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Xiaowen Tian
*Bond University*, Xiaowen_Tian@bond.edu.au

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# MANAGING FDI TECHNOLOGY SPILLOVERS: A CHALLENGE TO TNCs IN EMERGING MARKETS*

XIAOWEN TIAN

Abstract: Prior studies on FDI technology spillovers have offered little guidance to TNCs on how to protect and exploit technology across borders. The present paper argues that TNCs can manage technology spillovers through selection of entry modes, selection of technologies, and selection of investment priorities in the affiliates they establish in foreign markets. A number of hypotheses are derived from theoretical analyses and are tested against firm-level data from China. The findings of the paper have significant implications for TNCs that face fierce competition from local firms in emerging markets.

## INTRODUCTION

After World War II, internationalization of production accelerated and foreign direct investment (FDI) increased on an unprecedented scale. In the early period, FDI was primarily made in the developed world. In recent years, some developing countries, particularly China and India, grew rapidly, and began to attract a large amount of FDI. China has been, for instance, the largest FDI recipient in the developing world since the mid-1990s, and has been among the top four largest FDI recipients in the world since the early 2000s. The shift of FDI destination has resulted in increasing interaction between transnational corporations (TNCs) from developed countries and local firms in emerging markets.[1]

Given the technology gap between the developed and the developing world, technology transfer lies at the core of the interaction. Technology transfer may take direct forms. Local firms may, for instance, directly purchase advanced technology and equipments from TNCs. This kind of technology transfer is under control of TNCs. Most technology transfer takes, however, indirect forms, that is, the

so-called FDI technology spillovers. By definition, FDI technology spillovers are externalities, for which local firms do not pay if the effect is positive and do not get compensation if the effect is negative. In other words, FDI technology spillovers take place when the entry or presence of TNCs lead to productivity gains or losses in local firms, and TNCs are not able to internalise the full value of these benefits or losses (Blomstrom et al., 2000; also Buckley et al, 2002). Technology spillovers can not be easily controlled by either side in the interaction.

Scholars have now increasingly realized the importance as well as the complexity of FDI technology spillovers, and have begun to make great effort to research this subject. Consequently, the debate over FDI technology spillovers has intensified. In the beginning, the debate was dominated by arguments for positive FDI technology spillovers. Positive spillovers may take place through a competition effect. That is, competition from TNCs forces local firms to increase their competitive capacity by reforming management style and updating production technology. Moreover, positive spillovers may take place through a linkage effect. That is, local firms learn from observing TNCs in the same industry, and benefit from the technical support, the demand and the supply provided by TNCs with which they have an upstream or downstream relationship in business chains. Furthermore, positive spillovers may take place through an employment effect. That is, TNCs train their employees who later move to local firms with acquired skills (see Görg and Strobl, 2001).

In recent years, it was argued that FDI may generate negative technology spillovers in the sense that the entry or presence of FDI negatively affects the productivity of local firms. Negative spillvoers may take place through market stealing. That is, the aforementioned competition effect could turn negative if TNCs draw away demand from local firms and force them to cut down production. In this case, the productivity of local firms would decline as they have to spread the fixed cost over a smaller amount of products (Aitken and Harrison, 1999). Negative spillovers may also take place through skill stealing. That is, the aforementioned employment effect may turn negative if TNCs attract the best workers away from local firms, causing a decline of the productivity of the local firms (Girma,

Greenaway and Wakelin, 2001). Empirical studies have so far produced mixed results. Some studies showed evidence of positive technology spillovers from FDI to local firms, while other studies found that FDI negatively affects the productivity of local firms (see, for instance, Caves, 1974; Globerman, 1979; Kokko; Blomstrom and Wolff, 1996; Aitken and Harrison, 1999; Djankov and Hoekman, 2000; Kathuria, 2000; Chung, 2001; Chuang, Mitchell and Yeung, 2003; Javorcik, 2004; Wei and Liu 2006; Tian 2007; Buckley, Clegg and Wang 2007). [2]

