Technology Adoption and Creation in Multinational Enterprises:

The Case of China

Abstract

Technology adoption and creation in subsidiaries are essential for multinational enterprises to enhance their competitiveness in the global market. While there are separate studies, little research has been conducted on the mutual relationship between these two important phenomena. The current paper examines the determinants of technology adoption and creation, and how the two affect each other. Using a very unique panel data set covering 465 multinational subsidiaries in China for the period 1998-2005, our results show that technology adoption affects technology creation, though the reverse relationship is not established. Business networks, corporate and subsidiary strategies and competition in the host market have significantly different impacts on technology adoption and creation. Policy and managerial implications are discussed.

Key Words: Technology Adoption, Technology Creation, Technology Transfer, Multinational Enterprises, Subsidiary, China.

I. INTRODUCTION

Traditional theory of the multinational enterprise (MNE) suggests that technology is created at and transferred from the headquarters (HQ) in the home country to its overseas subsidiaries so that these subsidiaries can overcome the liability of "foreignness" and perform better than their local counterparts in host countries (Hymer, 1976), and achieve sustainable competitive advantage (Dyer and Nobeoka, 2000). Technologies adopted by multinational subsidiaries may well spill over to indigenous firms in host countries. In this sense, foreign direct investment (FDI) carried out by MNEs has long been regarded as the dominant form of resources and technologies from developed to developing countries (Lall, 1993; Tsai, 2001; Wei and Liu, 2006). Given its contributions to the competitiveness of multinational subsidiaries and local development in the host country, technology transfer from the parent to its overseas subsidiaries has attracted much attention.

Following the network approach, resource dependent theory and/or evolutionary theory, some recent literature suggests that technical, market, and functional knowledge is generated continuously in all parts of a corporation, and shared across the organization (e.g. Bartlett and Ghoshal, 1989; Hedlund, 1994; Gupta and Govindarajan, 2000; Tsai, 2001; Almeida and Phene, 2004, Cantwell and Mudambi, 2005). In this differentiated network of the corporation, there is a tendency for overseas subsidiaries to move from the role of "home-base exploiting"/ ""competence exploiting" to "home-base augmenting"/ ""competence augmenting" (Kuemmerle,

1999; Cantwell and Mudambi, 2005)[1]. An innovative subsidiary draws upon sources of knowledge located in the host country as well as in the home base (Zander, 1997; Frost, 2001) which enhances the competence of the entire corporation (Bartlett and Ghoshal, 1989; McEvily and Zaheer, 1999; Young and Tavares, 2004).

While there are separate studies of technology adoption and creation in multinational subsidiaries, little research has been conducted on their mutual relationships. Studies such as Kuemmerle (1999) and Cantwell and Mudambi (2005) distinguish the mandate of foreign subsidies as either technology adoption or technology creation. However, in the process of technology development, some subsidiaries may be involved in technology adoption and creation simultaneously. Technology adoption and creation can be positively associated with each other. Successful technology adoption improves a multinational subsidiary's technological capability and augments its knowledge base, which contributes to its ability to innovate and stimulates the creation of new technology. On the other hand, technology creation contributes to a subsidiary's technological capability, enabling it to have a greater capacity to absorb, circulate and utilize information. This leads to a greater demand for advanced technologies owned by other organizational units in the differentiated network of the MNE. Therefore, the first contribution of the paper is to explore the relationship between technology adoption and creation, helping us better understand organizational learning and innovation.

[1] Kuemmerle (1999) uses the terminology of "home-base exploiting" and "home-base augmenting". Cantwell and Mudambi (2005) apply the concepts of "competence exploiting" and "competence-creating". As competence comes from not only multinationals at home countries but also multinational subsidiaries in the rest of the world, we are more inclined to follow Cantwell and Mudambi (2005)'s terminology. However, as the focus of the paper is on technology, wherever appropriate, we will also use "technology exploiting" and "technology-creating".

Secondly, in this paper, we compare and contrast the determinants of technology adoption and creation in multinational subsidiaries. Multinational subsidiaries are embedded in a dual context of the MNE and the host environment. Being part of the multinational's network provides a subsidiary with an opportunity to access advanced knowledge, while residing in the host country exposes a subsidiary to knowledge and innovations of local systems and allows it to take advantage of the locational advantages (Almeida and Phene, 2004). Through interactions with these internal and external networks, a subsidiary's knowledge base is expanded, which increases its innovation output by providing economies of scale and scope in R&D. In addition, a subsidiary's strategies of entry, market orientation and autonomy are all important for technology acquisition from the parent and its own technology creation (Ghoshal and Bartleett, 1988; Belderbos, 2003; Almeida and Phene, 2004; Andersson et al. 2005). Do these determinants affect technology adoption in the same way as technology creation in multinational subsidiaries? An examination of these issues helps us understand sources of technological development in multinational subsidiaries and their competitiveness.

The empirical part of the study is based on a very unique panel data set covering 465 multinational subsidiaries in China for the period 1998-2005. Our results indicate that technology adoption affects technology creation, but the reverse relationship is not established. Business networks, corporate and subsidiary strategies and local competition have significantly different impacts on technology adoption and creation. The remainder of this paper is organized as follows. The next section reviews the relevant literature and develops hypotheses. After a description of the model, data and methodology, we discuss the empirical results. The final section concludes with a brief assessment of policy and managerial implications.

II. LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

Technology is always seen by an MNE as the key to its competitiveness in the world marketplace. The knowledge-based view of the firm emphasizes that the foundation of competitive advantage is formed by technology-based resources (Kogut and Zander, 1992). In the current highly competitive globalized world, the MNE's success and survival rest on its capability to effectively create in and efficiently transfer technology between subsidiaries. In an MNE's international expansion, its subsidiaries can ~~be~~ take the role of either "technology exploiting", or "technology-creating" or both. The MNE can transfer technology to its subsidiaries and the success of a subsidiary in its host market is in part determined by its ability to adopt the technology possessed by the MNE (Chen, 1996; Chung, 2001; Cui et al., 2006). In this case, the subsidiary becomes the MNE's agent for exploiting its ownership advantage (Rugman, 1982). Such an advantage enables the subsidiary to enjoy a superior competitive position in the local marketplace, particularly when the MNE is committed to developing a strong position in the host country (Delios and Beamish, 2001). A subsidiary may also act as a technology creator, conducting R&D to augment the MNE's existing knowledge base (Almeida and Phene, 2004; Cantwell and Mumdbai, 2005). There is now considerable evidence of the internationalization of R&D activities by MNEs (e.g. Kuemmerle, 1997; Frost, 2001; Feinberg and Gupta, 2004). Shortening product life cycle and increased global competition have driven MNEs to step up in their R&D efforts and MNEs increasingly recognize the distinctiveness of different countries/locations as sources of R&D and tap into and activate these dispersed knowledge sources as part of the organization's wider innovation programs (Frost, 2001).

Technology Adoption and Creation

Technology adoption and creation are ~~believed to be positively associated with~~mutually reinforcing each other. Successful technology transfer helps a firm facilitate fast learning, improve technological capability, and build up knowledge base (Kim, 1997). Firm level theories of technological development suggest that an increase of a firm's knowledge base significantly affects a firm's innovative ability (Ahuja and Katila, 2001). Tsai (2001) also argues that organization is a network arrangement and technology transfer among organizational units inside the network provides opportunities for mutual learning and inter-unit cooperation that contribute to innovative ability and stimulate the creation of new technology.

