class 257, encompasses all active solid state electronic devices. There are a number of subclasses representing the distinct technologies that make up this domain including amorphous semiconductor material, alloys of different semiconductors, superconductive elements and devices, anti-saturation diode, inductance of integrated circuits, to name but a few. Thus, the primary subclass combination of a patent portfolio can offer a finer grained picture of technological positions.

Dependent Variables

Our first dependent variable, *development of competence exploiting technologies by the subsidiary,* is constructed by comparing the patent portfolio of the subsidiary in year *t* to the patent portfolios of the subsidiary and the firm in the prior five years (i.e. *t-5* to *t-1,* both years included). We identify those primary class/subclass combinations that are present in the subsidiary portfolio in year *t* but a) *are not* present in the subsidiary portfolio in the prior five years and b) *are* present in the firm portfolio in the prior five years. These primary class/subclass combinations thus represent competence exploiting (Cantwell and Mudambi, 2005) forays by the subsidiary into areas in which the firm has expertise. The dependent variable is the number of patents filed by the subsidiary in these competence exploiting primary class/subclass combinations in year *t*. This represents a combination of the shifting of technological effort towards technologies that are new to the subsidiary and the extent of such a shift, captured by the number of patents in those technologies.

We construct our second dependent variable, *development of new competence creating technologies*, by comparing the patent portfolio of the subsidiary in year *t* to the patent portfolios of the subsidiary and the firm in the prior five years (i.e. *t-5* to *t-1*, both years included). We identify those primary class/subclass combinations that are present in the subsidiary portfolio in year *t* but a) *are not* present in the subsidiary portfolio in the prior five years and b) *are not* present in the firm portfolio in the prior five years. These primary class/subclass combinations reflect competence creation by the subsidiary in areas in which the firm does not have expertise. Similar to our first dependent variable, we use the number of patents filed by the subsidiary in these competence creating primary class/subclass combinations in year *t*.

Independent variables

Increase in MNC technological position in areas specific to subsidiary expertise is calculated as follows. We first consider the subsidiary's 5 year patent portfolio and identify the primary semiconductor classes in which the subsidiary filed patents. These are defined as areas of subsidiary expertise. Next we calculate the percentage increase, in year t-1 compared to year t-2, in patents filed by the MNC, across those primary class/ subclass combinations, where the primary class represents the specific areas in which the subsidiary possesses expertise (identified in the prior step)[4]. Higher values reflect greater increases in MNC technological position in areas specific to subsidiary expertise. *MNC technological increase at the broad industry level* measures the percentage increase, in year t-1 compared to year t-2, in the technological position of the MNC across those primary class/subclass combinations, where the primary class belongs to semiconductor industry classes, but excluding the primary classes in which the subsidiary has

[4] If there is no increase or if there is a decrease this value is set to zero.

expertise. Thus this variable reflects increases in broad industry, outside of subsidiary areas of expertise. *Host country technological increases, in areas specific to subsidiary expertise* and *at the broad industry level* are calculated in a manner analogous to that of the MNC technological changes by using the host country patent portfolios in specific semiconductor classes in which the subsidiary has expertise and across those semiconductor classes, outside subsidiary expertise, in year t-1 and t-2.

In accordance with our hypotheses, we use MNC and host country technological increases in areas specific to subsidiary expertise as independent variables in our models of competence exploiting technologies (Table 2), and as controls for our models of competence creating technologies (Table 3). Conversely, we use MNC and host country technological increases in broad industry as independent variables in Table 3, for competence creation and as controls in Table 2 for competence exploiting.

Moderator variables

Our measures of subsidiary embeddedness in the MNC and host country are based on patent cross citations between the subsidiary and the context respectively. These knowledge linkages may represent either the subsidiary's familiarity with the context and/or the extent of social relations that underlay this familiarity. *Subsidiary embeddedness in the MNC* is calculated as the percentage of cross citations between the subsidiary and the MNC (both headquarters and other subsidiaries) - these include citations by the subsidiary to the MNC and citations to the subsidiary by the MNC - compared to the total patents filed by the MNC in the prior five years. *Subsidiary embeddedness in the host country* is created in a similar manner as the percentage of cross citations between the subsidiary and other entities in the host country to the total patents filed by the host country in the prior five years.

Controls

Our model includes additional controls at the subsidiary, MNC and host country levels, lagged and measured at time t-1. Characteristics of the subsidiary related to its innovative capability, geographic distance and technological distinctiveness from the MNC may influence its ability and willingness to experiment with new technology. *Subsidiary innovative capability* is calculated as the stock of patents filed by the subsidiary in the 5 years prior to the current year of observation t. *Geographic distance of the subsidiary* is calculated as the great circle distance between the geographic center of the host and home country scaled by hundred. *Technological distinctiveness* is calculated as the Euclidean distance between the patent portfolio of the subsidiary and the MNC at time t-1. A few subsidiaries in our sample (10 out of the 215 subsidiaries) do not patent consistently across the years, we therefore control for *patenting gap for the subsidiary*. This is operationalized as a binary variable that takes a value of 1 across all the subsidiary's observation years if there is a gap. Some subsidiaries' portfolios include patents created through internal cooperation with other subsidiaries/ headquarters, which may influence their new technology development. We control for the percentage of *subsidiary collaborative patents*, identified as those patents in the subsidiary's portfolio that have more than one inventor country.

