

R&D OFFSHORING AND TECHNOLOGY LEARNING IN EMERGING ECONOMIES – FIRM LEVEL EVIDENCE FROM CHINA

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Abstract

This paper studies the impact of multinational enterprises' R&D offshoring to emerging economies on host country firms. We develop a two-stage non-cooperative game to analyze the strategic interaction of R&D investments between multinational enterprises and host country companies. Our empirical analysis of 12,309 manufacturing firms in the ICT industry in China shows that multinationals' R&D offshoring has a positive effect on host country firms' R&D intensity. However, the magnitude of the impact depends on the technological distance and the geographical distance between the multinationals and the host country firms. The policy implications of our findings are that host country governments should be cautious to advanced multinationals' R&D investment in an under-developed sector, but encourage such an investment in a developed sector; the industry R&D policy making should involve local governments because the positive impact of multinationals' R&D offshoring diminishes as the geographical distance between the multinationals and the host country firms increases.

Keywords: R&D, offshoring, spillover, emerging economies

JEL Code: F23, O32

1. Introduction

Geographical boundaries have become increasingly blurred for R&D activities of multinational enterprises (MNEs).¹ Rising R&D cost, increasing risk and complexity of technological development and intense competition in domestic and global markets force firms to locate their R&D activities out of the home borders (Stembridge, 2007). The primary destinations of MNEs' R&D offshoring appear to be emerging economies². A survey of 209 MNEs in the United States and Western Europe in 2005 demonstrated that about 70 percent of the respondents expected an increase of R&D employment in China in the next three years, and slightly more than 40 percent anticipated an expansion in India (Thursby and Thursby 2006).

MNEs' escalating R&D expansion to emerging economies has drawn extensive attention in their home countries. Policy makers in MNEs' home countries are worried that MNEs' R&D offshoring could lead to loss of crucial intellectual property to their overseas competitors (Hemphill, 2005), which would create immediate threats to the competitive advantage of their home countries (Lieberman, 2004; Bardhan and Jaffee, 2005). Moreover, the possible shedding of well-paid R&D jobs and the downward pressure on wages of engineers and research scientists in the home countries could bear serious consequences because home country students would be discouraged from pursuing engineering or science careers, which further exacerbates the problem of losing competitive advantage in the long run.

Different from policy makers, managers of MNEs are puzzled by an emerging "networked innovation system" based on their R&D offshoring actions (Engardio 2006; Bardhan 2006). The Boston Consulting Group (2005) argued that decisions such as the location of a new R&D center, roles of the new center, and how to integrate the center into a MNE's existing innovation infrastructure would directly impact the outcome of the investments, hence demand systematic attention.

¹ We use the terms of MNEs and foreign firms interchangeably to refer to the firms that not only operate in their home countries, but also in foreign countries. We use domestic firms, local firms and host country firms interchangeably to refer to the firms that only operate in countries where MNEs offshore their R&D.

² Emerging economies are defined as "low-income, rapid-growth countries using economic liberalization as their primary engine of growth" (Hoskisson et al. 2000; Arnold and Quelch 1998). China is commonly identified as an emerging economy (Hoskisson et al. 2000).

Responding to the concerns and questions about R&D offshoring, researchers have extensively investigated factors that motivate or inhibit R&D offshoring (e.g., Thursby and Thursby, 2006; Ambos 2005; Kuemmerle 1999; Le Bas and Sierra 2002) and the conditions on which R&D offshoring could benefit MNEs and their home countries (e.g., Gersbach and Schmutzler 2006). In general researchers reached a consensus that the prime purposes of MNEs' R&D offshoring are to seek resource and to exploit existing knowledge developed in MNEs' home countries³. Thursby and Thursby (2006) found that market growth potential and R&D personnel quality are the top two factors that drive MNEs to offshore R&D to emerging economies, while quality of intellectual property protection inhibits MNEs' R&D offshoring to these economies. In terms of the impact of MNEs' R&D offshoring on their home countries, Gersbach and Schmutzler (2006) found that R&D offshoring will usually increase home country welfare.

Beyond the above-mentioned research focusing on MNEs and their home countries, we find few studies tackling the issue from the perspective of host countries. This paper fills the gap by investigating the impact of MNEs' R&D offshoring on the R&D investment of host country firms in emerging economies. We argue that the influence of MNEs' R&D offshoring on host countries could have long term impact on both MNEs and the home countries of MNEs. This is because MNEs' R&D offshoring disturbs the equilibrium of R&D investment competition between foreign firms and domestic firms in host countries and forces host country firms to respond. Host country firms could learn from their foreign counterparts' R&D activities and strengthen their commitments to R&D to compete with the foreign entrants at advanced level. Furthermore, MNEs' R&D investment in host countries increases the R&D capital stock in host country which is manifested as scientific instruments, advanced machinery and sophisticated facilities. This could generate demand for the advanced facilities and machinery in host countries and stimulate the development of related high-tech industries. MNE's R&D investment could also create research-oriented jobs. This would motivate host countries to expand their higher education system, train more scientists and engineers and nurture the development of high caliber human resource. Overall, the effects of MNE's R&D offshoring on host countries could

³ Resource seeking means that a MNE offshores R&D to augment its "existing stock of knowledge"; resource exploiting means that a MNE utilizes its existing knowledge stock to "support offshore markets" (Ambos 2005).

affect the competitive edge of the MNEs as well as their home countries in the long run. MNEs and the policy makers of their home countries need to understand the possible reaction of host country firms before their R&D movement in order to succeed in overseas markets. Otherwise, they could be positioned at a disadvantage in the long run.

Host country governments, particularly those in emerging economies, have endeavored to facilitate technology spillover from foreign direct investments (FDI) (Lieberman 2004). They believe successful technology spillover can help domestic firms build indigenous technological capabilities and eventually move up in the value chain; however, evidences have shown that the presence of foreign capital does not guarantee technology spillover. Aitken and Harrison (1999) found that foreign investments negatively affected the productivity of domestically owned plants in Venezuela because joint ventures gained market share at the expense of domestically owned firms and forced the domestic firms to produce smaller outputs at higher average costs. In their study of Moroccan firms, Haddad and Harrison (1993) similarly rejected the hypothesis that the presence of foreign firms accelerated the productivity growth of domestic firms. Following Cohen and Levinthal (1989)⁴, we argue that without adequate own R&D investment it is difficult for a domestic firm to achieve technology spillover and improve their capabilities of indigenous innovation, even in the presence of foreign capital. The critical role of domestic firms' own R&D investment in successful technology learning requires that the policy makers and business managers in host countries recognize the impact of MNEs' R&D offshoring on domestic firms' R&D investment decision.

To understand how MNEs' R&D offshoring shapes domestic firms' R&D investment decision, we develop a two-stage noncooperative game. At the first stage, a MNE and a domestic firm engage in cost reduction R&D. At the second stage both firms participate in Cournot competition in a homogeneous product market. The model implies that MNEs' R&D offshoring could positively affect domestic firms' R&D investment decision if it is sufficiently easy for the domestic firms to learn from the MNEs. However, the influence from the MNEs could turn to be negative if it is difficult for the learning to take place.

⁴ Cohen and Levinthal (1989) argued that R&D develops a firm's ability to identify, assimilate and exploit knowledge in public domain or generated by its competitors.

Our empirical analysis of 12,309 manufacturing firms in the electronic and telecommunication (ICT) sector in China shows that MNEs' R&D offshoring has a positive effect on domestic firms' R&D intensity in the ICT industry in China. However, the magnitude of the impact depends on the "technological distance" and the "geographical distance" between MNEs and domestic firms. For domestic firms with relatively low technology and management capability, their R&D investment is primarily affected by the MNEs whose capabilities are inferior to theirs and less affected by the MNEs who are superior. On the contrary, for domestic firms with relatively high capabilities, their R&D investment decisions are mainly influenced by the MNEs who are superior to them in terms of labor productivity and less affected by the MNEs who are inferior. As to geographical distance, we find that the positive effect diminishes as the distance between the MNEs and the domestic firms increases.