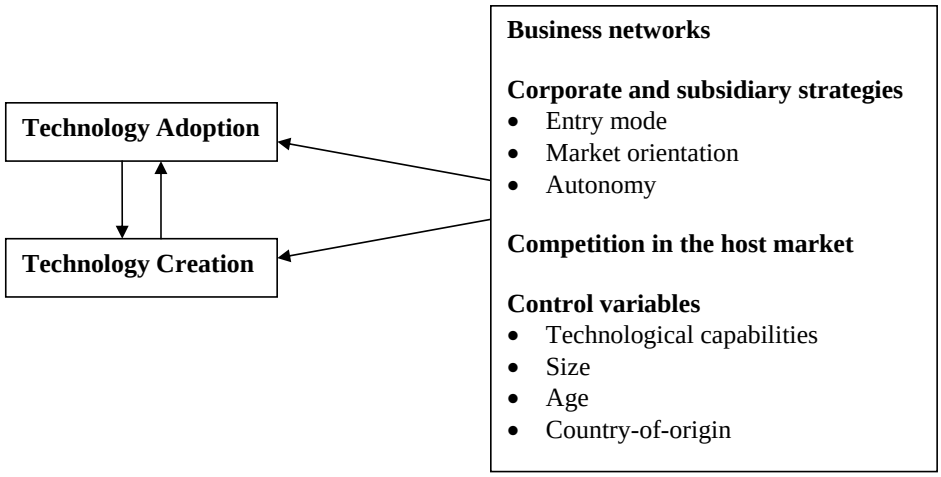
Equally, technology creation contributes to a multinational subsidiary's technological capability, enabling it to have a greater capacity to adopt new technology. An enhanced absorptive capacity leads to a greater demand of new knowledge (Cohen and Levinthal 1990; Tsai, 2001). As argued in network theory, knowledge is usually distributed unevenly across different organizational units. Multinational subsidiaries hence should pursue synergy through knowledge transfer and resource sharing.

Hypothesis 1: A multinational subsidiary's technology adoption and creation are positively related.

Figure 1 illustrates the relationship between technology adoption and creation. It also identifies the determinants of technology development behavior in a multinational subsidiary. Based on the existing literature three groups of factors are suggested to affect technology adoption and creation: business networks, corporate and subsidiary strategies and competition in the host

market. The rest of the section briefly reviews the relevant literature on the impacts of these factors at the subsidiary level and formulates the rest of our hypotheses.

Figure 1. An integrated framework of technology adoption and technology creation



Determinants of Technology Adoption and Creation

Business Networks

A multinational subsidiary is simultaneously embedded in two distinctive business contexts: internally within the MNE and externally in the host-country environment (Frost, 2001; Almeida and Phene, 2004). As a result, it has the potential to access resources from two distinct knowledge contexts. This differential exposure can influence technology adoption and creation of an MNE. In its internal networks, a subsidiary can, as part of the MNE, have the capacity to share knowledge within the MNE (Bartlett and Ghoshal, 1989). Such internal network embeddedness

can also be looked upon as a strategic resource influencing the subsidiary's capabilities in technology creation. Ghoshal and Bartlett (1988) argue that high levels of headquarter-subsidiary and inter-subsidiary communication facilitate creation, adoption, and diffusion of innovations by the subsidiary. Such communication makes the subsidiary aware of technology availability within the MNE, and encourages the subsidiary to obtain R&D and other technological support from the rest of the MNE, especially from the HQ. The provision of technology and managerial assistance by the MNE facilitates technology transfer and adoption (Lyles and Salk, 1996; Tsang, 2001).This enhances the subsidiary's ability to create its own innovations. Therefore,

Hypothesis 2a: R&D support from the MNE helps a multinational subsidiary's technology adoption and creation.

Human resources are considered to play a pivotal role in the successful adoption and creation of technology across international boundaries (Tung, 1994). Expatriates share experience and prior learning with other institutional members. Organizations acquire knowledge from others through 'grafting' individuals with special expatriates (Westney, 1988; Huber 1991; Lyles and Salk, 1996). These expatriates are in direct contact with local employees. They train local employees for management and operations and stay on to oversee the process. This is an effective means for subsidiaries to increase their knowledge stock, in particular when the relevant knowledge is tacit in nature, for technology assimilation and creation. Furthermore, expatriates often take a more direct/active role in defining technology structure of the overseas subsidiaries and in assessing new technologies in the context of the existing technology structure of the MNE.

Hypothesis 2b: Expatriates from the MNE help a multinational subsidiary's technology adoption and creation.

Network models also suggest the potential importance of inter-firm networks as sources of new technical knowledge (Freeman, 1991). Andersson et al. (2001) argue that a subsidiary's close business relationships with suppliers and customers, i.e. its external network, play a crucial role as a strategic resource for its competitiveness development. A multinational subsidiary can benefit from inter-firm knowledge flows in the host country via its social, professional, and technological relationships among firms (Porter, 1990). Resource interdependencies with this external context (as well as internal context) can enhance the development of knowledge and capabilities and the innovative ability of the multinational subsidiary (Andersson and Forsgren, 2000; Andersson et al., 2002; Almeida and Phene 2004).

Hypothesis 2c: External networks help a multinational subsidiary's technology creation.

Corporate and Subsidiary Strategies

Corporate and subsidiary strategies on entry, market orientation and autonomy are identified to be the determinants of technology adoption and creation.

Entry Strategy

The mode of entry ~~is a subsidiary characteristic~~ influenc<u>es</u>~~ing~~ technology adoption and creation. Transaction cost theory suggests that an MNE is more likely to transfer technology to its wholly

owned subsidiary (WOS) than joint venture (JV) as there is a risk of opportunism on the side of the foreign partner and of potential loss of proprietary technologies to a joint venture partner (Belderbos, 2003). This explains why a number of studies tend to confirm that an MNE planning to transfer advanced proprietary technologies prefer a WOS to a JV as the mode of entry into a foreign market (Mansfield and Romeo, 1980; Gatignon and Anderson, 1988; Gomes-Cassares, 1989; Hennart, 1991; Nakamura and Yeung, 1994; Mutinelli and Piscitello, 1998; Penner-Hahn, 1998; Wang et al. 2004).

On the other hand, transaction cost theory and resource-based views argue that a JV will be preferred if collaboration with the local partner permits access to complementary resources such as specific technologies and local market knowledge. Thus, there is potential value creation of combining distinct R&D capabilities of the multinational and the local partner in the case of a JV (Belderbos, 2003). Increased R&D capabilities will lead to increased technology creation. Following this line of argument, we develop the following hypothesis.

Hypothesis 3a: A wholly owned multinational subsidiary facilitates technology adoption while a joint venture promotes technology creation.

The above discussion focuses on the comparison between joint venture and wholly owned subsidiaries. To the best of our knowledge, there is no explicit study discussing the impact of foreign equity participation on technology creation in JVs. ~~However,~~ MNEs are expected to~~may~~ behave differently depending on the degree of equity participation in foreign subsidiaries[2]. If a multinational subsidiary has a higher degree of foreign equity participation, it is likely that the

[2] In this paper, a multinational subsidiary is defined as being either wholly or partially owned by an MNE.

MNE is more committed to its ~~the~~ subsidiaries~~y~~, and hence devotes more resources to transfer technologies~~y~~ to them~~is subsidiary~~. Desai et al. (2004) find evidence that majority-owned subsidiaries receive more intangible assets from their parent companies than do minority-owned subsidiaries.

However, high foreign equity participation implies low local equity involvement. ~~To the best of our knowledge, there is no study discussing foreign equity participation in JVs on technology creation~~Following our discussion leading to hypothesis 3a, while a multinational subsidiary with a high degree of foreign equity participation is more likely to adopt technology from its foreign parent, it may be less likely to create technology by itself. Low local equity participation will lead to a low contribution of distinct R&D capabilities from the local partner. ~~, but if a multinational subsidiary has a higher degree of foreign equity participation, then it may be more likely for this subsidiary to adopt technology from its foreign parent, and less likely for this subsidiary to create technology~~[3]~~. Zhao (2006) implies that in a poor institutional environment, a high level of control may enable an MNE to better substitute internal organization for external intellectual property rights (IPR) protection and take advantage of underutilized human capital without exposing itself to excessive risk, therefore a high level of foreign equity participation does not necessarily lower a multinational subsidiary's technology creation in a country with a poor institutional environment. Taking into account of these considerations, the following hypothesis can be formulated.~~

[3] There are different views on this relationship. For instance, Zhao (2006) implies that a high level of foreign equity participation does not necessarily lower a multinational subsidiary's technology creation in a country with a poor institutional environment. In such an environment, a high level of control may enable an MNE to better substitute internal organization for external IPR protection and take advantage of underutilized human capital without exposing itself to excessive risk.