MNC characteristics may enable access to resources conducive to the development of new technologies by the subsidiary[5]. *MNC size* is measured as the natural log of total assets of the firm. Large firms may offer better support to subsidiaries in developing new technologies. *MNC leverage* is captured by the firm's debt equity ratio, a highly leveraged firm may not

[5] Our use of firm controls to test a panel of subsidiaries over time is in accordance with accepted practice used by prior researchers for similar data, with different subsidiary outcomes (Cantwell and Mudambi, 2005; Phene and Almeida, 2008; Spencer and Gomez, 2011).

possess additional capacity for raising funds and this may restrict development of new technologies. *MNC slack* is measured as the current ratio. Greater slack may indicate resource availability to develop new technologies. *MNC profitability* is the firm's return on equity, as more profitable firms may be better able to invest in new technology development. *MNC R&D intensity* is measured as the percentage of R&D expenditure to sales. *MNC technological richness* is calculated as the percentage of semiconductor patents filed by the MNC to the total semiconductor patents filed worldwide. MNC R&D and technological richness represent extent of knowledge resources available to the subsidiary for the pursuit of new technologies

Cantwell and Kosmopoulou (2002) suggest that R&D may become most concentrated in those subsidiaries where the local conditions are conducive to technology creation. *Host country high technology exports*, calculated as the percentage of host country high technology exports to total manufactured exports, reflects the technological sophistication of the country. The incentives for the subsidiary to develop new technologies may be influenced by local growth opportunities, and we therefore control for *host country GDP growth rate*. *Host country technological richness* is calculated in a manner similar to that of the MNC and is the percentage of semiconductor patents filed with an inventor location in that country to total semiconductor patents filed worldwide.

Method

Our dependent variables represent counts of patents filed by the subsidiary in new competence exploiting and competence creating technologies. We use the negative binomial regression, as it is best suited to addressing the economic issues that arise from the count nature of our dependent variables (Phene and Almeida, 2008). Our data involves a panel structure with repeated observations of subsidiaries over the years. In order to control for unaccounted effects for the subsidiary and the year, we use the fixed effects specification[6].

FINDINGS

We present our summary statistics in Table 1.

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Insert Table 1 here
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Table 2 presents the results of our testing of the "A" hypotheses, with our first dependent variable of competence exploiting technologies

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MNC technological increases in areas specific to subsidiary expertise have a significant and positive effect on the development of new competence exploiting technologies by the subsidiary as hypothesized in H1A. Examining the co-efficient of MNC technological increase in areas of subsidiary expertise, in Model 2, reveals that a one standard deviation increase in this measure, while holding other variables at their mean values, results in an increase in subsidiary development of competence exploiting technologies by 19.73% or about 0.20 additional patents in these technologies. In contrast, host country technological activity in areas specific to subsidiary expertise does not have a significant effect on subsidiary development of competence exploiting technologies, we therefore find that H2A is not supported. Subsidiaries with competence exploiting mandates may be charged with the introduction and adaptation of the

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[6] Clark and Linzer (2012) suggest that the commonly used Hausman test is neither a necessary nor a sufficient test to determine choice between fixed and random effects models. Instead they recommend making a choice based on the number of units (in our sample a unit is represented by a subsidiary) and the number of observations per unit (equivalent to years of observation per subsidiary in our sample) in the sample. They propose that if the sample comprises of many units (>10) and many observations per unit (>5), then the more conservative fixed effects model is appropriate. In our sample the number of units (subsidiaries) is 173, with 8.5 average observations per subsidiary for the first sample. For the second sample the numbers are 135 and 5.7 respectively, suggesting a fixed effects specification.

MNC's products for the host market. Our results suggest that this pattern may be reflected in subsidiary innovation. The subsidiary plays a limited role by extending MNC technology into the local market. It does not appear to utilize host country based technological activity in its immediate field to guide such development.

Since interaction terms in nonlinear models provide "generally uninformative and sometimes contradictory and misleading results" (Greene, 2010, page 295), we test for the moderating effects of embededdness in the MNC and host country by considering split samples in Models 5-8. Models 5 and 6 represent subsamples of low and high embeddedness of the subsidiary in the MNC, while models 7 and 8 reflect low and high embeddedness in the host country[7]. We do not find support for H3A and H4A, in that highly embedded subsidiaries whether in the MNC or host country are not more able to respond to increases in the respective contexts to engage in competence exploiting technology development.