The rest of the paper is organized as follows. Section 2 provides a framework used to explain the rationale behind domestic firms' R&D investment decisions in response to MNEs' R&D offshoring. Section 3 presents the empirical evidence. We discuss the findings and related policy implications in Section 4. We conclude the paper in section 5.

2. A Theoretical Framework

2.1 Review of literature on FDI, technology spillover and host country firms' R&D investment

An extensive body of the FDI literature has underscored the issue of whether there is technology spillover from the MNEs to the host country firms⁵. The findings, however, are striking in that FDI oftentimes deliver non-significant technology spillovers or even negatively affect the productivity of the host country firms whereas the major incentive for the host countries to attract FDI is to achieve technology spillovers.

⁵ Technology spillover in the FDI literature in general refers to the positive effects of FDI on the productivity of host country firms. Detailed review of the FDI literature can be found in Blomstrom and Kokko (1998, 2001), Saggi (2002) and Marin and Bell (2006).

To account for the sharp contrast between the objective of favorable FDI policy and the empirical finding, Aitken and Harrison (1999) proposed a market stealing hypothesis. They argued that competition from foreign entrants forces domestic firms to reduce their outputs, which indirectly increases their average production cost. Consequently, the presence of foreign capital lowers the productivity of the domestic firms. Javorcik (2004) argued that studies by Haddad and Harrison (1993) and Aitken and Harrison (1999) fail to find positive FDI spillovers because they focused merely on intra-industry, or horizontal spillovers. Javorcik measured vertical (inter-industry) spillover in a study of Lithuanian manufacturing firms and found positive productivity spillovers between foreign affiliates and their local suppliers in upstream sectors.

Another stream of research, which emphasized the impact of FDI on the R&D investment of host country firms, provided a different explanation to the empirical finding of negative FDI spillover. It is known that domestic firms' own R&D investment not only directly contributes to the firms' productivity growth (Potterie and Lichtenberg 2001; Basant and Fikkert 1996) but also indirectly influence the growth by facilitating technology spillover from FDI (Kokko 1994; Koning 1999; Alvarez and Molero 2005). Therefore, domestic firms could invest less in R&D because of negative spillover from FDI. As a result, their productivity growth would be negatively affected due to the direct effect of R&D investment on productivity growth. Because of the indirect impact, domestic firms' opportunity of absorbing FDI spillover would be reduced, which also limits their productivity growth.

These studies reveal one important component of the causal relationship running from FDI to technology spillover, which is the impact of FDI on R&D investment of domestic firms. The previous theoretical works pertaining to this topic found either ambiguous or negative impacts. Sanna-Randaccio (2002) studied a two-country, two-firm problem where each firm decides the strategy of expansion in its home country and a host foreign country, i.e. how much to invest in R&D and how much to sell in each market. The equilibrium results proved that FDI have an ambiguous effect on domestic R&D. The author argued that spillover intensity, the technological characteristics of the firms and the sector characteristic together shape the effect of FDI on domestic R&D. Similarly, Haller (2004) investigated how MNEs' modes of entry would

influence the R&D decision of host country firms. The author found that the entry of a more efficient foreign firm will lead to lower domestic R&D investment but higher total R&D investment in an industry. However, the author ruled out the possibility of spillover from the MNEs to the domestic firms in the theoretical analysis, which is, however, our central argument in this paper.

Empirical studies in this stream of research by and large provided supporting evidences to the theoretical propositions. Veugelers and Houtte (1990) argued that MNEs in host country may stimulate domestic firms' innovative activity because of the potential knowledge spillovers. However, they also emphasized that competition from the MNEs may limit the domestic firms' production scale, hence reduce domestic R&D expenditure. Their empirical analysis pointed to a significant negative effect of MNEs on domestic firms' R&D expenditure in Belgium. Using industry level data of the United Kingdom, Driffield (2001) examined how R&D investments of foreign and domestic firms affect the productivity growth of the domestic firms. The author found statistically significant positive effects of the domestic firms' R&D, but insignificant effects of the foreign firms' R&D on domestic productivity growth. Moreover, the author found that the R&D investment of foreign firms crowds out the R&D of their domestic counterparts.

Different from the above literature, our study focuses on the impact of MNEs' R&D investment on host country firms in *emerging economies*, whose technological capability is in general inferior to that of firms in developed economies. The intensity of MNEs' technology spillover and MNEs' influence on domestic R&D intensity in our study could be different from those in the advanced countries such as Belgium and the UK. Moreover, economists usually considered FDI as a flow of homogenous capital to host countries and studied their overall impacts on the R&D investment of domestic firms without differentiating the diverse types of FDI. However, FDI engaging in production or service is supposed to exert different influence on local firms than FDI in R&D activities. For example, the so-called technology-exploiting MNEs could mainly employ local low skill workers in their manufacturing plants; in contrast, technology-seeking MNEs may hire primarily highly educated personnel, e.g. engineers and scientists, in their R&D

centers⁶. Accordingly, the mechanism and magnitude of technology spillover in these two circumstances could be fairly different⁷; their impacts on local firms' R&D investment could be different as well. We view R&D investment of foreign firms in emerging economies as an advanced form of FDI and disentangle its effect on the R&D investment of domestic firms from the overall impact of FDI.

Because of the important distinctions between our research and the prior literature, we did not draw on the existing literature of FDI, technology spillover and local R&D investment, which largely focuses on FDI in general rather than on FDI in R&D specifically. We built a simple model in the next section to develop a theoretical foundation for our analysis. Our intention is not to develop a theory, but to illustrate the underlying economic rationale in our research context.

2.2 A Simple Model of foreign and domestic R&D investments

Consider a MNE and a domestic firm who operate in a homogeneous product market in host country. The two firms' decision making process is modeled as a two-stage non-cooperative game (with no collusion). At the first stage, they simultaneously engage in cost reduction R&D activities⁸. At the second stage, they participate in a Cournot competition⁹.

The MNE's marginal cost of production is \hat{c}_1 before it invests in R&D in the host country. Similarly, the domestic firm's marginal cost of production is \hat{c}_2 ¹⁰. At the first stage, the MNE and the domestic firm simultaneously determine their cost-reduction R&D effort x_1 and x_2 . In

⁶ According to Chung and Alcacer (2002), technology exploiting and technology seeking are two major motives of FDI. The former means that a MNE internalizes its unique capabilities and utilizes them in foreign countries; the latter means that a MNE expands abroad in search of capabilities that are not available in its home country.

⁷ In surveys of literature characterizing the mechanisms through which spillover takes place, Blomstrom and Kokko (1998) and Saggi (2002) suggest that labor mobility effect is one of the channels through which spillover may be realized. The other three channels are demonstration effect, competition effect, and R&D stimulation effect.

⁸ We study cost reduction R&D because many MNEs offshore their business to China in order to reduce production cost, though MNEs could offshore R&D for the purpose of new product development as well. Moreover, to some extent, R&D for new product development could be viewed as R&D for cost reduction in a modeling framework (Tirole, 1988). So merely considering cost reduction R&D in our model does not limit generalization of our conclusion.

⁹ Cournot competition is a reasonable assumption in our setting because MNEs that invest in China aim to grab a high market share in one of the world's fastest growing market (von Zedtwitz 2004). Studies on the motives of R&D offshoring can be found in Ambos (2005), Le Bas and Sierra (2002) and Kuemmerle (1999).

¹⁰ In the rest of the paper, we used subscript 1 and 2 to denote the MNE and the domestic firm, respectively.

addition to the cost reduction resulting from own R&D, the domestic firm can reduce its production cost through absorbing R&D spillover from the MNE. As a result, the domestic firm's marginal production cost at the beginning of the second stage is $c_2 = \hat{c}_2 - x_2 - b_2x_1$, $0 < b_2 < 1$. b_2 represents how easy the domestic firm can absorb R&D spillover from the MNE; in other words, how easy the domestic firm can learn from the MNE's R&D activities. Similarly, the MNE can take in the local technological expertise as well. The MNE's marginal production cost at the beginning of the second stage is $c_1 = \hat{c}_1 - x_1 - b_1x_2$ ¹¹. b_1 represents the MNE's capability of exploiting local technological know-how and $0 < b_1 < 1$.