~~*Hypothesis 3a: A wholly owned multinational subsidiary facilitates technology adoption while a joint venture promotes technology creation.*~~

Hypothesis 3b: Higher foreign equity participation leads to a ~~both~~a higher level of technology adoption, but a low level of technology ~~but a lower~~higher ~~level of technology~~ creation.

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In explanation of why MNEs are increasingly conducting R&D in countries such as China and India, Zhao (2006) argues that in a poor institutional environment, a high level of control may enable an MNE to better substitute internal organization for external intellectual property rights (IPR) protection and take advantage of underutilized human capital without exposing itself to excessive risk. The implication is that a high level of foreign equity participation does not necessarily lower a multinational subsidiary's technology creation in a country with weak IPR protection. This seems to be contradictory to our hypothesis 3b. Nevertheless, Zhao (2006) concludes "in the face of weak legal institutions, firms have to strategically internalize their knowledge-intensive activities, and only a small number of firms are able to do so."

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Market Orientation Strategy

Market orientation may affect a multinational subsidiary's technology adoption and creation. Local market-seeking subsidiaries are established to serve local customers. Hence, they are more likely to adapt products to local tastes and circumstances. On the other hand, export-oriented subsidiaries may be less attentive to the local market and therefore may have less incentive for any technological innovations related to local adaptation. But Belderbos (2003) argues that a high export intensity may imply that the multinational subsidiary has the responsibility for the regional

or world markets in a product area rather than a more limited responsibility for the local market. Such a subsidiary may be more likely to possess substantial R&D expertise, and hence can function as an 'international adaptor' site or even as an 'international creator' site (Hakanson and Nobel, 1993; Nobel and Birkinshaw, 1998).

Hypothesis 4: A multinational subsidiary with a high export intensity is more likely to be involved in technology adoption and creation.

Autonomy

Autonomy in decision-making is found to be associated with a multinational subsidiary's technology adoption and creation. Ghoshal and Bartlett (1988) show that, a subsidiary with a low level of local autonomy neither creates nor diffuses innovations, but tends to be an effective adopter of new products and processes created by the parent. If resources required for innovation are highly centralized by the parent, or if application of local slack resources at the subsidiary is highly controlled by the parent, then it is impossible for the subsidiary to develop new technology as the freedom to experiment is necessary for creating innovations (Mohr, 1969). In this case, the subsidiary heavily depends on the headquarters for technology adoption as it has neither the authority nor the capability to resist. On the other hand, a relatively autonomous subsidiary creates and diffuses more innovations but is comparatively more resistant in adopting innovation created elsewhere (Ghoshal and Bartlett, 1988).

Hypothesis 5: Autonomy in decision-making has a negative impact on technology adoption but a positive impact on technology creation.

Competition in the host market

It is recognized that host country characteristics affect a multinational subsidiary's behavior of technology adoption and creation (Ghoshal and Nohria, 1989). As Cui et al. (2006) indicate, when entering a highly competitive foreign market, an MNE faces the challenge of acquiring market share and establishing a competitive position in the market via its subsidiary. Adopting technologies transferred from the parent enables the subsidiary to 'improve product quality, adapt product design to local market demand, and reduce production costs and prices to compete for market share'. Thus, a positive impact is expected of the degree of local competition on the extent to which a subsidiary adopts technology from its parent[4]. The analysis of the relationship between local competition and technology adoption can be easily extended to that between local competition and technology creation. A high degree of competition in the host country may force a multinational subsidiary to conduct extensive R&D to create new technology so that its competitive position can be maintained. Put another way, 'local competition is another variable that can affect innovation' (Tsai, 2001).

Hypothesis 6: Competition in~~at~~ the host country positively affects a multinational subsidiary's technology adoption and creation.

Control Variables

In addition to the above factors, a number of variables related to subsidiary characteristics have been identified in the literature to be of significance in explaining technology adoption and

[4] This may be particularly true when a subsidiary is local market orientated.

creation. They include technological capabilities, size, age and country of origin, and they are introduced into our model as the control variables.

Technological capabilities are a critical factor in determining technology transfer (Kedia and Bhagat, 1988; Stock *et al*., 1996). The effectiveness of technology transfer depends largely on the absorptive capability of the receiver. As defined by Cohen and Levinthal (1990), absorptive capability is the 'ability to recognize the value of new external knowledge, assimilate it, and apply it to commercial ends'. To recognize, absorb and exploit new technology, a firm's own technological capabilities are essential. Technological capabilities are also important for technology creation. As argued by Tsai (2001), high absorptive capacity tends to be developed cumulatively by building on prior related knowledge. A firm with relevant prior knowledge is likely to have a better understanding of new technology that can generate new ideas and develop new products. Put another way, a firm with a high level of absorptive capacity is likely to harness new knowledge from various sources to help its innovative activities (Cohen and Levinthal, 1990).

It is generally believed that firm size can have a positive impact on both technology adoption and creation. Technology adoption is not a costless process. As first demonstrated by Teece (1976), the costs of international technology transfers are often considerable, ranging in his sample of 26 projects 2%-59% of total project costs. Thus, large firms usually have more resources for technology adoption. The same analysis can be applied to technology creation. Tsai (2001) suggests that large organizational units tend to have more resources with which to enhance their innovation and performance. Scale economies may favor R&D in large subsidiaries (Belderbos,

2003). In addition, larger units or affiliates may be better able to bargain with the headquarters for support for their business operations and innovation activities (Tsai, 2001; Belderbos, 2003).

The operation period or age of a multinational subsidiary normally implies experience in the host country (Young and Tavares, 2004). This experience is important for an effective transfer of technology. MNEs have to adapt to differing societal, political, economic, and technological regimes (Beamish, 1988) and to varying preferences among buyers, suppliers, and customers (Abrahamson and Fombrun, 1994) in their different host country markets. The experiential process develops specific knowledge about the foreign culture, the institutional environment, and the site in which the firm is investing (Barkema et al., 1996), and makes it easier to adapt existing capabilities in the local environment (Delios and Beamish, 2001**)**. The host-country experience also contributes to the development of new knowledge and capabilities, and this development influences a firm's strategy and performance (Kogut, 1983; Pennings et al., 1994; Barkema et al., 1996). This experience can stimulate innovative activities and knowledge generation (Barkema and Vermeulen, 1998).

The nationality of a MNE is also expected to affect its subsidiary's technology adoption and creation. For instance, developed countries are the world's leaders of technology. Therefore, more technology adoption and creation are expected in multinational subsidiaries from developed countries than those from developing countries. In addition to technological capabilities, the international experience and R&D strategy of MNEs affect technology transfer, adoption and creation (Belderbos, 2003). For instance, it is found that European MNEs were the most active in the internationalization of their R&D operations, followed by American firms and then Japanese firms (Bartlett and Ghoshal, 1991; Patel, 1996). The limited overseas R&D operations of

Japanese MNEs are due to their relative lack of experience as the latecomers in this regard (Westney, 1996; Belderbos, 1997, 2001) and their orientation towards manufacturability and the associated speed of new product introduction (Westney, 1993) which require a relatively strong geographical concentration of manufacturing, applied R&D, and engineering facilities near headquarters in Japan (Kenney and Florida, 1994; Westney, 1994; Belderbos, 2003).