One explanation may be that highly embedded subsidiaries actively seek cues from alternate contexts to balance or offset their overreliance on the environment in which they are embedded. Indeed, we find that this may be the case, as demonstrated in the cross context effects[8]. Subsidiaries that are highly embedded in the MNC are better able to utilize technological changes in the host country in their areas of expertise to pursue competence exploiting technologies (Model 6). A possible explanation for this finding may be that subsidiary embeddedness in the MNC not only reflects complementarity, but also potentially represents the capability of the subsidiary in the MNC. A subsidiary with high embeddedness is likely sought

[7] Given the distribution of our embeddedness variables, low embeddedness in the MNC or host country translates to no cross citations between the subsidiary and the each context, while high embeddedness reflects the presence of any cross citations.

[8] To ensure that these are cross context effects, and to ensure that they are not driven by subsidiaries that are highly embedded in the MNC and also highly embedded in the host country, we ran another test. We created a subsample of subsidiaries that were simultaneously highly embedded in both the MNC and host country context, but do not find significance for any of the technological change variables for competence exploiting technologies.

after as source of knowledge and also receives flows of knowledge from the rest of the firm. It could be that this capability puts the subsidiary in a better position to monitor technological cues from the host context as well as to respond to them through the development of competence exploiting technologies. The other cross context effect is in the significant effect of MNC technological changes in subsidiary areas of expertise for subsidiaries that are highly embedded in the host country, in the development of competence exploiting technologies (Model 8). Subsidiary embeddedness in the host country likely reflects exposure to and potentially a better understanding of different knowledge approaches adopted by entities in that context. This may enable the subsidiary to better recognize and utilize technological cues from other subsidiaries of the MNC. In both cross context effects, embeddedness in the same context may not be as necessary and potentially redundant, because this is an area in which the subsidiary has expertise. As long as it is embedded in a particular context, it may cultivate a breadth of exposure that is relevant to the other context, allowing it to respond and pursue competence exploitation.

Table 3 presents the results of our testing of the "B" hypotheses, with our dependent variable of competence creating technologies

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Insert Table 3 here

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H1B is not supported, as MNC technological changes in broad areas do not spur the subsidiary to develop new competence creating technologies. In contrast, country technological changes in broad areas has a significant and positive effect on our dependent variable, supporting H2B. This translates to an increase of 20.72% (about 0.21 additional patents) due to a one standard deviation increase in host technological changes in broad areas, based on the coefficient in Model 11. This contrasts with our findings for the "A" hypotheses, and may reflect subsidiary strategic mandates. Subsidairies with competence creating mandates may be tasked with acquiring new information from the host country in order to add to an existing MNC stock of technologies. This may predispose the subsidiary to use broad increases in the host country for competence creation. Broad changes in the MNC, while signaling upheaval, may be less useful in identifying new areas for competence creation.

Testing for moderating effects of embeddedness, we find a pattern of cross context effects for embeddedness in the MNC, similar to that for competence exploiting technologies. H3B is not supported, i.e. broad technological changes in the MNC do not have a significant effect on competence creating technologies for subsidiaries highly embedded in the MNC. But for such subsidiaries, broad increase in the country has a significant effect on competence creation (Model 14). The strong capability that such embeddedness may reflect enables the subsidiary to recognize and respond to the increase in the host country for competence creation purposes. We find support for H4B, as embeddedness in the host country enables the subsidiary to better respond to broad changes in the host country (Model 16). Yet subsidiaries that are embedded in the host country also appear to be less likely to engage in competence creation in response to broad increases in the MNC. One explanation may be that in the context of technological increases at the broader industry level in the MNC, subsidiaries that are more embedded in the host country pull back from competence creation efforts in order to gather more information about the broad level organizational changes and gauge their implications. Since they are strongly embedded in the host country (and not necessarily as embedded in the organization), understanding the broad organizational change and its repercussions for own efforts, such as modifications needed to current technology development efforts, necessarily takes time and therefore, the immediate effect that we observe is a reduction in competence creation.

Another explanation could be that subsidiary choices of competence creating technologies are likely to be more constrained within the firm because of the nature of the organizational relationship. The existence of a formal hierarchical relationship may represent a clearly pronounced and specialized division of labor and technologies across subsidiaries in the firm, limiting the subsidiary's ability to move freely toward competence creating technologies. In contrast, if the subsidiary is heavily embedded in the host country, it can identify and potentially pursue competence creating technologies in response to specific changes in the host country without similar hierarchical deterrents. In fact competitive actions would work in the opposite manner, spurring it to develop competence creating technologies.