Following D'Aspremont and Jacquemin (1988), we assume the costs of R&D to be quadratic and model them as $\gamma x_1^2/2$ and $\gamma x_2^2/2$ for the MNE and the domestic firm, respectively. We use the same parameter γ for the MNE and the domestic firm because they employ the same pool of resources for their R&D activities (D'Aspremont and Jacquemin 1988).¹² At the second stage of the game, the two firms engage in a Cournot competition. Each firm determines its production quantity (q_1 for the MNE and q_2 for the domestic firm) conditional on x_1 and x_2 . The inverse demand function is modeled as $p = 1 - Q$, where $Q = q_1 + q_2$ and p denote the market clear price. The model is solved using backward induction. At the second stage, the profit of firm i is¹³:

$$(1) \pi_i = (1 - Q)q_i - c_i q_i - \gamma \frac{x_i^2}{2}, i = 1, 2.$$

Substituting c_i into the profit function:

$$(2) \pi_i = (1 - Q)q_i - (\hat{c}_i - x_i - b_i x_j)q_i - \gamma \frac{x_i^2}{2}, i, j = 1, 2, j \neq i.$$

The Nash-Cournot equilibrium is computed as

$$(3) q_i^* = \frac{1 - 2c_i + c_j}{3}, i, j = 1, 2, j \neq i.$$

We assume no exit option in the game, i.e., $q_i^* > 0$, because we are interested in the relationship between the MNE's and the domestic firm's R&D decision. Going back to the first stage, we

¹¹ We consider domestic firm's R&D investment as the only source of local technological expertise in order to simplify the analysis, though there are other ways through which the MNE can exploit local technological expertise, e.g., collaboration with local universities and research institutes (Thursby and Thursby 2006).

¹² We do not assume the MNE to be more efficient in R&D than the domestic firm, i.e., $\gamma_1 < \gamma_2$, because it is not clear whether this is the case in the ICT sector in China. Moreover, incorporating this constraint into the model would not change the main findings. To keep it simple, we choose to stay with $\gamma_1 = \gamma_2 = \gamma$.

¹³ Fixed cost of production is normalized to zero.

substitute q_i^* into the profit function and solve for x_i . There is a unique optimal solution for x_i when b_j satisfy

$$(4) b_j > 2 - 3\sqrt{\frac{\gamma}{2}}, j \neq i.$$

The unique optimal x_i satisfy $\frac{\partial \pi_i}{\partial x_i} = 0$, which is equivalent to

$$(5) \frac{2}{3}(1 - 2c_i + c_j)\left(\frac{2}{3} - \frac{1}{3}b_j\right) - \gamma x_i^* = 0, i, j = 1, 2, j \neq i.$$

We derive the relationship between x_1 and x_2 by differentiating the left hand side of equation (5) with respect to x_j :

$$(6) \frac{dx_i}{dx_j} = -\frac{\partial^2 \pi_i / \partial x_i \partial x_j}{\partial^2 \pi_i / \partial x_i^2} = \frac{\frac{2}{3}\left(\frac{2}{3} - \frac{1}{3}b_j\right)(2b_i - 1)}{-\partial^2 \pi_i / \partial x_i^2}, i, j = 1, 2, j \neq i.$$

The sign of equation (6) is determined by the nominator, which is positive when $b_i > 1/2$ and negative when $b_i < 1/2$. Combining these conditions with the optimality condition in (4) and assuming $\gamma < 1/2$, we derive the complete relationship between x_1 and x_2 . For $i, j = 1, 2$ and $j \neq i$,

$$(7) \frac{dx_i}{dx_j} > 0 \text{ when } b_i > \frac{1}{2}, \text{ and}$$

$$(8) \frac{dx_i}{dx_j} < 0 \text{ when } 2 - 3\sqrt{\frac{\gamma}{2}} < b_i < \frac{1}{2}.$$

(7) and (8) imply that the MNE's R&D investments have a positive effect on the domestic firm's R&D investments if it is sufficiently easy for the domestic firm to learn from the MNE. The MNE's R&D investment has a negative effect if it is difficult for the domestic firm to learn from the MNE. We examine the rationale behind these results by inspecting how the MNE's R&D investments affect the domestic firm's output¹⁴.

$$(9) \frac{\partial q_2}{\partial x_1} = \frac{\partial q_2}{\partial c_2} \frac{\partial c_2}{\partial x_1} + \frac{\partial q_2}{\partial c_1} \frac{\partial c_1}{\partial x_1}.$$

¹⁴ Because $\frac{\partial q_2^*}{\partial x_2}$ is always positive, the sign of $\frac{\partial x_2}{\partial x_1}$ is determined by $\frac{\partial q_2}{\partial x_1}$.

The first multiplicative expression in equation (9) is always positive and represents a spillover effect: the domestic firm absorbs the R&D spillover from the MNE, hence is able to reduce its cost and raise its output. The second expression is always negative and represents a competition effect: an increase in the MNE's R&D investments cuts its own production cost, but indirectly raises the domestic firm's cost, leading to a decrease in the domestic firm's output. The two processes compete with each other and the observed result is their net effect.

To summarize, when it is sufficiently easy for the domestic firms to learn from the MNEs, that is, when absorbing R&D spillover from the MNEs is easy, the spillover effect dominates the competition effect, leading to a net positive effect of the MNEs' R&D offshoring on the R&D investment of the domestic firm. When it is difficult for the domestic firms to learn from the MNEs, the competition effect dominates the spillover effect, leading to a net negative effect of the MNEs' R&D offshoring. In general, how easy it is for the domestic firms to learn from the MNEs determines the net impact of the two competing factors.

3. Empirical evidence from the electronic and telecommunication sector in China

3.1 Data

We explore empirical evidence using a dataset constructed by National Bureau of Statistics of China on a yearly basis from 2001 to 2005. The cleaned dataset includes 12309 manufacturing firms in the two-digit electronic and telecommunication sector (ICT). There are 4506 firms in the 2001 data, 4834 in the 2002 data, 5565 in the 2003 data, and 8525 in the 2005 data¹⁵. Each firm is assigned an invariant code in the dataset so that we can match the observations of each firm across the four-year observation period. The dataset contains more than 50 statistical indicators including firm input, output, R&D expenditure, capital composition, employment, geographical location, the sector where it operates (at four-digit sector level), the ownership status and assets and liabilities.

¹⁵ The data cleaning is implemented through deleting the observations with negative industrial output value, employee number, sales volume, industrial added value and R&D investment value. The data in 2004 are not included in this analysis because of the lack of R&D investment value.

ICT industry in China is an excellent example for our empirical research. First, China's ICT sector developed rapidly in recent years. The development of the Chinese ICT sector was mainly driven by rapid development of domestic firms and inflow of foreign investments to this industry. China's trade volume of ICT products increased from 35 billion US Dollars in 1996 to 180 US Dollars in 2004, with an average annual growth rate of 38 percent (OECD, 2005). China is now the sixth most important global ICT market. Meng and Li (2002) documented that in the end of 1990s, 47 percent of electronic products in China were produced by foreign firms or joint ventures. Majority of MNEs in the ICT sector transferred their manufacturing branches to China to reduce the production cost. They imported the critical components which were normally developed in advanced countries, assembled in the production base in China and exported the final products to overseas market.¹⁶ This so-called "processing trade" made China the biggest exporter of ICT goods in the world in 2004 (OECD, 2005; Katsuno, 2005). Second, we believe there is substantial competition and interaction between foreign firms and local competitors in the Chinese ICT industry. In spite of their relatively limited size and technological know-how, Chinese domestic ICT firms are rapidly developing their production, export and R&D capacities. They compete effectively with MNEs in various product markets within China. A few of them have even emerged as global players and were active in overseas markets.¹⁷

3.2 Econometric framework

To test how R&D investment of MNEs affects local firms, we adopt the following general econometric framework in the empirical analysis.

$$(10) \text{ (R\&D intensity of domestic firm)}_{ijt} = f \{ \text{ (R\&D intensity of MNEs)}_{jt}, \text{ (control variables)}_{ijt} \} ,$$

¹⁶ Research by Lemoine and Unal-Kesenci (2004), China's National Bureau of Statistics (2005), and Fung (2005) attributed the recent expansion of China's exports in machinery, electrical equipment, and electronic products, in large part to processing trade and the global division of labor, especially in East Asia.