DATA, MODEL AND METHODS

Sample

We test the hypotheses using survey data from foreign subsidiaries in China. A random sample was drawn from the lists of foreign invested firms in Beijing, Chongqing and Jiangsu Province in China. These three locations were chosen for two reasons. Firstly, because of resource constraints, only limited locations could be chosen. Secondly, these three locations may represent different levels of development in China. Beijing is the capital and one of the commercial centers of China. Jiangsu is a highly developed industrial and commercial region in China. According to Chinese Economic Annual Report 2005 (Chinese Industrial and Commercial Bureau, 2006), Jiangsu Province was the No. 2 inward FDI destination in China. Chongqing, located in the southwest of China, is the commercial and transportation centre in western China. Comparing with eastern regions, western regions are less developed. Since the Chinese government announced the western development program more than a decade ago, Chongqing has already become one of the fastest growing areas, and is the youngest metropolitan in China. It is the lead city that can represent the western China.

Taggart (1998) argues that a postal questionnaire can be the appropriate method of data collection for studying subsidiary roles or strategies because of resource constraint and generalizability of results. Extending this research strategy to a study on subsidiary knowledge transfer and creation, we pre-tested a draft research instrument via personal interview with chief executive officers or other senior managers of 14 multinational subsidiaries. The questionnaire was then modified and finalized. This pretest also allowed us to obtain insights into multinational subsidiaries in China, and provide an assessment of the questions' validity and the likely reliability of the data that will be collected (Saunders et al, 2003). The questionnaire was sent to 1223 multinational subsidiaries and 493 of them responded. This led to the response rate of as high as 40.3%. Among the respondents, 205 (41.6%) were the founders or chief executive officers, 188 (38.1%) were chief financial officers and the rest (20.3%) were senior human resource managers. ~~However, a~~A~~f~~ter thorough checking, 465 firms have provided valid data for the purpose of this research covering the period of 1998-2005. Because ~~some~~ subsidiaries were~~are~~ established in different years ~~during sample period~~, our dataset is an unbalanced panel.

Model and Measures

Based on the analytical framework developed in the literature review section, the following models for technology adoption and creation are specified:

(1) $$TA = \alpha_0 + \alpha_1 TC + \alpha_2 In\_RD\_Support + \alpha_3 em\_\exp at + \alpha_4 JV + \alpha_5 For\_equity + \alpha_6 Export\_Orient + \alpha_7 Autonomy + \alpha_8 Competiton + \gamma \mathbf{C}ontrol\_Variables$$

(2) $$TC = \beta_0 + \beta_1 TA + \beta_2 In\_RD\_Support + \beta_3 em\_\exp at + \beta_4 Ex\_RD\_Support + \beta_5 JV + \beta_6 For\_equity + \beta_7 Export\_Orient + \beta_8 Autonomy + \beta_8 Competiton + \delta \mathbf{C}ontrol\_Variables$$

The individual measurement items for all variables are listed in Table 1. The central concepts of the paper are technology adoption (TA) and technology creation (TC). To define whether a patent is "owned" by a subsidiary or by its parent, ~~in the questionnaire,~~ we asked the respondents two questions: ~~to the surveyed subsidiary:~~ (1) How many patents adopted in production are ~~transferred~~ from the headquarter or other subsidiaries? (2) How many patents are self-develop~~creat~~ed? Therefore, TA is measured by the number of~~referred to~~ patents developed and "owned" by the ~~parent company or another part of the~~ MNE group that were actually ~~being~~ used by~~in~~ the subsidiary ~~subsidiary's own production facilities~~, while TC is ~~referred~~measured by the number of ~~to~~ patents developed and "owned" by the ~~surveyed local~~ subsidiary itself.

Consistent with Simonin's (2004) division of resource-based learning capability into human and tangible support assets, we adopt two measures of technological capabilities: the number of employees with at least college degree (em_college) and R&D expenditure (tech_inpu). For variables of competition, technological gap, technical support in the network of multinationals, external networks and autonomy, senior managers in the subsidiaries were asked to answer questions on a 5- point Likert-type scale.

<Insert Table 1 here>

Methodology

Our survey allows us to use more direct measures of technology adoption and creation, i.e. the number of patents of the parent and sister subsidiaries applied by the receptive subsidiary in

China and the number of patents developed ~~owned~~ by the subsidiary itself in China. Using patent data has advantages over other input measures such as R&D expenditure. The latter do not reflect whether the acquired foreign technology has been internalized successfully and whether it has increased the recipient's technological capability. Firms may well have spent on the acquisition of technology, but fail to use it and integrate it to create new technologies. Hence, more R&D inputs do not guarantee the improvement of a firm's technological capability. On the other hand, there are some potential limitations to using patent data. First, not all innovations are patented or patentable. Second, the patent document usually contains extensive knowledge, while patent largely reflects codified knowledge not tacit knowledge. However, codified knowledge and tacit knowledge are closely linked and complementary (Mowery et al., 1996). Therefore, the number of ~~. Despite these,~~ patents ha~~s~~ve been widely used as an important indicator for innovation~~s~~ (e.g. Griliches, 1990; Almeida and Phene, 2004).

As patents are not produced with certainty, a Poisson process that describes events that happen independently and randomly in time is suitable to estimate a function of patents (Hausman et al. 1984). However, the Poisson model needs to meet the requirement of equality between its first two moment conditions. Because of the unobserved effects, such as the uncertainty inherent in undertaking R&D or patenting, a problem of 'overdispersion' may occur, whereby the conditional variance exceeds the conditional mean. In this case, a negative binomial model can be used to overcome the problem. As shown in Table 1, the variance of technology transfer and that of technology creation are substantially larger than the corresponding means. The distribution of both variables is displaying a sign of overdispersion. Therefore, we present results from a negative binomial model.

Because our data are of panel structure, the estimation procedure uses a random effects formulation to control for the unobserved subsidiary-specific effect for two considerations. First, since variables such as entry, nationality and foreign equity share are constant within group, a fixed effects model, which focuses on year-by-year variation, would not produce the desired information. Secondly, a fixed effects model could produce noisy results when the explanatory variables are slow moving. Therefore, the use of the random effects model allows us to utilize the panel structure of our data set in a more efficient way.

Since it is expected that there can be a bi-directional relationship between technology adoption and creation, we use the Wu-Hausman test to test for endogeneity of technology creation (adoption) in the statistical model of technology adoption (creation) in order to determine whether a simultaneous system of equations (1) and (2) should be estimated. If there exists a two-way relationship, the estimation of individual equations for technology adoption and technology creation respectively will lead to biased results.

EMPIRICAL RESULTS

The regression results are presented in table 2. According to the Wald test statistics, the negative binomial panel regression with a random effects approach appears to fit both models extremely well. The likelihood ratio (LR) test, test of the overdispersion, indicates that the standard Poisson distribution is inappropriate, justifying our use of a negative binomial model. The Wu-Hausman test for endogeneity suggests that there is an interactive relationship between technology adoption and creation, but the direction is one-way, from technology adoption to creation only~~, not vice versa~~. Hence, we employ a two-stage approach to estimate the equations. The first step is to

obtain predicted values of the dependent variables from an equation including all the determinants of technology adoption and creation on the right-hand side. Then we use the predicted variables in the corresponding equations of technology adoption and creation.

<Insert Table 2 here>

Hypothesis 1: Relationship between technology adoption and creation

From table 2, we can find that technology creation has the expected positive sign, but is statistically insignificant. On the other hand, technology transfer not only has the expected positive sign, but also is statistically significant. Put another way, while technology adoption significantly affects technology creation, the latter is not a significant determinant of the former. Thus, hypothesis 1 is only partially supported. Our tentative explanation is as follows. Technology adoption may well enhance a subsidiary's technological competences and ability to innovate. However, once successful in innovations, the subsidiary will have a high level of slack resources such as R&D and manufacturing capabilities. According to Ghoshal and Bartlett (1988), slack resources may impede adoption because "local search activities promoted by slack may identify valid reasons why direct adoption of innovations created in other environments is not appropriate".

Hypothesis 2: Business networks

Hypothesis 2a is supported for the technology creation equation[5] but not in technology adoption equation as the corresponding variable In_RD_Support is statistically significant in the formerlatter, but not in the latterformer. Put another way, the internal business networks only have a positive impact on technology creation, but not adoption. This result is consistent with some technology creation studies such as Almeida and Phene (2004) but not with some studies of technology transfer, e.g. Lyles and Salk (1996) and Tsai (2001). Hypothesis 2b is not supported at all, because the variable em_expat is statistically insignificant in both equations.