These findings also appear to represent the tradeoffs facing the subsidiary. Interestingly, while high embeddedness in the country makes the influence of MNC broad increases less useful for competence creation, the converse is true, i.e. high embeddedness in the MNC makes the influence of country broad changes more useful for competence creation[9]. Thus, the better option for the subsidiary to use the host environment technological increase for competence creation is through the counterintuitive pursuit of MNC embeddedness.

Of the controls, we find some significance for the negative effects of MNC broad increases on competence exploitation, which may reflect constraints imposed by the formal hierarchy on subsidiary specialization that hampers subsidiary ability to respond to such changes and build out new areas, whether in the competence exploiting or, as discussed earlier, in the competence creating realms. The positive effects of MNC increases in specific areas on

[9] Just as in the case of the first dependent variable, to ensure that these are not driven by subsidiaries that are highly embedded in the MNC and also highly embedded in the host country, we ran another test with a subsample of subsidiaries that were simultaneously highly embedded in both the MNC and host country context. Our results indicate that for this set the effect of broad increases in the country is positive and significant but the negative effect of broad increases in the MNC becomes marginal, suggesting that it is subsidiaries highly embedded in the country that are vulnerable to this challenge.

competence creation suggest that perhaps competence creation is enabled by recombinations involving subsidiary core areas of expertise. Embeddedness in the MNC and host country appears to constrain development of competence exploiting technologies. This negative aspect suggests that greater embeddedness may reflect subsidiaries with established technological mandates and expertise that serve as key sources and/or recipients of knowledge flows. These subsidiaries may continue on existing paths, reinforcing existing areas of established technology, rather than exploring the margins of new competence exploitation. The effects of embeddedness are less evident and mostly not significant for competence creation. Perhaps embeddedness confers exposure to new knowledge that may be useful for competence creation, but at the same time, the presence of established technological mandates for the highly embedded subsidiaries, results in the two effects cancelling each other out and a lack of significance. The effects of subsidiary innovative capability, collaborative patents, firm size, technological richness, as well as some effects for firm leverage and profitability are as expected. Subsidiary distance from home limits competence exploiting technologies, perhaps pointing to distance-moderated access to knowledge resources from the parent firm. We also find some support for the negative effects of subsidiary technological distance on competence creation, suggesting that subsidiaries may need some overlap with the MNC in order to pursue new competence creation.

DISCUSSION AND CONCLUSIONS

Our study aligns with Bathelt and Gluckler's (2003) conceptualization of the four icons of relational economic geography – organization, innovation, evolution and interaction. We consider subsidiary evolution through its innovation as a result of interactions with technological changes in key environments – the organization and the host country. Our theoretical contribution relates to the distinctive pattern of effects of specific and broad changes on subsidiary development of competence exploiting and competence creating technologies, respectively. By considering the creation of new technologies in response to technological changes in the subsidiary's organizational and geographic spaces, we provide a holistic view of the co-evolution of the subsidiary with the corporate and host country space. Using the concept of local search, we make complementary theoretical contributions to the organizational and geographic perspectives, demonstrating that particular contextual change (specific compared to broad) is more influential for different types of new technology development. Using the communities of practice ideas we propose that embeddedness creates complementarity, in certain cases, moderating the relationship between technological change and subsidiary development of new technologies.

For a typical subsidiary, development of competence exploiting technologies is influenced by MNC technological increase in narrow areas of expertise, while development of competence creating technologies is driven by host country technological increase in the broad spectrum. The two contexts appear to take on very specific and distinct roles in determining the technological trajectory of subsidiaries. The boundaries of local search function differently for the type of technology, with subsidiaries relying on the organization for competence exploitation and the location for competence creation. The nature of related variety sourced from within the organization appears to be more specific than that from the host country. However, this characterization becomes more complex when subsidiary participation in communities of practice (reflected in the embeddedness) is considered. More embedded subsidiaries are better able to utilize increases that may occur, either from the alternate context as in the case of competence exploiting technologies or from the same context, as in the case of competence creation. Cross context effects may be a result of subsidiary efforts to actively search outside the embedded context and the possibility that a subsidiary could do so, for competence exploitation, without the benefit of embeddedness in a particular context.

For competence creation, the story differs, particularly for embeddedness in the host country. This is likely because competence creation involves extension outside of subsidiary areas of expertise and needs to be supported by embeddedness. In this case, broad changes in the MNC hurt subsidiary efforts to create competence, perhaps reflecting organizational strategic constraints on subsidiary expansion to new domains. Embeddedness in the host country also demonstrates a dark side, particularly in the effect of MNC broad technological changes on competence creation.