¹⁷ For example, Lenovo acquired IBM personal computer business in 2004 and became the world's third largest personal computer producer. TCL acquired the television business of Thomson in France in late 2003. Huawei and ZTE are active players in the world's telecommunication equipment market.

where i, j, t represent a firm, a four-digit level industry and time, respectively. The data for the variables of R&D intensity of domestic firm and control variables are at the firm level, but those for R&D intensity of MNEs are at four-digit industry level.

In this framework, we use domestic firm's R&D intensity, i.e. the ratio of R&D expenditure to sales value, as dependent variable. The average R&D intensity of foreign firms at four-digit industry sector level enters the right-hand side of the function as a key independent variable. Since a firm's R&D investment decision is not only influenced by its foreign competitors, but also by many other factors such as the strategy of the firm, the financial capability, the competition in the sector etc, we include these factors as control variables in the regression. We discuss the control variables in detail in section 3.2.2.

The theoretical model in Section 2 implies that how MNEs' R&D investment in host country impacts R&D decision of domestic firms would depend on ease of learning of domestic firms or in other words, how difficult the spillover would take place. The difficulty of testing the propositions lies in measuring the ease of learning of domestic firms and constructing the key independent variables. We discuss the measurement issue and our approach of constructing the key independent variable in section 3.2.1.

3.2.1 Measurement of ease of learning and construction of MNE R&D intensity

Kaiser (2002) reviewed several different methodologies of constructing knowledge spillover variables. These include measuring technological distance between firms by firm patent activities (Jaffe, 1986) and by firms' share of scientists (Adams, 1990); measuring Euclidean distance of firm characteristics (Inkmann and Pohlmeier, 1995). Ornaghi (2006) measured ease of spillover by grouping firms according to their size, R&D expenditure and geographical location.

In this paper, we measure domestic firm's ease of learning using both technological distance and geographical distance between MNEs' subsidiary company in China and local firms. We use labor productivity to construct the technological distance since we do not have firm-level data of patent application and employed scientists to measure in our dataset. Moreover, we possess data

about size and R&D expenditure of MNEs' subsidiaries, but hesitate to use them as indicators of foreign firms' technology level because this information only represent the characteristics of foreign firms' subsidiaries in China, rather than the foreign firms' overall technology capability. Labor productivity, which is defined as added value divided by number of employees, represents a manufacturing firm's technology and management skill in general.

To test the effect of technological distance on the relationship between the R&D intensities of MNEs and domestic firms, we construct three variables, i.e., "R&D intensity of same-group MNEs", "R&D intensity of higher-level-group MNEs" and "R&D intensity of lower-level-group MNEs", and include them as key independent variables in our analysis. We follow Ornaghi (2006) to divide the dataset into five subsets (groups) according to all firms' average labor productivity in the observation period. Each of the groups contains one fifth of the firms in the dataset¹⁸. Suppose a domestic firm is classified in the group characterized by the lowest labor productivity¹⁹. Then the average R&D intensity of the foreign firms who are in the same lowest labor productivity group and in the same four-digit sector of the domestic firm is taken as the value of the variable "R&D intensity of same-group MNEs" for this domestic firm. Similarly we construct this variable for the domestic firms in the other four groups. The variable "R&D intensity of higher-level-group MNEs" is constructed by taking the average R&D intensity of the foreign firms which are in a group of higher labor productivity, compared with the group of the domestic firm, and are also in the same four-digit sector of the domestic firm. For example, suppose a domestic firm is in Group 1. For this domestic firm, the variable "R&D intensity of the higher level group MNEs" is calculated by taking the average R&D intensity of the foreign firms who are in Group 2 and in the same four-digit sector of the domestic firm. For a domestic firm in Group 2, the average R&D intensity of the foreign firms who are in Group 3 and in the same four-digit sector of the domestic firm is taken as the value of the variable. Different from Ornaghi (2006), we take 1 as the value of the variable "MNE R&D intensity of higher level group" for a domestic firm in the Group 5, i.e., the group of highest labor productivity, because 1 represents the upper bound of R&D intensity of a firm. This numerical manipulation is justified

¹⁸ In our study, a firm classified in a relatively high labor productivity group would be equipped with more advanced machinery and equipment or have established a more efficient organizational and management structure.

¹⁹ The labor productivity of Groups 1, 2, 3, 4, 5 is in an ascending order, i.e. Group 1 has lowest labor productivity and Group 5 has highest labor productivity.

by the analysis of our data which demonstrates in Table 1 that foreign firms in the groups of higher labor productivity in general hold higher R&D intensity. Similarly, we construct the variable “R&D intensity of lower-level-group MNEs” by entering the average R&D intensity of the foreign firms who are in the group directly below the group of the domestic firm. For example, for a domestic firm in group 2, the average R&D intensity of the foreign firms who are in group 1 and in the same four-digit sector of the domestic firm is taken as the value of the variable “R&D intensity of lower-level-group MNEs”. For a domestic firm in group 1, i.e., the group of lowest labor productivity, 0 is taken as the value of the variable because foreign firms in the group of lower productivity tend to have lower R&D intensity (Table 1). The methodology of constructing the variables “R&D intensity of same-group MNEs”, “R&D intensity of higher-level-group MNEs” and “R&D intensity of lower-level-group MNEs” is summarized in Table 2.

(Here insert Table 1)

(Here insert Table 2)

Incorporating the three variables into our general econometric framework, we further identify our econometric function as:

$$(11) \text{ (R\&D intensity of domestic firm)}_{ijt} = f \{ \text{(R\&D intensity of same-group MNEs)}_{jt}, \text{(R\&D intensity of higher-level-group MNEs)}_{jt}, \text{(R\&D intensity of lower-level-group MNEs)}_{jt}, \text{(control variables)}_{ijt} \},$$

where i, j, t represent a firm, a four-digit level industry and time, respectively.

By constructing the variables “R&D intensity of same-group MNEs”, “R&D intensity of higher-level-group MNEs” and “R&D intensity of lower-level-group MNEs” and estimating their coefficients, we are able to study how foreign firms with different levels of technology and management capability affect a domestic firm’s R&D investment decision. In other words, we can test how the “technology distance” between domestic and foreign firms determines the impact of foreign R&D investment on domestic R&D decision. Our econometric strategy of analyzing Equation 11 is regressing on four sub-samples of domestic firms separately. The first

sub-sample includes the domestic firms of Group 1 (the lowest labor productivity group), Group 2, Group 3 and Group 4 and excludes domestic firms of Group 5 (the highest labor productivity). The second sub-sample includes the domestic firms of Group 1, 2 and 3 and excludes domestic firms of Group 4 and 5. Regressing on the two sub-samples separately allows us to focus on domestic firms with relatively low technology and management capability and examine the effect of technology distance on the relationship between the R&D investments of these domestic firms and MNEs. By the same token, we run regressions using the other two sub-samples that focus on domestic firms with relatively high technology and management capability. The third sub-sample includes domestic firms of Groups 2, 3, 4 and 5 and excludes domestic firms of Group 1; the fourth sub-sample includes domestic firms of Groups 3, 4 and 5 and excludes domestic firms of Group 1 and 2. The regression functions that differentiate the two types of domestic firms are presented in the following:

$$(12) \text{ (R\&D intensity of low-capability domestic firm)}_{ijt} = f \{ (\text{R\&D intensity of same-group MNEs})_{jt}, (\text{R\&D intensity of higher-level-group MNEs})_{jt}, (\text{R\&D intensity of lower-level-group MNEs})_{jt}, (\text{control variables})_{ijt} \},$$

and

$$(13) \text{ (R\&D intensity of high-capability domestic firm)}_{ijt} = f \{ (\text{R\&D intensity of same-group MNEs})_{jt}, (\text{R\&D intensity of higher-level-group MNEs})_{jt}, (\text{R\&D intensity of lower-level-group MNEs})_{jt}, (\text{control variables})_{ijt} \},$$

where i, j, t represent a firm, a four-digit level industry and time, respectively.