Table 2 shows that the impact of external networks on technology creation is statistically insignificant. Thus, hypothesis 2c is not supported. This may be related to the nature of China as a host emerging or developing country. The technological capabilities of local Chinese firms are in general not high, and multinational subsidiaries may not be able to significantly benefit from their links with these firms in terms of technology creation. This may explain why our results are inconsistent with Andersson and Forsgren (2000), Andersson et al. (2001) and Almeida and Phene (2004).

Hypothesis 3: Entry modestrategy

From table 2, it is apparent that hypothesis 3a is not supported as the dummy variable "JV" is statistically insignificant in both regressions. In other words, a multinational subsidiary's decision on technology adoption and creation is not affected by its entry mode of being WOS or JV. This result is inconsistent with existing studies cited in the literature review on this topic and with

[5] Please note that, as shown in Table 1, the questionnaire is designed in such a way, 1 = very helpful; and 5 = very unhelpful. Hence we expect a negative sign for variable In_RD_Support.

Deng (2001) who notes that a large number of foreign investors in China have chosen wholly-owned subsidiary over joint venture in order to avoid the possibility of loss of control over proprietary technology and know-how and long-term competitive advantages.

However, as the dummy treats all non-100% foreign owned subsidiaries as one category – joint venture, any possible differences within the JV category are blurred. For instance, a subsidiary with 90% foreign ownership may well behave differently from a subsidiary with only 25% foreign ownership. Hence we employ another measure of foreign ownership, i.e. foreign equity share. As can be seen in table 2, this variable is positive and statistically significant in the technology adoption regression and negative and statistically significant in the technology creation regression. Thus, hypothesis 3b is ~~partially~~ supported. This result is interesting. It implies that, with foreign ownership increasing, a multinational subsidiary will be more willing to receive new technologies from its parent (so will be the parent to transfer them) as high equity share increases the control of proprietary technology ~~controlled~~ by the foreign partner. With foreign ownership increasing, a subsidiary reduces the amount of distinct R&D capabilities contributed by the local partner, which can have a negative impact on subsidiary innovations. A wholly-owned subsidiary is only one special case in this whole range of ownership arrangement.

Hypothesis 4: Market orientation

As table 2 shows, a multinational subsidiary's export intensity is negatively associated with ~~its~~ technology adoption from its parent, but it has a significantly positive impact on technology creation in the multinational subsidiary in China. Thus, hypothesis 4 is partially supported. In an emerging economy like China, multinational subsidiaries are more likely to see it as an export

base of labor-intensive products. This is consistent with the fundamental comparative advantage this country possesses. In this case, the products exported by a subsidiary require technologies which should be as compatible with China's natural endowments of large-labor force as possible. Technologies directly adopted from the parent may not be very suitable. Instead, technologies created by the subsidiary may be more relevant. Thus, a more export-oriented multinational subsidiary may be involved in less technology adoption, but more technology creation.

Hypothesis 5: Autonomy in R&D

Autonomy appears to be insignificant in both technology adoption and creation equations. Therefore, hypothesis 5 is not supported. One possible explanation is that, although multinational subsidiaries are assigned autonomy by their parents, there might be a lack of subsidiary initiative to make best use of the decision-making power in order to be actively engaged in technology adoption and creation. As defined by Birkinshaw (2000), subsidiary initiative is 'undertaken with a view to expanding the subsidiary's scope of responsibility'. With an initiative to develop technological capabilities, autonomy in R&D decision-making could be effectively utilized to proactively promote technology adoption and creation.

Hypothesis 6: Competition in the host market

As demonstrated in table 2, the coefficient on competition is statistically significant in the technology adoption equation, but with an unexpected sign, indicating that when the degree of local competition is high, the multinational subsidiary's technology adoption is low[6]. Hypothesis

[6] Please note that, as shown in Table 1, the questionnaire is designed in such a way, 1=very fierce and 5 = not fierce at all. Hence we expect a negative sign for variable *competition*.

6 is not supported in this equation. In contrast, hypothesis 6 is supported in the technology creation equation as the competition variable has the expected sign and is statistically significant. This is different from Tsai (2001) where the impact of competition on business unit innovation is insignificant. Our tentative explanation of the above results is that this may be related to China's weak intellectual property protection. When local competition is severe, MNEs may be less willing to transfer their state-of-art technologies to China because they worry about the issues of illegal copying, but they may be more willing to encourage their subsidiaries to develop products and processes with indigenous features.

Control Variables

As mentioned earlier, our control variables include technology capability, subsidiary size, age, and country of origin. Two measures of technological capabilities are used: the number of employees with at least college degree (em_college) and R&D expenditure (tech_inpu). Both have the expected signs and are statistically significant in the technology creation regression, but are not statistically significant in the technology adoption regression. The results tend to indicate that both human and tangible resources in multinational subsidiaries are more oriented towards technology creation than technology adoption. The confirmed role of human resources and R&D expenditure (tangible support assets) in technology creation agrees with Tasi (2001). As the subsidiary's own technological capabilities do not seem to affect technology adoption, we wonder whether a subsidiary's internal technology gap (the level of technological capabilities relative to the parent and other sister subsidiaries) and external technology gap (the level of technology relative to the local competitors) affect its technology adoption. An MNE would transfer technologies to its subsidiaries if the internal technological gap is large, i.e. Tech_gap1 is

expected to be positive. On the other hand, a narrow external technology gap should give the MNE a reason to bring in new technology (Kokko and Blomstrom, 1995). Therefore, Tech_gap2 is also expected to be positive. As shown in table 2, only Tech_gap1 is statistically significant with the expected positive sign. This indicates that the MNE's strategy for technology transfer is more often based on its recognition of the internal rather than external technology gap.

Table 2 shows that subsidiary size is positive but statistically insignificant in determining technology adoption, and is negative and statistically significant in determining technology creation. We do not think that the results are a surprise as the empirical studies have so far provided mixed results on the relationships between subsidiary size and its technology adoption and creation.

Similar to a number of existing studies, we use age to control for the impact of subsidiary experience in the host market. Here we also include squared age to see whether there is a diminishing effect associated with experience. Subsidiary age is found to have an opposite effect on technology adoption and creation. When the subsidiary grows older, there is less technology adoption but more technology creation, but the negative effect of age on technology adoption does diminish over time.

As for nationality, our results show that there is no significant difference in terms of technology creation in multinational subsidiaries of different country of origin, except in those from other Asian economies than Japan, Hong Kong, Macao and Taiwan that appear to have developed significantly fewer new technologies.

Table 2 also shows that multinational subsidiaries from Japan and EU are more likely to adopt technologies from their parents and sister subsidiaries than those from other economies such as the United States, Australia and Hong Kong, Macao and Taiwan. This does not fully agree with Bartlett and Ghoshal's (1991) and Patel's (1996) observation that American firms are more active in the internationalization of their R&D operations than Japanese firms. One possible reason is that our data are much more recent which are able to demonstrate that Japanese MNEs are now already experienced and rather active in overseas expansion of R&D.

To summarize, our hypothesis 1 suggests that technology adoption and creation should reinforce each other, but our result shows that technology adoption positively affects technology creation while the reverse relationship is not established. Thus, this key hypothesis is only partially supported. In addition, business networks and corporate and subsidiary strategies have significantly different impacts on technology adoption and creation. Specifically, our hypothesis 2 argues both internal and external networks should positively affect technology adoption and creation. Our results indicate that internal R&D support positively affects technology adoption, but not technology creation, while expatriates from the parent to the subsidiary (the other aspect of internal business networks), and external business networks do not seem to affect technology adoption or creation. Hence, only hypothesis 2a is partially supported.