Interestingly enough, both sides in the debate have looked at the issue almost exclusively from the perspective of local firms that receive the spillovers rather than the perspective of TNCs that generate the spillovers. As a result, the discussion can offer little, if any, guidance to TNCs on how to manage technology spillovers in emerging markets. This paper is intended to fill this vacuum. In the paper, I discuss theoretically how TNCs may manage FDI technology spillovers across borders through selection of entry modes, selection of technologies, and selection of investment priorities, and test empirically some derived hypotheses. Based on the empirical findings, I discuss specific measures that TNCs may take to protect as well as exploit technology in emerging markets. The paper is organized as follows. In section 2, I review the current debate on cross-border technology management, develop a framework of FDI technology spillovers, and propose some hypotheses. In section 3, I explain the method, variables and data that are used to test the hypotheses. In section 4, I present the empirical results. In section 5, I discuss the main contributions and limitations of the study. The final section concludes the paper.

## THEORETICAL ANALYSES AND HYPOTHESES

When TNCs invest directly in an overseas market, they want to make full use of their technology to gain cost and sales advantages abroad, but do not want local firms to gain quick access to their technology lest they may lose competitive leadership to local competitors (Anderson and Gatigno, 1986; and Isobe, Makino and Montgomery, 2000). They need, therefore, to think about how to exploit as well as protect their technology in the overseas market they enter. Cross-border technology

management thus became an important topic of discussion in the management science, particularly in the management of technology (MOT) discourse. Driven by the needs to formulate appropriate technology strategy and business strategy at the same time, the MOT discourse tended to move away from the traditional R&D management, innovation management and technology planning schools, which discuss technology strategy in isolation, toward an emerging strategic MOT school. The strategic MOT school takes management of technology as "actually the practice of integrating technology strategy with business strategy in the company" (Gaynor, 1991, p.2; also Drejer, 1996).

An early attempt to integrate technology strategy with business strategy can be traced back to internalization theory (Buckley and Casson, 1976). According to internalization theory, selecting an appropriate entry strategy is an effective approach to technology management. That is, TNCs should choose to establish wholly owned subsidiaries rather than joint ventures (or other entry modes that involve local partners) to minimize unwanted technology appropriation. The rationale behind the argument is that whole ownership enables TNCs to exploit firm-specific knowledge internally, to avoid the costs of monitoring partner's use of their knowledge, and to minimize the risks of partner's appropriation of their knowledge. Despite the importance of entry strategy to cross-border technology management, however, increasing evidence shows that TNCs often have compelling reasons for entering an overseas market through joint ventures. In such developing countries as China, for instance, certain industries are open to joint ventures rather than wholly owned subsidiaries. TNCs that do not want to miss the opportunity of entering these industries have to establish joint ventures. Even without policy restrictions, moreover, TNCs may choose to establish joint ventures in order to benefit from local partners' knowledge, marketing networks and social networks. Entry mode selection based on internalization theory is, therefore, insufficient for cross-border technology management (Cannice, Chen and Daniels, 2003). TNCs have to think about what they should do to protect their technology if they have to enter an overseas market through joint ventures.

In search for new approaches, scholars recently turned to resource-based theory and focused on the technologies that TNCs use in their foreign affiliates. An important contribution was made by Cannice, Chen and Daniels (2004). It was argued that technologies can be divided into core technologies and periphery technologies according to how critical they are to the distinctive competencies of TNCs. Technologies can also be divided into dependent technologies and independent technologies according to the extent to which they can operate independently. Technologies can be further divided into tacit technologies and explicit technologies according to whether they can be codified. It was suggested that TNCs should choose to use periphery, dependent and tacit technologies in foreign affiliates in order to protect themselves from unwanted technology appropriation. This line of thinking is also evident in other recent studies, and has indeed offered a new approach to cross-border technology management (see, for instance, Norman, 2002; Cannice, Chen and Daniels, 2003; Jordan and Lowe, 2004).

As is argued in this paper, however, neither selection of technologies nor selection of entry modes can eliminate technology spillovers that are externalities under control of neither side of the interaction. No matter what types of technologies (core or periphery, dependent or independent, and tacit or explicit) are used in foreign affiliates (wholly owned or jointly owned), the technologies are likely to spill over to local firms through various channels. Unfortunately, the current research in management of technology stops at this point, and does not move further to investigate the specific channels by which foreign technologies spill over to local firms. Clearly, neither internalization theory nor resource-based theory can offer sufficient guidance in this regard.