Our study contributes to the literatures on innovation in the multinational and economic geography literature. While these streams have considered outcomes related to innovation by the subsidiary or the firm as consequence of the multinational or local context (Almeida and Phene, 2004; Audretsch and Feldman, 1996), our study sheds light on the nature of such innovation by focusing on the nature of new technologies developed by the subsidiary. By considering the influence of technological changes in the host country context on subsidiary technology development, we complement research at the regional level in the economic geography literature. Just as the locational hierarchy of regions within a country influences technological specialization of foreign firm's R&D units (Cantwell and Iammarino, 2000), technological changes within the country shape the direction of technology development by the subsidiary. Further, by demonstrating subsidiary evolution in response to externalities from the home market, our study complements work by Boschma and Frenken (2011) that proposes an evolutionary economic geography approach. The subsidiary and the host country appear to be interconnected in this evolutionary process. As our study demonstrates the host country influences subsidiary development, but undoubtedly the subsidiary also contributes to the evolution of the region and country.

Studies of innovation in the economic geography and management arenas demonstrate an intertwined trajectory of development, with some areas that offer substantial promise for mutual development, particularly “the shifting geographical and organizational boundaries of the firm, the role of knowledge and innovation interactions over space and time; and how changing geography (and responses to it), will shape firm development and growth” (Howells and Bessant, 2012, page 936). Our study contributes to these areas by exploring how subsidiary navigation of internal and external boundaries, in the technological arena, through a process of embedding can shape knowledge interactions and influence innovation.

Our study has several limitations. Our perspective on location is at the host country level. The economic geography literature tends to focus on regional or cluster level effects, although there has been consideration of trans-local effects and arguments for better theorizing related to these effects (Bathelt et al, 2004). We discuss locational effects at the host nation level, but the national level tends to reflect the sum of sub-national regional or cluster effects. Our data do not distinguish locations on a sub-national level. Future studies could consider how regional cluster effects may augment host country effects. Our findings appear to suggest that there is greater evidence of competence exploitation than competence creation. This may point to the role of subsidiaries as followers of corporate guidance that shape its technology development (Tallman and Koza, 2016). An interesting exploration of leader - follower roles would involve a qualitative survey of senior managers/subsidiaries that assesses whether corporate guidance to subsidiaries changes and whether subsidiaries lead or follow.

We rely on patent data to measure several of our constructs of new technology development, technological change and embeddedness. However, patents are a partial measure of technology development and innovation. Our focus on the semiconductor industry where multinational firms and subsidiaries develop and maintain extensive patent portfolios helps to alleviate this issue to some extent (Almeida and Phene, 2004). Patents may cover a wide variety of innovations ranging from minor modifications to very significant advances. Future research may explore alternate characterizations of embeddedness through social relationships and exchanges or power dynamics. The semiconductor industry is fast paced industry with a short product lifecycle of about five years (Stuart and Podolny, 1996). Keeping this window in mind, it is reasonable to assume that subsidiaries are able to observe technological changes, conduct research and develop a patent within the observation period. This is particularly true for the competence exploiting realm where subsidiaries already possess capabilities to spot the signal and assimilate towards their own innovative efforts. Exploring the effects of changes over a longer lag, particularly for competence creation, may be an interesting extension. While our variables distinguish the nature of new technology development by subsidiaries, there are interesting avenue for further exploration. Future research could extend the implications of our framework by considering a finer characterization of the dependent variable that considers MNC specialization in the new technologies created by the subsidiary.

In a globalized and hypercompetitive world, sustainable competitive advantage depends on organizational ability to innovate and grow. For MNCs, overseas subsidiaries offer opportunities for such innovation, but do not consistently produce new competence exploiting or creating technologies. Our study suggests that technological increases in both the organizational and locational contexts of the subsidiary, in conjunction with its embeddedness in each context affect the propensity for subsidiaries to develop technological innovations. For MNC managers, these findings suggest that understanding the situations facing individual subsidiaries is as important as understanding their internal capabilities in developing expectations for their contributions of new technology.