For a purpose of examining the robustness of the results obtained by classifying the firms into 5 groups, we also divide the firms into 3 groups, each of which contains one third of all the firms, and estimate the coefficients. We compare the estimation of the five-group and three-group approaches in Section 3.4.

A different “distance” between domestic firms and foreign firms is their geographical distance. We make use of the geographical code in the dataset to identify the geographical location of each firm. We construct three additional variables: “R&D Intensity of MNEs within City”, “R&D Intensity of MNEs within Province” and “R&D Intensity of MNEs within Neighboring Provinces”. For a domestic firm, “R&D Intensity of MNEs within City” is the average R&D intensity of foreign firms that are in the same four-digit sector and in the same city of the domestic firm. “R&D Intensity of MNEs within Province” is the average R&D intensity of foreign firms that are in the same four-digit sector, in the same province but in a different city of the domestic firm. By the same token, “R&D Intensity of MNEs within Neighboring Provinces” is the average R&D intensity of foreign firms that are in the same four-digit sector, within the area of the same province plus neighboring provinces, but in a different city of the domestic firm. Foreign firms encompassed by the variable “R&D Intensity of MNEs within Neighboring Provinces” are spread in a wider area than those included in the calculation of variable “R&D Intensity of MNEs within Province”. The geographical areas covered by these two variables overlap, but they are mutually exclusive to the area covered by the variable “R&D Intensity of MNEs within City”. As a result, the variables “R&D Intensity of MNEs within Province” and “R&D Intensity of MNEs within Neighboring Provinces” enter the regression separately. The regression functions are presented in the following:

$$(14) (R\&D\ intensity\ of\ domestic\ firm)_{ijt} = f_i\{(R\&D\ Intensity\ of\ MNEs\ within\ City)_{jt}, (R\&D\ Intensity\ of\ MNEs\ within\ Province)_{jt}, (control\ variables)_{ijt}\},$$

and

$$(15) (R\&D\ intensity\ of\ domestic\ firm)_{ijt} = f_i\{(R\&D\ Intensity\ of\ MNEs\ within\ City)_{jt}, (R\&D\ Intensity\ of\ MNEs\ within\ Neighboring\ Provinces)_{jt}, (control\ variables)_{ijt}\},$$

where i, j, t represent a firm, a four-digit level industry and time, respectively.

Our dataset shows that among the provinces, Guangdong province hosted most foreign and domestic ICT firms. Shanghai and Jiangsu followed to host the second and third largest number

of ICT firms. However, the firms locating in Guangdong are more than those locating in Shanghai and Jaingsu combined. Given the importance of Guangdong province to the Chinese ICT industry, we single out the data of the firms locating in Guangdong and compare the results based on them to the results obtained from the firms all over the country.

3.2.2 Control Variables

More financial resource gives a firm greater opportunity to experiment and less stringent requirement for performance, which conduces to the risky investment in R&D. Having more financial resource, a firm will be more likely to invest in R&D or increase R&D investment. Following the studies on slack resource by Greve (2003), Daniel, Lohrke, Fornaciari and Turner (2004) and Tan and Peng (2004), we include the ratio of administrative, financial and selling expenses to sales value in the function to measure the financial resource of a firm.

Schumpeter (1950) was among the first to advocate the hypothesis that in a mature capitalist economy large firms generate a disproportionately large share of society's technological advances. Scholars in favor of this hypothesis articulated that larger firms possess larger scale internally-generated funds, so they secure more resource to conduct risky R&D projects. Scale economies of R&D activity and return to R&D investment given larger volume of sales also contribute to the advantage of larger firms. However, Cohen, Levin and Mowery (1987) argued that these points were flawed because of the inadequate attention to the unit of analysis and to the industry effects. They found overall firm size has a very small, statistically insignificant effect on business unit R&D intensity. In a recent study, Lee and Sung (2005) contested that firm size does not directly affect R&D intensity, but exert influence through affecting firm-specific technological competence. Although no consensus was reached on the relationship between firm size and R&D intensity in previous literature, we include the number of the employees of the firm divided by the average number of the employees of all the firms in the database as a control variable in our analysis.

Prior to conducting R&D activities, a firm needs to invest in sophisticated technological equipment (Del Canto and Gonzalez, 1999). The investment in R&D equipment, similar as the

investment in ordinary machinery and production, is typically classified as fixed asset investment. A firm investing more in fixed asset, i.e. having higher capital intensity, is more likely to expand its R&D investment. We therefore include the ratio of fixed asset investment to added value as an explanatory variable to control for the effect of capital intensity on R&D investment.

Committed to fixed asset investment in R&D equipment, a firm also has to invest in human capital to build an efficient R&D team. Scientists and technicians with qualifications, knowledge and skills are the necessary components of the team. Their experience, know-how, abilities and wisdom constitute human resource of the firm, which contributes to the success of R&D projects. Following Del Canto and Gonzalez (1999), we use the compensation per employee of the firm, which is the total compensation divided by the number of employees, as a proxy variable for human resource of the firm.

The relationship between industry R&D intensity and market structure has been intensively explored by the literature of industry organization. According to Lee (2005), numbers of studies found that the relationship between industry R&D intensity and market concentration can be described as an inverted-U shape. This indicates that moderately concentrated industries invest more in R&D activity than either highly competitive or highly concentrated industries. Bearing this in mind, we include in the regression a variable of Herfindahl-Hirschman Industrial Concentration Index (HHI), calculated at the four-digit sector level, to account for the potential impact of market structure on a firm's R&D investment.

We also include a few ownership and year dummy variables in the functions to control for ownership and time effect, respectively. The definition of all the dependent and independent variables are summarized in Table 3. The descriptive statistics of the variables are displayed in Table 4.

(Here insert Table 3)

(Here insert Table 4)

3.3 Estimation methodology

More than half of the domestic firms in our dataset did not conduct R&D in the observation period. The R&D intensities of these firms were zero. This type of dependent variable is known as a censored dependent variable, i.e., the values of the variables in a certain range are all reported as a single value, e.g., zero. The conventional linear regression method is not able to distinguish the difference between the non-linear “zero” observations and the continuous observations. We thus use Tobit model as our baseline model. Moreover, some time-invariant characteristics of domestic firms could also affect the dependent variable, but their impact is not captured by the baseline Tobit model. Therefore, we run panel Tobit model to control for these firm-specific unobserved factors.

The theoretical model presented in Section 2 clearly shows that R&D intensity of foreign firms is endogenous in the structural functions because of the strategic interaction between a foreign firm and a domestic firm. To correct the bias caused by endogeneity of the explanatory variable, we instrument the R&D intensity of foreign firms with two instrumental variables: new-product intensity defined as new-product value divided by industrial output and the ratio of administrative, financial, and selling expenses to sales value.

Legitimate instrumental variables need to be highly correlated with the endogenous variable but not correlated with the residual of the structural function. R&D activity leads to the development of new products, so R&D intensity is correlated with new product development. However, R&D investment of a host country firm in a particular four-digit sector could not substantially impact the average new product intensity of all the MNEs in that sector. In this sense, new-product intensity is a qualified instrumental variable. In section 3.2.2 we argue that a firm’s financial resource contributes to its R&D investment. Therefore the R&D investment variable is highly correlated with the variable measuring a firm’s financial capability. Furthermore, R&D decision of a host country firm can hardly affect the average ratio of the administrative, financial and selling expenses to sales value of all the MNEs in the same four-digit industry sector. Therefore, the ratio of administrative, financial, and selling expenses to sales value is a valid instrument variable of the R&D intensity of foreign firms. The definition of the two instrumental variables is also summarized in Table 3.

3.4 Empirical results

The estimation results of Function 11 are presented in Table 5. The coefficients of “R&D intensity of lower-level-group MNEs” are significant and positive in all four regression models. The coefficients of “R&D intensity of higher-level-group MNEs” and “R&D intensity of same-group MNEs” are significant and positive in three of the four regression models. To correct the endogeneity of explanatory variables, we instrument the four statistically significant variables in the Tobit model results, i.e., “R&D intensity of same-group MNEs” and “R&D intensity of lower-level-group MNEs” in the five-group result and “R&D intensity of higher-level-group MNEs” and “R&D intensity of lower-level-group MNEs” in the three-group result, and report the instrumental variable regression results in Table 6. Table 6 shows that “R&D intensity of higher-level-group MNEs” and “R&D intensity of lower-level-group MNEs” are all maintained to be statistically significant in instrumental variable Tobit models. The statistical significance of “R&D Intensity of same-group MNEs” has changed. Overall, the prevalent and robust positive signs of coefficients indicate that MNEs’ R&D offshoring stimulated the R&D investment of domestic firms in the ICT sector in China.