To move a step further, it is essential to develop a framework about how technologies (no matter whether they are core or periphery, dependent or independent, and tacit or explicit) in foreign affiliates (no matter whether they are joint ventures or wholly owned subsidiaries) spill over to local firms via different channels. Based on prior empirical findings on sources of FDI technology spillovers, this paper proposes a tentative framework. As shown in Figure 1, foreign technologies may spill over to

local firms through the input foreign affiliates use in the production process as well as the output foreign affiliates produce and sell. The input includes both capital input, either tangible or intangible, and labour input, either skilled or unskilled. The output includes new products or traditional products on the one hand, and exported products or domestically sold products on the other. The productivity of local firms may be affected by foreign technology spillovers through these channels, either positively or negatively, depending on the nature and the scale of the spillovers through each of these specific channels.

(Insert Figure 1 about here)

It is crucial to note that these specific spillover channels actually represent investment priorities of TNCs in an overseas market. To manage FDI technology spillovers, therefore, TNCs can choose not only between different entry modes in light of internalization theory and between different technologies in light of resource-based theory, but also between different investment priorities in light of the spillover framework proposed in this paper. That is, they can choose between investment in tangible assets and investment in intangible assets, between investment in projects that require employment of skilled workers and investment in projects that require employment of unskilled workers, between investment in production of exported products and investment in production of domestically sold products, and between investment in development of new products and investment in production of traditional products. A combination between selection of entry modes, selection of technologies, and selection of investment priorities is a more promising approach to cross-border technology management.

The next step that follows from the above discussion is to investigate possible differentials in the spillover effect between specific channels of FDI technology spillovers in specific entry modes in relation to specific types of technologies used in foreign affiliates. As information of the specific types of technologies that TNCs use in their foreign affiliates is not available and related hypotheses are not testable, I focus discussion on possible differentials in the spillover effect between specific channels of

FDI technology spillovers in specific entry modes, and propose ten testable hypotheses about the differentials.[3]

With regards to entry modes, as suggested by internalization theory, there are marked differences in the organizational structure of different types of foreign affiliates, which are likely to lead to differentials in the impact of FDI on the productivity of local firms. Foreign affiliates in the form of joint ventures involve close cooperation between TNCs and local partners. Within this organizational framework, it is very difficult for TNCs to prevent their technology from being learnt by local partners and then being spread to other local firms. FDI is expected, therefore, to generate positive technology spillovers in joint ventures, and the positive spillover effect may be strong enough to offset any negative spillover effects. In wholly owned subsidiaries, by contrast, TNCs can exploit their firm-specific technology internally and can thus effectively prevent their technology from spilling over to local firms. I would expect, therefore, little positive FDI technology spillovers in wholly owned subsidiaries. Without the positive offsetting the negative, negative FDI technology spillovers may prevail. Hypotheses 1 and 2 are derived from these analyses.

***Hypothesis 1***. *Positive FDI technology spillovers are more likely to occur in joint ventures than wholly owned subsidiaries.*

***Hypothesis 2.*** *Negative FDI technology spillovers are more likely to occur in wholly owned subsidiaries than joint ventures.*

With regards to spillovers through input, tangible assets of foreign affiliates are difficult to be protected from being observed and copied by local firms and are, therefore, likely to generate positive technology spillovers to local firms. By contrast, intangible assets of foreign affiliates are normally well protected from being ‘stolen’ by local firms and are, therefore, unlikely to generate positive technology spillovers to local firms. Moreover, foreign affiliates that employ skilled workers with high salaries are likely to draw away skilled employees from local firms, thus negatively affecting the productivity of local firms. Foreign affiliates that employ unskilled workers with low salaries are not,

by contrast, in fierce competition with local firms for skilled workers and yet they have to provide training for the unskilled local recruits, so they are likely to generate positive technology spillovers to local firms. Hypotheses 3, 4, 5 and 6 are derived from these analyses.

**Hypothesis 3.** FDI technology spillovers via tangible assets are likely to be positive and the positive effect is likely to be, according to hypothesis 1, stronger in joint ventures than wholly owned subsidiaries.

**Hypothesis 4.** FDI technology spillovers via intangible assets are likely to be either insignificant or negative and the negative effect, if there is any, is likely to be, according to hypothesis 2, stronger in wholly owned subsidiaries than joint ventures.