Hypothesis 3 is that a wholly owned multinational subsidiary facilitates technology adoption while a joint venture promotes technology creation, and that high~~er~~ foreign equity participation leads to a ~~a~~ high~~er~~ level~~s~~ of technology adoption ~~but a lower level of~~ but~~and~~ a low level of technology creation. Our results show that entry mode has no significant impact, but foreign equity participation positively affects technology adoption and negatively affects technology

creation. Thus, hypothesis 3 is ~~largely~~ supported only in the latter case. According to hypothesis 4, export orientation should positively impact technology adoption and creation. This hypothesis is only partially supported as our results show that export orientation has a negative impact on technology adoption but a positive impact on technology creation.

Hypothesis 5 suggests that autonomy in decision-making has a negative impact on technology adoption but a positive impact on technology creation. Nevertheless, this hypothesis is not supported by the Chinese evidence as autonomy is not statistically significant at all. Finally, hypothesis 6 argues that competition in the host country positively affects a multinational subsidiary's technology adoption and creation, but it is only partially supported as it has a negative impact on technology adoption but a positive one on technology creation.

DISCUSSIONS AND CONCLUSIONS

Technology adoption and creation in subsidiaries are essential for MNEs to enhance their competitiveness in the global market. Although these two important phenomena have been investigated in separate studies, little is known about their relationships. The current paper has aimed to fill in this research gap. Six hypotheses have been developed and tested on data collected from 465 multinational subsidiaries in China for the period 1998-2005.

Our empirical results only partially support the hypotheses for several reasons. Firstly, this may be due to the unique institutional, economic and technical characteristics of China as an emerging host economy. For instance, the unexpected sign of competition on technology adoption may be

caused by China's weak intellectual property protection. The different impact of export orientation on technology creation and adoption may be caused by multinational subsidiaries' efforts to create compatible technologies with China's natural endowments of cheap labor force rather than rely on technologies from the parents for their production. Furthermore, the insignificant impact of external business networks on technology creation may be due to the fact that multinational subsidiaries do not benefit from their links with local Chinese firms *in terms of innovation* because these local firms as a whole do not possess strong technological competences. However, this does not mean that multinational subsidiaries can learn nothing from local Chinese firms. On the contrary, both case studies and statistical evidence suggest~~s~~ that spillovers of Chinese firms' local knowledge and indigenous technologies positively affect the *productivity* of multinational subsidiaries in Chinese manufacturing (Wei at al. 2008).

Secondly, some widely recognized hypotheses may need to be refined in order to more accurately theorize business relationships. For instance, the insignificant impact of entry mode may be due to the simple (naïve) division of a whole series of ownership arrangements into two categories only. Foreign equity participation may be a better variable to be examined.

The data set of this research is very unique. It contains mostly ~~the~~ hard statistics such as the number of patents, share of employees with college education, R&D expenditure, entry mode, foreign equity share and country of origin, but also some self-assessment based data such as R&D support, internal and external links and subsidiary autonomy. While the second type of data is as important as the hard statistics for the current research, the limitation is that it is based on subsidiary memory of its operation history. While every effort is made to ensure the retrospective to be as accurate as possible (e.g. comparing responses with all available historical data), it is no

substitute for truly longitudinal research. As a result, caution should be used when interpreting the relevant results.

The results from this study bear a number of policy and managerial implications. Firstly, institutional improvements in areas such as intellectual property protection enhance the impact of healthy competition and hence stimulate technology adoption and creation. Secondly, as foreign equity participation is positively related to technology adoption but negatively related to technology creation, inward FDI policy can be selective. Although technologies adopted by multinational subsidiaries may gradually spill over to local firms, the encouragement of local equity participation in multinational subsidiaries is an effective channel to promote technology creation in the host economy. Thirdly, in order to effectively adopt technology, subsidiary managers need to pursue R&D support from their parent firms. Finally, in order to effectively create technology, subsidiary managers need to be actively involved in technology adoption. By so doing, the international competitiveness of not only the subsidiaries but also their parent firm can be significantly enhanced.

One important theoretical implication is that we should not take it granted that seemingly common factors of technology adoption and creation would affect these two important phenomena in the same directions. As one aspect of future research, a comparative study can be conducted to see if the findings in China can be generalized to other countries, especially those transition economies.

REFERENCES

Abrahamson, E. & Fombrun, C.J. 1994. Macrocultures: Determinants and consequences. *Academy* of *Management Review*, 19: 728-755.

Almeida, P. & Phene, A. 2004. Subsidiaries and knowledge creation: the influence of MNC and host country on innovation. *Strategic Management Journal*, 25: 847-864.

Andersson, U., Bjorkman, I. & Forsgren, M. 2005. Managing subsidiary knowledge creation: The effect of control mechanisms on subsidiary local embeddedness. *International Business Review*, 14: 521–538.

Andersson U. & Forsgren, M. 2000. In search of centers of excellence: network embeddedness and subsidiary roles in multinational corporations. *Managemen*t *International Revie*w 40(4): 329–338.

Andersson, U., Forsgren, M. & Holm, U. 2001. Subsidiary embeddedness and competence development in MNCs - A multi-level analysis. *Organization Studies* 22(6): 1013-1034.

Andersson, U., Forsgren, M. & Holm, U. 2002. The strategic impact of external networks: subsidiary performance and competence development in the multinational corporation. *Strategic Management Journal* 23: 976-996.

Ahuja, G. & Katila, R. 2001. Technological acquisitions and the innovation performance of acquiring firms: a longitudinal study. *Strategic Management Journal* 22(3): 197-220.

Barkema, H.G., Bell, J.H.J. & Pennings, J.M. 1996. Foreign entry, cultural barriers and learning. *Strategic Management Journal*, 17: 151-166.

Barkema, H.G. & Vermeulen, F. 1998. International expansion through start-up or acquisition: A learning perspective. *Academy of Management Journal*, 41: 7-26.

Bartlett, C.A. & Ghoshal, S. 1989. *Managing across borders: the transnational solution. Boston.* MA: Harvard Business School Press.

Bartlett, C.A. & Ghoshal, S. 1991. Managing innovation in the transnational corporation. In C.A. Bartlett, Y. Doz & G. Hedlund (Eds.), *Managing the Global Firm*. London: Routledge.

Beamish, P.W. 1988. *Multinational joint ventures in developing countries.* London and New York: Routledge.

Belderbos, R.A. 1997. *Japanese electronics multinationals and strategic trade policies*. Oxford: Oxford University Press.

Belderbos, R.A. 2001. Overseas innovations by Japanese firms: an analysis of patent and subsidiary data. *Research Policy*, 30(2): 313–332.

Belderbos, R.A. 2003. Entry mode, organizational learning, and R&D in foreign affiliates: Evidence from Japanese firms. *Strategic Management Journal*, 24: 235-259.

Birkinshaw, J. 2000. *Entrepreneurship in the global firm*. London: Sage Publications.

Cantwell, J. & Mudambi, R. 2005. MNE competence-creating subsidiary mandates. *Strategic Management Journal*, 26: 1109-1128.

Cantwell, J. & Santangelo, G.D. 2006. The boundaries of firms in the new economy: M&As as a strategic tool toward corporate technological diversification. *Structural Change and Economic Dynamics*, 17: 174-199.

Chen, E. 1996. *Transnational corporations and technology transfer to developing countries*, UNCTAD, Transnational Corporations & World Development. London: Thomson Business Press.

Chung, W. 2001. Identifying technology transfer in foreign direct investment, influence of industry conditions and investing firm motives. *Journal of International Business Studies*, 32(2): 211– 229.

Cohen W.M. & Klepper, S. 1996. A reprise of size and R&D. *Economic Journal*, 106: 925–951.

Cui, A.S., Griffith, D.A., Cavusgil, S.T. & Dabic, M. 2006. The influence of market and cultural environmental factors on technology transfer between foreign MNCs and local subsidiaries: A Croatian illustration *Journal of World Business*, 41: 100–111.

Deng, P. 2001. WFOEs: The Most Popular Entry Mode into China. *Business Horizons*, July-August, 63-72.