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Table 1: Summary Statistics

	Variables	1	2	3	4	5	6	7	8	9	10	11
1	Subsidiary development of competence exploiting technologies	1.00										
2	Subsidiary development of competence creating technologies	0.56	1.00									
3	MNC technological increase (in areas specific to subs. expertise)	0.05	0.10	1.00								
4	MNC technological increase (broad industry level)	-0.09	0.01	0.07	1.00							
5	Host country technological increase (in areas specific to subs. expertise)	0.05	0.04	0.05	-0.01	1.00						
6	Host country technological increase (broad industry level)	-0.05	-0.03	-0.05	0.13	0.16	1.00					
7	Subsidiary embeddedness in MNC	0.05	0.05	0.17	-0.05	0.02	-0.06	1.00				
8	Subsidiary embeddedness in host	0.08	0.06	0.09	-0.07	0.12	-0.05	0.11	1.00			
9	Subsidiary innovative capability	0.57	0.49	0.17	-0.15	0.05	-0.16	0.23	0.37	1.00		
10	Subsidiary geographic distance	0.03	0.01	-0.08	-0.02	0.11	0.09	-0.04	0.12	0.02	1.00	
11	Subsidiary technological distinctiveness	-0.15	-0.17	-0.22	0.01	0.01	0.01	-0.13	-0.09	-0.23	0.05	1.00
12	Subsidiary gap in patenting	-0.07	-0.05	0.02	0.04	-0.01	0.07	-0.02	-0.03	-0.08	0.06	-0.05
13	Subsidiary collaborative pats	0.11	0.08	0.03	0.02	-0.01	0.01	0.05	0.03	0.07	0.02	-0.05
14	MNC size	0.23	0.16	-0.24	-0.17	0.01	0.03	-0.08	0.02	0.21	0.01	-0.09
15	MNC leverage	0.01	0.02	-0.01	-0.17	0.01	0.00	0.01	-0.01	0.02	0.01	0.01
16	MNC slack	-0.15	-0.12	0.05	-0.10	-0.01	-0.03	0.10	-0.03	-0.09	0.05	0.02
17	MNC profitability	-0.01	-0.01	0.05	-0.01	0.01	-0.01	-0.01	-0.01	0.01	-0.01	-0.03
18	MNC R&D intensity	-0.07	-0.07	-0.02	0.01	-0.01	-0.03	0.01	-0.02	-0.08	0.08	0.09
19	MNC tech richness	0.31	0.12	-0.18	-0.16	0.04	0.02	-0.07	0.07	0.23	-0.02	-0.06
20	Host country high tech exports	0.02	0.01	-0.01	-0.02	0.07	0.01	0.05	0.14	0.03	0.46	-0.02
21	Host country GDP growth	-0.09	-0.07	-0.03	-0.04	0.06	0.15	0.02	0.11	-0.08	0.44	0.01
22	Host country tech richness	0.17	0.19	0.02	0.02	-0.06	-0.30	-0.02	-0.05	0.22	0.04	-0.03
	Mean	0.99	0.64	3.63	78.06	4.13	76.70	0.98	0.53	9.65	93.24	0.60
	Standard Deviation	2.27	1.48	10.15	59.63	30.01	46.36	4.21	2.75	20.03	31.38	0.24

Table 1 - Continued

	Variables	12	13	14	15	16	17	18	19	20	21	22
12	Subsidiary gap in patenting	1.00										
13	Subsidiary collaborative pats	0.01	1.00									
14	MNC size	0.03	0.09	1.00								
15	MNC leverage	-0.01	0.01	0.03	1.00							
16	MNC slack	-0.08	-0.03	-0.31	0.02	1.00						
17	MNC profitability	0.03	0.01	0.05	0.16	-0.02	1.00					
18	MNC R&D intensity	-0.04	-0.09	-0.34	0.01	0.20	-0.08	1.00				
19	MNC tech richness	-0.04	0.07	0.69	0.02	-0.30	0.05	-0.31	1.00			
20	Host country high tech exports	-0.09	0.01	-0.03	-0.01	0.05	-0.03	0.07	-0.04	1.00		
21	Host country GDP growth	0.10	0.02	0.04	0.09	0.06	0.04	0.03	-0.01	0.22	1.00	
22	Host country tech richness	0.01	-0.03	-0.05	0.01	-0.10	0.06	-0.04	-0.01	-0.01	-0.28	1.00
	Mean	0.06	6.91	8.62	0.29	0.28	0.17	15.98	1.02	24.33	3.62	4.32
	Standard Deviation	0.24	20.45	1.66	3.38	0.16	0.58	9.02	1.10	14.99	2.87	8.89

Table 2 – Effects of MNC, Host Country Technological Increases in Subsidiary Specific Areas of Expertise on Development of Competence Exploiting Technologies