(Here insert Table 5)

(Here insert Table 6)

In addition, the results presented in Table 5 reveal that a host country firm with more financial resource, larger size, and better R&D human resource would be more likely to invest more in R&D. Moreover, the more concentrated is an industry sector, the more will a host country firm invest in R&D. However, contradictory to our prediction, a firm investing more in fixed asset tends to invest less in R&D. The average R&D intensity of host country firms in the four-digit sector has no statistically significant influence on R&D decision of an individual firm. We also find that limited liability and stock companies tend to invest more in R&D than firms of other ownership status. There is a statistically significant difference between domestic firms’ R&D investment level in 2001 and 2002, but no such difference is found between 2001 and 2003 or between 2001 and 2005.

We present the regression results of Function 12 and 13 in Table 7 for the five-group and in Table 8 for the three-group case. Table 7 shows that when we use the sub-sample of domestic firms in Group 1, 2 and 3 (domestic firms with relatively low technology and management capability) and exclude the domestic firms of Group 5 and 4 in the regression, the coefficients of “R&D intensity of higher-level-group MNEs” and “R&D intensity of same-group MNEs” turn out to be insignificant; the coefficients of “R&D intensity of lower-level-group MNEs” are by and large significant and positive in the regressions. When we use the sub-sample of domestic firms in Group 1, 2, 3 and 4 or Group 1, 2 and 3 (domestic firms with relatively high technology and management capability) in the regression, the coefficients of “R&D intensity of lower-level-group MNEs” turn out to be insignificant; the coefficients of “R&D intensity of higher-level-group MNEs” and “R&D intensity of same-group MNEs” are in general significant and positive in the regressions. Table 8 shows a similar pattern in the results for the three-group case, implying the robustness of our results.

(Here insert Table 7)

(Here insert Table 8)

The regression results of Function 14 and 15 are presented in Table 9. The regression using full sample reveals significant and positive effects of “R&D intensity of MNEs within city” in both Tobit model and Panel Tobit model, but insignificant effects of “R&D intensity of MNEs within province” and “R&D intensity of MNEs within neighboring provinces”. The regression analysis of host country firms in Guangdong province shows that “R&D intensity of MNEs within city” is in general significant and has a positive impact on domestic firms’ R&D intensity, but both “R&D intensity of MNEs within province” and “R&D intensity of MNEs within neighboring provinces” have significantly negative effects on domestic firms’ R&D intensity.

(Here insert Table 9)

4. Discussions and Policy Implications

The empirical results using technological distance to measure domestic firm's ease of learning imply that in general R&D investment of host country firms in the ICT sector in China is positively affected by MNEs' R&D investment. R&D intensity of a domestic firm with relatively low technological and management capability is only affected by the R&D investment of MNEs whose capabilities are lower than the domestic firms and not by the R&D investment of more advanced MNEs. For domestic firms with relatively high technological and management skill, we find that their R&D decision is only affected by MNEs whose capabilities are higher than the domestic firms and not by MNEs with lower technological and management capabilities.

The results based on the geographical distance demonstrate that R&D investment decision of domestic firms in the ICT sector in China is only positively affected by the MNEs within the same city. The influence from the MNEs locating out of the city is rather trivial. Furthermore, the analysis of domestic firms in Guangdong province shows that the R&D investment of MNEs out of the city, but within the same province and the neighboring provinces, has negative impact. The findings based on the data of the firms all over China and within Guangdong province consistently reveal a geographical boundary for the positive impact of MNEs' R&D offshoring in the Chinese ICT industry.

Given the insights derived from the theoretical model and the empirical evidence, we argue that the governments of emerging economies should be cautious to MNEs' R&D offshoring since its positive impact on domestic firms' R&D investment decision would not take place unconditionally. However, these governments could stimulate the positive impact by designing sound industry policies which facilitate the technology spillover, e.g. a policy encouraging cooperation between domestic and foreign firms. Our findings show that limited technological and management capability of domestic firms would impede them to benefit from the spillover generated by MNEs' R&D investment. If an industry in a developing economy is relatively developed, industry policies favorable to foreign R&D offshoring would provide domestic firms with opportunities to learn from the advanced foreign competitors. The knowledge gained from this learning is much needed for emerging economies to achieve successful technological upgrading in a later stage. On the contrary, if a sector falls into the category of infant industry, the government of developing economy has reasons to be suspicious of substantial positive

impact of MNEs R&D investment on domestic firms' R&D decision, though the R&D investment of MNEs could still exert positive influence on local economy such as increasing local employment opportunities.

We find that the geographical barrier for the positive impact of MNEs' R&D investment on domestic firms' R&D decision is insurmountable in the Chinese ICT industry. Since the positive impact is limited within a certain area, local firms and residents in that area could be the primary beneficiaries of MNEs' R&D investment. Local governments hence should play an important role in forming effective industry R&D policy. The decisions related to fiscal incentive for R&D expenditure and funding industrial R&D activities could be left for the discretion of local governments.

5. Conclusion

MNEs' R&D offshoring to emerging economies has become a prominent phenomenon in recent years. In this paper we investigate how MNEs' R&D offshoring affects the R&D investments of host country firms. We develop a two-stage non-cooperative game as a theoretical foundation to study this issue. A large dataset of 12,309 manufacturing firms in the ICT industry in China is analyzed to provide the empirical evidences.

We find that in general the domestic firms in the Chinese ICT industry increased their R&D investments in response to MNEs' R&D offshoring decision, which implies that the positive spillover effects exceeded the negative competition effects of MNEs' R&D offshoring on the R&D investment of domestic firms. Nevertheless, the magnitude of MNEs' impacts is determined by the relative "distance" between the MNEs and the domestic firms. The R&D investment decision of a domestic firm with relatively high technology and management skills would not be affected by the R&D investment of inferior MNEs. Similarly, the R&D decision of a domestic firm with relatively low technology and management capability could not be positively affected by the R&D investment of more advanced MNEs. The positive impact of MNEs' R&D investment on domestic firms diminishes as the geographical distance between them increases.

Our findings provide important policy implications to both the host and the home countries. Understanding host country competitors' response is not only critical for the MNEs to choose the right R&D offshoring strategies, but also important for policy makers in the MNEs' home countries to better regulate MNEs' R&D offshoring to emerging economies. For host country policy makers, our findings provide important implications regarding how emerging economies could leverage their FDI policy to facilitate technology spillover from the MNEs and technology learning of the domestic firms. The success of technology spillover and technology learning in host countries will greatly contribute to the domestic firms' development of indigenous innovation capabilities in the long run.

Our study is limited in scope because we only investigate intra-industry R&D spillovers, but do not examine the R&D spillover from MNEs in one industry to other industries in the host country, such as upstream and downstream industries. As a result, our findings could underestimate the overall positive effect of MNEs' R&D offshoring on the host country firms in general. In addition to including upstream and downstream industry sectors in the analysis, it is interesting to extend our study to industries other than the ICT sector. This would allow us to examine the extent to which our findings are general and investigate the R&D spillover patterns in the sectors other than the ICT industry. It is also interesting to examine whether the potential influence of MNEs' R&D offshoring on domestic firms' R&D investment would result in the change of the productivity of domestic firms.