Delios, A. & Beamish, P.W. 2001. Survival and ~~Profitability~~profitability: The ~~Roles~~ roles of ~~Experience~~ experience and ~~I~~intangible a~~A~~ssets in f~~F~~oreign s~~S~~ubsidiary p~~P~~erformance, *Academy of Management Journal*, 44(5), 1028-1038.

Desai, M.A., Foley, C.F. & Hines, J.R. Jr. 2004. The costs of shared ownership: Evidence from international joint ventures, *Journal of Financial Economics*, 73(2), 323-374.

Dyer, J.H. & Nobeoka, K. 2000. Creating and managing a high-performance knowledge-sharing network: The Toyota case. *Strategic Management Journal*, 21(3): 345–367.

Feinberg, S.E. & Gupta, Anil K. 2004. Knowledge spillovers and the assignment of R&D responsibilities to foreign subsidiaries. *Strategic Management Journal*, 25(8/9): 823-845

Freeman, C. 1991. Networks of innovators: a synthesis of research issues. *Research Policy*, 20: 499-514.

Frost, Tony S. 2001. The geographic sources of foreign subsidiaries' innovations. *Strategic Management Journal*, 22(2): 101-123.

Gatignon, H. & Anderson, E. 1988. The multinational corporation's degree of control over foreign subsidiaries: an empirical test of a transaction cost explanation. *Journal of Law, Economics, and Organization*, 4(2): 305–336.

Ghoshal, S. & Bartlett, C.A. 1988. Creation, adoption and diffusion of innovations by subsidiaries of multinational corporations. *Journal of International Business Studies*, 19(3): 365–388.

Ghoshal, S. & Nohria, N. 1989. Internal differentiation within multinational corporations. *Strategi*c *Managemen*t *Journal*, 10(4): 323–337.

Gomes-Cassares, B. 1989. Ownership structures of foreign subsidiaries: theory and evidence. *Journal of Economic Behavior and Organization*, 11: 1–25.

Griliches, Z. 1990. Patent statistics as economic indicators: a survey, *Journal of Economic Literature* 28: 1661–1707.

Gupta, A. K., & Govindarajan, V. 2000. Knowledge flows within multinational corporations, *Strategic Management Journal*, 21**:** 473-96.

Hakanson, L. & Nobel, R. 1993. Determinants of foreign R&D in Swedish multinationals. *Researc*h *Policy*, 22: 397–411.

Hausman, J., Hall, B. & Griliches, Z. 1984. Econometric models for count data with an application to the patents–R&D relationship. *Econometrica* 52: 909–938

Hedlund, G. 1994. A model of knowledge management and N form corporation, *Strategic Management Journal*, 15: 73–90.

Hennart, J.F. 1991. The transaction costs theory of joint ventures: an empirical study of Japanese subsidiaries in the United States. *Managemen*t *Science*, 37: 483–497.

Huber, G.P. 1991. Organizational learning: The contributing processes and the literatures. *Organization Science*, 2(1): 88-1 15.

Hymer, S.H. 1976. *The International Operations of National Firms, a Study of Direct Foreign Investment*. Cambridge: MIT Press.

Kedia, B.L. & Bhagat, R.S. 1988. Cultural constraints on transfer of technology across nations: implications for research in international and comparative management. *Academy of Management Review*, 13(4): 559–571.

Kenney, M. & Florida, R. 1994. The organization and geography of Japanese R&D: results from a survey of Japanese electronics and biotechnology firms. *Researc*h *Policy*, 23: 305–323.

Kim, L. 1997. The dynamics of Samsung's technological learning in semiconductors, *California Management Review*, 39(3): 86–100.

Kogut, B. 1983. Foreign direct investment as a sequential process. In C. P. Kindleberger (Ed.), *The Multinational Corporations in the 1980s:* 147-167. Cambridge. MA: MIT Press.

Kogut, B., & Zander, U. 1992. Knowledge of the firm, combinative capabilities, and the replication of technology. *Organization Science*, 3: 383-397.

Kokko, A. & Blomstrom, M. 1995. Policies to encourage inflows of technology through foreign multinationals, *World Development*, 23(3): 459-468.

Lall, S. 1993. Promoting technology development: the role of technology transfer and indigenous effort. *Third World Quarterly,* 14(1): 95-108.

Lyles, M.A. & Salk, J.E. 1996. Knowledge acquisition from foreign parents in international joint ventures: An empirical examination in the Hungarian context. *Journal of International Business Studies*, 27(5): 877-903.

Mansfield, E. & Romeo, A. 1980. Technology transfer to overseas subsidiaries by US based firms. *Quarterly Journal of Economics*, 95(4): 737–750.

McEvily, B. & Zaheer, A. 1999. Bridging ties: a source of firm heterogeneity and competitive capabilities. *Strategic Management Journal*, 20, 1133–1156.

Minbaeva, D., Pedersen, T., Bjo¨rkman, I., Fey, C.F. & Park, H.J. 2003. MNC knowledge transfer, subsidiary absorptive capacity, and HRM. *Journal of International Business Studies*, 34: 586-599.

Mohr, L.B. 1969. Determinants of innovation in organizations. *American Political Science Review*, 63: 111-136.

Mowery, D.C., Oxley, J.E. & Silverman, B.S. 1996. Strategic Alliances and Interfirm Knowledge Transfer. *Strategic Management Journal*, 17: 77-91.

Mutinelli, M. & Piscitello, L. 1998. The entry mode choice of MNEs: an evolutionary approach. *Researc*h *Policy*, 27: 491–506.

Nakamura, M. & Yeung, B. 1994. On the determinants of foreign ownership shares: evidence from U.S. firms' joint ventures in Japan. *Managerial and Decision Economics*, 15: 96–106.

Nobel, R. & Birkinshaw, J. 1998. Innovation in multinational corporations: control and communication patterns in international R&D operations. *Strategi*c *Managemen*t *Journal*, 19(5): 479–496.

Patel, P. 1996. Are large firms internationalizing the generation of technology? Some new evidence. *IEE*E *Transaction*s *o*n *Engineerin*g *Management*, 43(1): 41–47.

Penner-Hahn, J.D. 1998. Firm and environmental influences on the mode and sequence of foreign research and development activities. *Strategi*c *Managemen*t *Journal*, 19(2): 149–168.

Penning, J.M., Barkema, H.G. & Douma, S.W. 1994. Organizational learning and diversification. *Academy of Management Journal*, 37: 608-640.

Porter, M. 1990. *The Competitive Advantage of Nations*. Free Press: New York.

Rugman, A.M. 1982. *New Theories of the Multinational Enterprise*. New York: St. Martin's.

Saunders, M., Lewis, P. and Thornhill, A. 2003. *Research Methods for Business Student*, 3rd ed., Prentice Hall: London.

Simonin, B.L. 1999. Ambiguity and the process of knowledge transfer in strategic alliances. *Strategic Management Journal*, 20(7): 595–623.

Simonin, B.L. 2004. An empirical investigation of the process of knowledge transfer in international strategic alliances. *Journal of International Business* Studies, 35(5): 407-427.

Stock, G.N., Greis, N.P. & Dibner, M.D. 1996 Parent-subsidiary communication in international biotechnology R&D. *IEEE Transactions on Engineering Management,* 43(1): 56–67.

Taggart, J. H. 1998. Strategy shifts in MNC subsidiaries. *Strategic Management Journal*, 19, 663–681.

Teece, D.J. 1976. *The Multinational Corporation and the Resource Cost of International. Technology Transfer*. Cambridge: Ballinger Publishing Co.

Tsai, W. 2001. Knowledge transfer in intraorganizational networks: effects of network position and absorptive capacity in business unit innovation and performance. *The Academy of Management Journal*, 44(5): 996-1004.

Tsai, W. & Ghoshal, S. 1998. Social capital and value creation: The role of intrafirm networks. *Academy of Management Journal*, 41(4): 464-476.