**Hypothesis 5.** FDI technology spillovers via employment of skilled local workers are likely to be either insignificant or negative and the negative effect, if there is any, is likely to be, according to hypothesis 2, stronger in wholly owned subsidiaries than joint ventures.

**Hypothesis 6.** FDI technology spillovers via employment of unskilled local workers are likely to be positive and the positive effect is likely to be, according to hypothesis 1, stronger in joint ventures than wholly owned subsidiaries.

With regards to spillovers through products, the products foreign affiliates sell within host countries can be easily observed and imitated by local firms, so they may generate positive technology spillovers to local firms. The products foreign affiliate export to overseas markets are, by contrast, relatively difficult to be observed and imitated by local firms, so they may not generate positive technology spillovers to local firms. Similarly, the design of new products is normally treated as top secret and, therefore, is not easily observed and imitated by local firms, at least in the short run. Over time, however, new products become traditional products, and local firms manage to observe and imitate them. Therefore, traditional products, rather than new products, of foreign affiliates may

generate positive technology spillovers to local firms. Hypotheses 7, 8, 9 and 10 are derived from these analyses.

**Hypothesis 7**. FDI technology spillovers via exported products are likely to be either insignificant or negative and the negative effect, if there is any, is likely to be, according to hypothesis 2, stronger in wholly owned subsidiaries than joint ventures.

**Hypothesis 8.** FDI technology spillovers via locally sold products are likely to be positive and the positive effect is likely to be, according to hypothesis 1, stronger in joint ventures than wholly owned subsidiaries.

**Hypothesis 9.** FDI technology spillovers via newly developed products are likely to be either insignificant or negative and the negative effect, if there is any, is likely to be, according to hypothesis 2, stronger in wholly owned subsidiaries than joint ventures.

**Hypothesis 10.** FDI technology spillovers via traditional products are likely to be positive and the positive effect is likely to be, according to hypothesis 1, stronger in joint ventures than wholly owned subsidiaries.

Finally, it is useful to think about how the FDI technology spillovers analysed above are related to different types of technologies employed by TNCs in foreign affiliates, and to formulate some hypotheses that, though not testable in this research, may stimulate future research. As argued by Cannice, Chen and Daniels (2004), it is relatively easy for local firms to learn and benefit from core, independent and explicit technologies used by TNCs in their affiliates in host countries. In these affiliates, therefore, FDI is expected to generate positive technology spillovers to local firms, and the effect of positive technology spillovers may be strong enough to offset the effect of negative spillovers. In contrast, it is relatively difficult for local firms to learn and benefit from periphery, dependent and tacit technologies used by TNCs in their affiliates in host countries. In these affiliates, I would expect

little positive FDI technology spillovers. Without the positive offsetting the negative, negative FDI technology spillovers may prevail. Hypotheses 11 and 12 are derived from these analyses.

**Hypothesis 11.** Positive FDI technology spillovers via the various channels discussed above are more likely to occur in TNCs' affiliates that use core, independent and explicit technologies, especially if these affiliates are, according to hypothesis 1, in the form of joint ventures.

**Hypothesis 12.** Negative FDI technology spillovers via the various channels discussed above are more likely to occur in TNCs' affiliate that use periphery, dependent and tacit technologies, especially if these affiliates are, according to hypothesis 2, in the form of wholly owned subsidiaries.

In the following section, I proceed to empirically test the hypotheses that are testable with the data available.[4]

## METHOD, VARIABLES AND DATA

In the empirical estimation, I follow Aitken and Harrison (1999) and Tian (2007) to use basic log-linear production functions at the firm level in the form:

(1) $$Y_{ijt} = C + \beta_1 FDI_share_{jt} + \beta_3 X_{ijt} + \varepsilon_{ijt}$$

where log output *Y* for firm *i* in sector *j* at time *t* is regressed on a vector of inputs (***X***) and the presence of FDI in an industrial sector (*FDI_share*). On the basis of this benchmark model, I proceed to compare the effects of FDI technology spillovers in the three main entry modes prevailing in China – wholly owned subsidiary (WOS), equity joint venture (EJV) and cooperative joint venture (CJV), and divide *FDI_share* into three separate components representing the presence of the three entry modes in an industrial sector, respectively.[5] I thus rewrite Equation (1) as

(2) $$Y_{ijt} = C + \beta_1 EJV_share_{jt} + \beta_2 CJV_share_{jt} + \beta_3 WOS_share_{jt} + \beta_4 X_{ijt} + \varepsilon_{ijt}$$

where log output *Y* for firm *i* in sector *j* at time *t* is regressed on a vector of inputs (***X***), the presence of equity joint ventures in an industrial sector (*EJV_share*), the presence of cooperative joint ventures in an industrial sector (*CJV_share*), and the presence of wholly owned subsidiaries in an industrial sector (*WOS_share*).