Appendix

(Here insert Table 10)

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Table 1: Ranking of Average R&D Intensity of MNEs among Different Groups

Four-digit Sector	R&D Intensity					Ranking of R&D Intensity among 5 Groups				
	Group 1 (Lowest labor productivity)	Group 2	Group 3	Group 4	Group 5 (Highest labor productivity)	Group 1 (Lowest labor productivity)	Group 2	Group 3	Group 4	Group 1 (Lowest labor productivity)
4111	.0120	.0065	.0156	.0088	.0256	3	5	2	4	1
4112	.0104	.0019	.0019	.0135	.0203	3	5	4	2	1
4113	.0022	.0082	.0023	.0049	.0046	5	1	4	2	3
4119	.0041	.0018	.0016	.0060	.0062	3	4	5	2	1
4130	.0026	.0029	.0062	.0041	.0074	5	4	2	3	1
4141	.0024	.0000	.0002	.0020	.0009	1	5	4	2	3
4143	.0024	.0026	.0026	.0021	.0026	4	2	3	5	1
4151	.0010	.0032	.0022	.0009	.0010	3	1	2	5	4
4153	.0054	.0018	.0077	.0093	.0027	3	5	2	1	4
4155	.0055	.0048	.0003	.0048	.0081	2	3	5	4	1
4160	.0009	.0027	.0017	.0022	.0019	5	1	4	2	3
4171	.0015	.0008	.0015	.0023	.0091	3	5	4	2	1
4172	.0002	.0008	.0016	.0017	.0047	5	4	3	2	1
4182	.0002	.0000	.0010	.0113	.0368	4	5	3	2	1
4189	.0043	.0084	.0010	.0040	.0062	3	1	5	4	2
Sum of Ranks						52	51	52	42	28

Note:

1. The labor productivity of groups 1, 2, 3, 4, 5 is in an ascending order, i.e. Group 1 has lowest labor productivity and Group 5 has highest labor productivity.

Table 2: Methodology of Constructing the Variables “R&D Intensity of Lower-Level-Group MNEs”, “R&D Intensity of Same-Group MNEs” and “R&D Intensity of Higher-Level-Group MNEs”

A domestic firm in different groups	Variables		
	R&D intensity of lower-level-group MNEs	R&D Intensity of same-group MNEs	R&D intensity of higher-level-group MNEs
A domestic firm in Group 1 (lowest labor productivity)	0	A	B
A domestic firm in Group 2	A	B	C
A domestic firm in Group 3	B	C	D
A domestic firm in Group 4	C	D	E
A domestic firm in Group 5 (highest labor productivity)	D	E	1

Note:

1. The labor productivity of groups 1, 2, 3, 4, 5 is in an ascending order, i.e. Group 1 has lowest labor productivity and Group 5 has highest labor productivity.
2. A: Average R&D investment intensity of the MNEs in Group 1, which are also in the same four-digit sector of the domestic firm;
 B: Average R&D investment intensity of the MNEs in Group 2, which are also in the same four-digit sector of the domestic firm;
 C: Average R&D investment intensity of the MNEs in Group 3, which are also in the same four-digit sector of the domestic firm;
 D: Average R&D investment intensity of the MNEs in Group 4, which are also in the same four-digit sector of the domestic firm;
 E: Average R&D investment intensity of the MNEs in Group 5, which are also in the same four-digit sector of the domestic firm

Table 3: The Variables

Variable Name	Definition and note
Domestic Firm R&D Intensity (Dependent Variable)	R&D expenditure of a domestic firm / Added value of a domestic firm
Domestic Firm R&D Intensity at Four-digit Sector Level (Independent Variable)	Sum of R&D expenditure of domestic firms in the same four-digit sector / Sum of added value of domestic firms in the same four-digit sector
R&D intensity of same-group MNEs	Sum of R&D expenditure of MNEs in the same four-digit sector / Sum of added value of MNEs in the same four-digit Sector (The MNEs are classified into the same labor productivity group as the group of domestic firms)
R&D intensity of higher-level-group MNEs ¹	Sum of R&D expenditure of MNEs in the same four-digit sector / Sum of added value of MNEs in the same four-digit Sector (The MNEs are classified into a higher labor productivity group compared with the group of domestic firms)
R&D intensity of lower-level-group MNEs ¹	Sum of R&D expenditure of MNEs in the same four-digit sector / Sum of added value of MNEs in the same four-digit Sector (The MNEs are classified into a lower labor productivity group compared with the group of domestic firms)
Financial Resource	Administrative, financial and selling expenses / Sales
Firm Size	Number of employees / Average number of employees of firms in the sample
Fixed Asset Investment Intensity	Fixed asset investment / Added value
Human Resource	Employee compensation value / Number of employees
Herfindahl-Hirschman Industrial Concentration Index (HHI)	$\sum_{j=1}^n (\text{Market share (Percentage) of } j \text{ firm in a four-digit sector})^2$
Ownership Dummy Variables	For domestic firms, the base group is “other domestic firms”. The dummy variables represent state-owned, collective, employee shareholding cooperatives, joint operation enterprises, limited liability companies, stock companies, private enterprises.
Year Dummy Variables	The base group is 2001. The dummy variables represent 2002, 2003 and 2005.
MNE R&D Intensity within City	Average R&D intensity of MNEs that are in the same four-digit sector and within the same city or county of domestic firms.
MNE R&D Intensity within Province	Average R&D investment intensity of MNEs that are in the same four-digit sector, in the same province but in a different city or county of domestic firms.
MNE R&D Intensity within Neighboring Provinces	Average R&D intensity of MNEs that are in the same four-digit sector, within the area of the same province plus neighboring provinces but in a different city or county of domestic firms.
MNE new-product intensity	Sum of new product value of MNEs in the same four-digit sector / Sum of output value of MNEs in the same four-digit Sector
Ratio of the administrative, financial and selling expenses to sales value of MNE	Sum of administrative, financial, and selling expenses of MNEs in the same four-digit sector / Sum of sales value of MNEs in the same four-digit Sector

Note: 1. The detailed definition of the variable is presented in Section 3.2.1.

Table 4: Summary Statistics of Variables

Year	Number of Domestic Firms		Domestic Firm R&D Intensity (Dependent Variable)	Domestic Firm R&D Intensity at Four-digit Sector Level (Independent Variable)	R&D Intensity of same-group MNEs	R&D intensity of higher-level-group MNEs	R&D intensity of lower-level-group MNEs	Financial Resource	Firm Size	Fixed Asset Investment Intensity	Human Resource	Herfindahl-Hirschman Industrial Concentration Index (HHI)
2001	2294	Mean	.0065	.011	.0026	.16	.0020	.66	.82	20	13	.039
		Standard Deviation	.025	.017	.0045	.36	.0045	13	2.2	510	20	.041
		75 th Percentile	.0011	.0092	.0026	.0074	.0015	.27	.67	1.9	14	.058
2002	2486	Mean	.012	.013	.0028	.17	.0018	.34	.79	5.5	14	.042
		Standard Deviation	.20	.019	.0039	.37	.0032	2.0	2.4	72	12	.043
		75 th Percentile	.0021	.011	.0028	.0081	.0016	.26	.63	1.7	14	.062
2003	2727	Mean	.014	.012	.0035	.18	.0023	.34	.73	2.6	15	.034
		Standard Deviation	.31	.018	.0061	.38	.0051	6.2	2.3	21	14	.037
		75 th Percentile	.0022	.011	.0029	.0072	.0020	.22	.59	1.4	17	.046
2005	4046	Mean	.010	.014	.0053	.19	.0034	.17	.63	2.7	17	.032
		Standard Deviation	.031	.0091	.0085	.38	.0039	.57	2.3	32	14	.052
		75 th Percentile	.0014	.020	.0047	.013	.0044	.18	.50	1.2	19	.041

Table 5: Effect of MNEs' R&D Activity: Ease of Learning Measured by Labor Productivity