Tsang, E.W.K. 2001. Managerial learning in foreign-invested enterprises of China, *Management International Review*, 41(1): 29–51.

Tung, Rosalie L. 1994. Human resource issues and technology transfer. *International Journal of Human Resource Management*, 5(4): 807-825.

United Nations Conference on Trade and Development (UNCTD) 2005. *World Investment Report: Transnational Corporations and the Internationalization of R&D*. United Nations, New York and Geneva.

Wang, P., Tong, T.W. & Koh, C.P. 2004. An integrated model of knowledge transfer from MNC parent to China subsidiary. *Journal of World Business*, 39: 168-182.

Wei, Y. & Liu, X. 2006. Productivity spillovers from R&D, Exports and FDI in China's manufacturing sector. *Journal of International Business Studies*, 37(4): 544-557.

Wei, Y., Liu, X. & Wang, C. 2008. Mutual productivity spillovers between foreign and local firms in China, *Cambridge Journal of Economics*, Accessed online on January 3, 2008.

Westney, D.E. 1988. Domestic and foreign learning curves in managing international cooperative strategies. In E.J. Contractor & P. Hrange (Eds.) *Cooperative strategies in International Business*: 339-346. Lexington: Lexington, Mass.

Westney, D.E. 1993. Cross-Pacific internationalization of R&D by U.S. and Japanese firms. *R&D Management*, 23(2): 171–181.

Westney, D.E. 1994. The evolution of Japan's industrial research and development. In M. Aoki & R. Dore (Eds.) *The Japanese firm*: *The Sources of Competitive Strength*: 154–177. Oxford: Oxford University Press.

Westney, D.E. 1996. Japanese multinationals in North America. In L. Eden (Ed.) *Multinationals in North America*: 253–275. Calgary, Alberta: University of Calgary Press.

Young, S. & Tavares A.T. 2004. Centralization and autonomy: back to the future, *International Business Review*, 13, 215–237.

Zahra, S. & George, G. 2002. Absorptive capacity: a review, re-conceptualization and extension. *Academy of Management Review*, 27(2): 185–302.

Zander, I. 1997. Technological diversification in the multinational corporation: historical trends and future prospects. *Research Policy*, 26(2): 209-227.

Zhao, M. 2006. Conducting R&D in countries with weak intellectual property rights protection, *Management Science*, 52(8): 1185-1199.

Table 1 Measure of Variables and Descriptive Statistics

Variables	Expected sign	Description	Obs	Mean	s.d.
Technology adoption(TA)		Number of patents adopted from the parent and sister subsidiaries	2380	3.670	11.893
Technology creation(TC)		Number of self developed patents	2382	2.731	10.066
Internal Business Networks (In_RD_Support)	-	"In_RD_Support: to what extent do the parent firm and other sister subsidiaries provide R&D support?" 1 = Very helpful…, 5 = Very unhelpful.	2379	1.799	0.734
em_expat	+	Number of expatriates	2383	7.773	14.283
External Business Networks (Ex_RD_Support)	-	"Ex_RD_Support: to what extent, do local cooperative partners provide R&D support?" 1 = Very helpful…; 5 = Very unhelpful	2380	2.351	0.600
JV	+/-	1 = joint venture; 0 = wholly owned subsidiary	3451	0.613	0.487
Foreign equity (For_equity)	+	Share of foreign equity in the subsidiary	3451	67.163	29.003
Export orientation (Export_Orient)	-	Share of exports in total sales	2378	27.995	37.097
Autonomy	+	"Autonomy: who makes decision on subsidiary's R&D?" 1 = the subsidiary; 0 = the parent makes decision.	2379	0.695	0.460
Competition	-	"Competition: what is the level of competition with local Competitors?" 1 = very fierce, …, 5 = not fierce at all	2380	2.144	0.855
em_college	+	the number of employees with at least college degree	2381	104.508	195.448
tech_inpu	+	Subsidiary's R&D expenditure	2374	1645.457	7681.939
Technology capability1 (TECH_GAP1)	+	"TECH_GAP1: what is the technological level of the subsidiary relative to the parent and other sister subsidiaries?" 1 = very advantageous, …, 5 = very disadvantageous.	2379	3.326	1.064
Technology capability2 (TECH_GAP2)	+	"TECH_GAP2: what is the technological level of the subsidiary relative to local Competitors?" 1 = very advantageous, …, 5 = very disadvantageous.	2379	2.267	0.904
Size	+/-	Total capital	2376	16846.09	77943.78

Age	+/-	Number of years of operation up to 2006	2207	5.714	3.597
Age^2	+/-	Squared Age	2207	45.581	50.761
US		1 = US-invested firms; 0 = otherwise	3451	0.164	0.371
Japan		1 = Japanese-invested firms; 0 = otherwise	3451	0.134	0.341
Canada		1 = Canadian-invested firms; 0 = otherwise	3451	0.020	0.141
Australia		1 = Australian-invested firms; 0 = otherwise	3451	0.014	0.118
EU		1 = EU-invested firms; 0 = otherwise	3451	0.185	0.388
HMTS		1 = Hong Kong, Macao, Taiwan and Singapore-invested firms; 0 = otherwise	3451	0.371	0.483
Asia		1 = Other Asian-invested firms; 0 = otherwise	3451	0.079	0.270

Table 2: Negative Binomial Panel Regression, Random Effects

Hypothesis	*Variable*	*Expected sign*	*Technology transfer (TA)*	*Technology creation (TC)*
H1: Technology creation	TC	+	0.787	
			(0.498)	
H1: Technology adoption	TA	+		0.772**
				(0.327)
H2a: Internal Networks	In_RD_Support	-	0.071	-0.101*
			(0.066)	(0.053)
H2b: Internal Networks	em_expat	+	3.543E-04	0.002
			(0.006)	(0.005)
H2c: External Networks	Ex_RD_Support	-		0.032
				(0.058)
H3a: Entry Mode	JV	+	0.333	0.006
			(0.492)	(0.551)
H3b: Foreign equity share	For_equity	+	0.024***	-0.024***
			(0.008)	(0.009)
H4: Export orientation	Export_Orient	+	-0.010*	0.011***
			(0.005)	(0.002)
H5: Autonomy	Autonomy	+	-0.026	-0.021
			(0.074)	(0.072)
H6: Competition	Competition	-	0.283**	-0.302***
			(0.087)	(0.075)
Technology capability	em_college	+	4.716E-04	4.04E-04**
			(9.096E-04)	(6.942E-04)
	tech_inpu	+	-7.74E-06	1.21E-05**
			(8.16E-06)	(5.24E-06)
	Tech_gap1	+	0.105***	
			(0.040)	
	Tech_gap2	+	0.019	
			(0.098)	
Size	Size	+	2.54E-06	-3.51E-06***
			(2.11E-06)	(7.63E-07)
Age	Age	+	-0.144***	0.155***
			(0.037)	(0.041)
	Age^2	+/-	0.004***	-0.003*
			(0.001)	(0.002)
Country-of-origin	US		0.557	-0.471
			(0.405)	(0.568)
	Japan		0.998***	-1.001*
			(0.405)	(0.614)
	Canada		1.381*	-1.555
			(0.765)	(1.036)
	Australia		0.174	-0.147
			(0.689)	(0.985)
	EU		0.455	-0.270
			(0.473)	(0.613)
	HMTS		0.504	-0.740
			(0.504)	(0.490)
	Asia		1.224**	-1.425**
			(0.614)	(0.648)
	Regional Dummies		Yes	Yes
	Diagnostic tests			
	Wald		306.76***	469.68***
	LR		1570.06***	1393.57***
	Wu-Hausman		2.50	5.56**

Notes: Standard errors are in parentheses. *, **, *** indicate statistical significance at the 10%, 5%, and 1% level, respectively. The omitted dummies are: wholly foreign owned subsidiaries, foreign firms from other developing countries than Asia and no autonomy. Wu-Hausman statistics test the endogeneity of technology creation and technology adoption in relevant regressions.

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