		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
						Split sample – Low embed. of subs. in MNC	Split sample – High embed. of subs. in MNC	Split sample – Low embed. of subs. in host	Split sample – High embed. of subs. in host
Independent Variables									
MNC tech increase (specific to subs. expertise)	H1A		0.018** (0.007)		0.018** (0.007)	0.007 (0.013)	0.015 (0.010)	-0.011 (0.023)	0.019* (0.008)
Host country tech increase (specific to subs. expertise)	H2A			0.001 (0.001)	0.001 (0.001)	0.0004 (0.001)	0.011* (0.005)	0.001 (0.004)	0.005 (0.005)
Controls									
MNC tech increase (broad industry level)		-0.002 (0.001)	-0.002* (0.001)	-0.002 (0.001)	-0.002* (0.001)	-0.001 (0.002)	-0.003 (0.002)	-0.0003 (0.002)	-0.003 (0.002)
Host country tech increase (broad industry level)		0.0004 (0.001)	0.0005 (0.001)	0.0003 (0.001)	0.0004 (0.001)	-0.0005 (0.002)	-0.001 (0.002)	-0.0007 (0.001)	0.002 (0.002)
Subs embeddedness in MNC		-0.022	-0.025*	-0.022	-0.025*	Omitted	Omitted	-0.152	-0.025
		(0.012)	(0.012)	(0.012)	(0.012)			(0.102)	(0.016)
Subs embeddedness. in host		-0.038**	-0.034*	-0.039**	-0.035*	-0.045	-0.040*	Omitted	Omitted
		(0.014)	(0.014)	(0.015)	(0.015)	(0.060)	(0.020)		
Subs innovative capability		0.007***	0.005**	0.007***	0.005**	0.016	0.003	0.038**	0.001
		(0.002)	(0.002)	(0.002)	(0.002)	(0.009)	(0.002)	(0.013)	(0.002)
Subs geographic distance		-0.011*	-0.011*	-0.012*	-0.012*	-0.014	-0.021	-0.066	-0.009
		(0.005)	(0.005)	(0.005)	(0.005)	(0.010)	(0.013)	(0.044)	(0.008)
Subs tech. distinctiveness		-0.229	-0.169	-0.231	-0.171	0.414	-0.365	-0.031	-0.240
		(0.173)	(0.173)	(0.173)	(0.174)	(0.295)	(0.246)	(0.276)	(0.240)
Subs patenting gap		-0.747	-0.859	-0.739	-0.851	0.300	-1.167	-1.466	-1.428
		(0.588)	(0.596)	(0.589)	(0.596)	(2.972)	(0.921)	(1.408)	(0.873)
Subs collaborative patents		0.008***	0.008***	0.008***	0.008***	0.010***	0.007***	0.013***	0.007***
		(0.001)	(0.001)	(0.001)	(0.001)	(0.003)	(0.002)	(0.003)	(0.002)
MNC size		0.259**	0.275**	0.260**	0.276**	0.303	0.084	1.344**	0.226
		(0.100)	(0.101)	(0.100)	(0.101)	(0.224)	(0.190)	(0.458)	(0.127)
MNC leverage		0.118	0.121	0.120	0.123	0.335**	-0.393	0.423*	0.002
		(0.089)	(0.093)	(0.089)	(0.093)	(0.104)	(0.292)	(0.207)	(0.160)
MNC slack		-0.086	-0.078	-0.093	-0.084	0.163	-0.967	-1.019	0.069
		(0.417)	(0.416)	(0.418)	(0.416)	(0.627)	(0.612)	(0.853)	(0.625)

MNC profitability		-0.120	-0.155	-0.127	-0.161	-0.160	-0.192	-0.231	-0.250
		(0.246)	(0.250)	(0.246)	(0.250)	(0.324)	(0.592)	(0.547)	(0.355)
MNC R&D intensity		-0.002	-0.004	-0.002	-0.004	-0.005	0.012	-0.025	-0.002
		(0.009)	(0.009)	(0.009)	(0.009)	(0.013)	(0.018)	(0.022)	(0.012)
MNC tech richness		0.282***	0.292***	0.278***	0.289***	0.570**	0.271**	0.263	0.233**
		(0.061)	(0.061)	(0.062)	(0.062)	(0.199)	(0.091)	(0.199)	(0.072)
Host high tech exports		0.001	0.001	0.001	0.001	-0.003	0.010	-0.019	-0.009
		(0.009)	(0.009)	(0.009)	(0.009)	(0.017)	(0.015)	(0.024)	(0.013)
Host ctry GDP growth		0.019	0.020	0.019	0.020	0.025	0.021	0.058	0.004
		(0.020)	(0.020)	(0.020)	(0.020)	(0.032)	(0.029)	(0.040)	(0.029)
Host ctry tech richness		-0.009	-0.009	-0.008	-0.009	-0.016	0.018	-0.180	0.013
		(0.013)	(0.013)	(0.013)	(0.013)	(0.023)	(0.029)	(0.150)	(0.019)
Wald ChiSquared		209.19***	213.34***	210.15***	214.09***	80.81***	125.47***	112.14***	125.56***
N		1463	1463	1463	1463	773	548	680	672

Standard errors in parentheses, Models include fixed effects for subsidiary and year, * p<0.05, **p<0.01, ***p<0.001
Number of observations in split samples vary because Stata automatically drops groups with all zero outcomes

Table 3 – Effects of MNC, Host Country Technological Increases in Broad Areas on Development of Competence Creating Technologies