Independent Variable	The R&D Intensity of Host Country Firms as Dependent Variables			
	Five Groups		Three Groups	
	Tobit Model	Panel Tobit Model	Tobit Model	Panel Tobit Model
R&D Intensity of same-group MNEs	.84(.47)*	.30(.11)***	.18(.43)	.24(.10)**
R&D intensity of higher-level-group MNEs	.011(.0084)	.0080(.0026)***	.037(.0070)***	.015(.0022)***
R&D intensity of lower-level-group MNEs	1.7(.73)**	.44(.18)**	2.7(.67)***	.47(.16)***
Average R&D Intensity of host country firms in the same four-digit sector (Independent Variable)	.050(0.82)	.067(.062)	.21(.21)	.095(.061)
Financial Resource	.037(.00038)***	.00049(.00031)	.037(.00039)***	.00049(.00030)
Firm Size	.0066(.0011)***	.0018(.00037)***	.0067(.0011)***	.0018(.00037)***
Fixed Asset		-		-
Investment Intensity	-.0022(.000035)***	.000041(.000020)**	-.0022(.000035)***	.000040(.000020)**
Human Resource	.0019(.00018)***	.00069(.000050)***	.0017(.00018)***	.00064(.000050)***
Herfindahl-Hirschman Industrial Concentration Index (HHI)	.28(.074)***	.077(.019)***	.23(.074)***	.063(.019)***
Ownership Dummy Variables which are Statistically Significant at 10 Percent	limited liability companies and stock companies	stock companies	limited liability companies and stock companies	stock companies
Year Dummy Variables which are Statistically Significant at 10 Percent	2002 and 2003	2002	2002	2002
Number of Observations	11553	11553	11553	11553
Number of Groups for Panel Model		6456		6456
Likelihood-ratio Chi-squared Statistics for Tobit Model / Wald Chi-squared Statistics for Panel Tobit Model	2613.6***	625.8***	2650.3***	672.5***

Note: 1. The data in parentheses are standard deviation. *** denotes significance at 1% level, ** denotes significance at 5% level, * denotes significance at 10% level.

Table 6: Instrumental Variable Tobit Model

Independent Variable	Instrumental Variable Tobit Model (The R&D Intensity of Domestic Firms as Dependent Variables)			
	Five Groups		Three Groups	
	R&D Intensity of same-group MNEs is instrumented	R&D intensity of lower-level-group MNEs is instrumented	R&D intensity of higher-level-group MNEs is instrumented	R&D intensity of lower-level-group MNEs is instrumented
R&D Intensity of same-group MNEs	-2.4(1.7)	-.68(.61)	.073(.43)	-.84(.50)*
R&D intensity of higher-level-group MNEs	.020(.0096)**	-.0075(.0097)	.045(.0074)***	.030(.0072)***
R&D intensity of lower-level-group MNEs	2.8(.93)***	12(2.7)***	2.6(.67)***	9.3(1.8)***
Wald Test of Exogeneity (Chi-squared Statistics)	3.6*	15.9***	12.0***	15.4***

Note:

1. The data in parentheses are standard deviation. *** denotes significance at 1% level, ** denotes significance at 5% level, * denotes significance at 10% level.
2. To simplify, the coefficients of the controlling and dummy variables are not reported.

Table 7: Impact of Technological Distance: Firms Divided in Five Groups

Independent Variable	The R&D Intensity of Domestic Firms as Dependent Variables							
	Groups 1, 2, 3, 4		Groups 1, 2, 3		Groups 2, 3, 4 and 5		Groups 3, 4 and 5	
	Tobit Model	Panel Tobit Model	Tobit Model	Panel Tobit Model	Tobit Model	Panel Tobit Model	Tobit Model	Panel Tobit Model
R&D Intensity of same-group MNEs	1.0(.89)	.38(.15)**	.97(1.2)	.24(.24)	.48(.19)***	.22(.12)*	.41(.17)**	.23(.11)**
R&D intensity of higher-level-group MNEs	.55(.61)	.25(.11)**	.40(1.3)	.29(.26)	.0078(.0033)**	.0088(.0026)***	.0040(.0028)	.0067(.0026)***
R&D intensity of lower-level-group MNEs	2.2(.93)**	.21(.16)	4.8(1.5)***	1.0(.31)***	.49(.29)*	.22(.18)	.0052(.26)	-.15(.18)

Note:

1. The data in parentheses are standard deviation. *** denotes significance at 1% level, ** denotes significance at 5% level, * denotes significance at 10% level.
2. The labor productivity of groups 1, 2, 3, 4, 5 is in an ascending order, i.e. Group 1 has lowest labor productivity and Group 5 has highest labor productivity.
3. To simplify, the coefficients of the controlling and dummy variables are not reported.

Table 8: Impact of Technological Distance: Firms Divided in Three Groups

Independent Variable	The R&D Intensity of Domestic Firms as Dependent Variables			
	Group 1 and 2		Group 2 and 3	
	Tobit Model	Panel Tobit Model	Tobit Model	Panel Tobit Model
R&D Intensity of same-group MNEs	-.86(1.1)	.0081(.22)	.25(.15)*	.20(.11)*
R&D intensity of higher-level-group MNEs	1.2(.75)	.21(.15)	.012(.0026)***	.011(.0025)***
R&D intensity of lower-level-group MNEs	6.1(1.5)***	1.2(.32)***	.67(.24)***	.28(.18)

Note:

1. The data in parentheses are standard deviation. *** denotes significance at 1% level, ** denotes significance at 5% level, * denotes significance at 10% level.

2. To simplify, the coefficients of the controlling and dummy variables are not reported.

Table 9: Effect of MNEs' R&D Activity: Ease of Learning Measured by Geographical Distance

Independent Variable	The R&D Intensity of Domestic Firms as Dependent Variables					
	Total Host Country Firms		Host Country Firms in Guangdong Province			
	Tobit Model	Panel Tobit Model	Tobit Model	Panel Tobit Model	Tobit Model	Panel Tobit Model
R&D Intensity of MNEs within City	.61(.24)**	.65(.24)***	1.4(.57)**	.73(.52)	1.5(.58)***	.88(.53)*
R&D Intensity of MNEs within Province	-.26(.38)	-	-	-	-	-
R&D Intensity of MNEs within Neighboring Provinces	-	-1.0(1.1)	-	-	-9.9(4.1)**	11.8(4.0)***

Note:

1. The data in parentheses are standard deviation. *** denotes significance at 1% level, ** denotes significance at 5% level, * denotes significance at 10% level.

2. To simplify, the coefficients of the controlling and dummy variables are not reported.

Table 10: List of Neighboring Provinces

Province	Neighboring Provinces
Beijing	Tianjin, Hebei
Tianjin	Beijing, Hebei
Hebei	Beijing, Tianjin, Shanxi, Inner Mongolia, Liaoning, Shandong, Henan
Shanxi	Hebei, Inner Mongolia, Henan, Shaanxi
Inner Mongolia	Hebei, Shanxi, Liaoning, Jilin, Heilongjiang, Shaanxi, Gansu, Ningxia
Liaoning	Hebei, Inner Mongolia, Jilin
Jilin	Inner Mongolia, Liaoning, Heilongjiang
Heilongjiang	Inner Mongolia, Jilin
Shanghai	Jiangsu, Zhejiang
Jiangsu	Shanghai, Zhejiang, Anhui, Shandong
Zhejiang	Shanghai, Jiangsu, Anhui, Fujian, Jiangxi
Anhui	Jiangsu, Zhejiang, Jiangxi, Henan, Hubei
Fujian	Zhejiang, Jiangxi, Guangdong
Jiangxi	Zhejiang, Anhui, Fujian, Hubei, Hunan, Guangdong
Shandong	Hebei, Jiangsu, Henan
Henan	Hebei, Shanxi, Anhui, Shandong, Hubei, Shaanxi
Hubei	Anhui, Jiangxi, Henan, Hunan, Chongqing, Shaanxi
Hunan	Jiangxi, Hubei, Guangdong, Guangxi, Chongqing, Guizhou
Guangdong	Fujian, Jiangxi, Hunan, Guangxi, Hainan
Guangxi	Hunan, Guangdong, Hainan, Guizhou, Yunnan
Hainan	Guangdong, Guangxi
Chongqing	Hubei, Hunan, Sichuan, Guizhou, Shaanxi
Sichuan	Chongqing, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai
Guizhou	Hunan, Guangxi, Chongqing, Sichuan, Yunnan
Yunnan	Guangxi, Sichuan, Guizhou, Tibet
Gansu	Inner Mongolia, Sichuan, Shaanxi, Qinghai, Ningxia, Xinjiang
Qinghai	Sichuan, Tibet, Gansu, Xinjiang
Ningxia	Inner Mongolia, Shaanxi, Gansu
Xinjiang	Tibet, Gansu, Qinghai