		Model 9	Model 10	Model 11	Model 12	Model 13	Model 14	Model 15	Model 16
						Split sample – Low embed. of subs. in MNC	Split sample – High embed. of subs. in MNC	Split sample – Low embed. of subs. in host	Split sample – High embed. of subs. in host
Independent Variables									
MNC tech increase (broad industry level)	H1B		-0.001 (0.001)		-0.001 (0.001)	-0.001 (0.001)	-0.005@ (0.003)	-0.0003 (0.002)	-0.007** (0.002)
Host country tech increase (broad industry level)	H2B			0.004** (0.001)	0.004** (0.001)	0.001 (0.002)	0.006** (0.002)	0.002 (0.002)	0.007** (0.002)
Controls									
MNC tech increase (specific to subs. expertise)		0.013* (0.006)	0.015* (0.007)	0.014* (0.006)	0.016* (0.007)	0.006 (0.010)	0.013 (0.013)	-0.008 (0.021)	0.031*** (0.009)
Host country tech increase (specific to subs. expertise)		-0.0003 (0.001)	-0.0003 (0.001)	-0.001 (0.001)	-0.001 (0.001)	-0.001 (0.001)	0.003 (0.005)	-0.004 (0.005)	0.009 (0.007)
Subs embeddedness in MNC		0.013	0.013	0.013	0.013	Omitted	Omitted	0.014	0.003
		(0.014)	(0.014)	(0.014)	(0.014)			(0.058)	(0.018)
Subs embeddedness. in host		-0.029	-0.029	-0.027	-0.027	0.035	-0.056*	Omitted	Omitted
		(0.017)	(0.017)	(0.017)	(0.017)	(0.027)	(0.028)		
Subs innovative capability		0.005**	0.005*	0.005**	0.005**	0.007	0.009***	0.009	0.003
		(0.002)	(0.002)	(0.002)	(0.002)	(0.010)	(0.002)	(0.019)	(0.002)
Subs geographic distance		-0.005	-0.006	-0.005	-0.005	-0.010	0.005	0.029	0.000
		(0.006)	(0.006)	(0.006)	(0.007)	(0.010)	(0.022)	(0.029)	(0.012)
Subs tech. distinctiveness		-0.567**	-0.568**	-0.561**	-0.563**	-0.429	-0.372	-0.316	-0.516
		(0.196)	(0.195)	(0.195)	(0.195)	(0.317)	(0.287)	(0.347)	(0.273)
Subs patenting gap		-0.897	-0.924	-0.859	-0.888	-1.698	-1.223	11.581	-1.063
		(0.600)	(0.603)	(0.600)	(0.602)	(0.943)	(1.017)	(402.947)	(0.803)
Subs collaborative patents		0.007***	0.007***	0.007***	0.007***	0.006*	0.009**	0.015***	0.003
		(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.004)	(0.003)
MNC size		0.084	0.061	0.102	0.078	-0.106	0.037	-0.069	0.170
		(0.093)	(0.095)	(0.092)	(0.095)	(0.211)	(0.207)	(0.276)	(0.140)
MNC leverage		-0.378**	-0.404***	-0.390**	-0.421***	-0.072	-1.065**	0.117	-0.749***
		(0.119)	(0.122)	(0.120)	(0.123)	(0.092)	(0.339)	(0.257)	(0.173)
MNC slack		0.136	0.046	0.185	0.084	-0.588	-0.121	0.062	-0.360
		(0.400)	(0.408)	(0.398)	(0.406)	(0.579)	(0.713)	(0.869)	(0.640)
MNC profitability		0.785*	0.850**	0.806*	0.882**	0.486	1.539*	0.616	1.189*

		(0.318)	(0.326)	(0.320)	(0.328)	(0.422)	(0.674)	(0.639)	(0.466)
MNC R&D intensity		0.010	0.011	0.010	0.011	0.002	-0.001	-0.020	0.013
		(0.010)	(0.010)	(0.010)	(0.010)	(0.015)	(0.021)	(0.025)	(0.013)
MNC tech richness		0.053	0.055	0.061	0.063	-0.119	0.383**	0.341	0.147
		(0.081)	(0.082)	(0.081)	(0.081)	(0.203)	(0.125)	(0.304)	(0.102)
Host high tech exports		0.015	0.014	0.019	0.019	0.029	0.040	0.048	0.033
		(0.011)	(0.011)	(0.011)	(0.011)	(0.017)	(0.031)	(0.035)	(0.019)
Host ctry GDP growth		0.009	0.007	0.012	0.010	0.051	-0.011	0.141**	-0.036
		(0.023)	(0.023)	(0.023)	(0.023)	(0.037)	(0.033)	(0.050)	(0.030)
Host ctry tech richness		0.052	0.052	0.052	0.053*	0.041	0.048	0.371	0.057
		(0.027)	(0.027)	(0.027)	(0.027)	(0.032)	(0.084)	(0.192)	(0.041)
Wald ChiSquared		145.10***	146.38***	154.05***	155.52***	65.82***	146.69***	81.18***	151.26***
N		1296	1296	1296	1296	680	530	539	631

Standard errors in parentheses, Models include fixed effects for subsidiary and year, @ p<0.10, * p<0.05, **p<0.01, ***p<0.001
Number of observations in split samples vary because Stata automatically drops groups with all zero outcomes.