I employ the ordinary least squares (OLS) approach in the empirical estimation with White's correction for heteroscedasticity.[6] Before running the regression, I need to consider some econometric issues. The first issue is related to possible omission of unobserved variables, such as firm-specific, industry-specific and time-specific factors that are unknown to the econometrician but known to the firm. These factors may affect the estimated coefficient of FDI technology spillovers. Following Haskel, Preira and Slaughter (2002), I use first differencing as well as industry dummies and year dummies to address the problem.[7] The second issue is related to possible multicollinearity between entry mode variables and industry dummies. I run correlation tests to detect this possibility. None of the correlation coefficient is more than 0.45, so multicollinearity between these variables is very unlikely.[8] The third issue is related to possible endogeneity of the explanatory variables. The decision on capital and labour inputs is, for instance, likely to be made on the basis of productivity, so is the decision on entry mode. If this is the case, the estimated coefficient of FDI technology spillovers may be biased. Two approaches can be used to deal with the problem. We can employ the econometric techniques developed by Olley and Pakes (1996) that take into account productivity-led variations in inputs of individual firms.[9] Alternatively, we can use the lagged value of all the explanatory variables that are suspected of being endogenous in the regression analysis. As the endogeneity problem is not only with the inputs but also with the entry mode selection, I prefer to use the second approach to deal with the problem. The empirical model to be estimated is thus expressed as Equation (3).

$$\Delta Y_{ijt} = C + \beta_1 \Delta EJV_share_{jt-1} + \beta_2 \Delta CJV_share_{jt-1} + \beta_3 \Delta WOS_share_{jt-1} + \beta_4 \Delta X_{ijt-1} + \varepsilon_{ijt} \quad (3)$$

I use the value added for output, the capital stock for capital input and the number of employment for labour input, respectively. I deflate the value added at the 1990 constant price and deflate the capital stock by the GDP deflator. In addition to the three major independent variables in the production function, I include four-digit ISIC industry dummies to control for productivity differences across industries, and annual time dummies to control for time-varying components. I also include a variable, productivity gap, to control for the productivity differentials between foreign affiliates and local firms, which is defined as the ratio of the average labour productivity of foreign affiliates in the relevant four-digit ISIC industry to the labour productivity of individual local firms in that industry.

The data are obtained from the China National Bureau of Statistics. The Department of Industrial and Transportation Statistics of the China National Bureau of Statistics maintains a large database that contains the most comprehensive information about domestic and foreign enterprises in China's industrial and transportation sector. The China National Bureau of Statistics kindly provided the author with a randomly chosen sample of manufacturing enterprises in the period from 1996 to 1999. The sample includes 11324 firms in each year, of which 1166 are foreign affiliates: 904 equity joint ventures, 103 cooperative joint ventures, and 159 wholly owned subsidiaries. The data of these foreign affiliates are used to produce variables representing foreign presence in an industrial sector. As the focus of the study is the spillover effect of FDI on local firms, the 1166 foreign affiliates are excluded in the sample for regression analysis. Consequently, the sample includes 10158 local firms only in each year. A number of observations are deleted because of missing information about the firm's output, capital or employment. The reduced sample includes 9055 local firms each year, and 36220 local firms for the four year period. Information about foreign share in new products and exports are available only for the years of 1998 and 1999, so the sample size is cut by half in regressions on the two variables.

The dataset contains detailed information about firm-level inputs and output. As determined by the purpose of the study, I am particularly interested in the information about the variables representing

foreign presence in an industrial sector. First, I use the equity joint venture share, the cooperative joint venture share and the wholly owned subsidiary share in total capital of an industrial sector to capture the effect of FDI technology spillovers on local firms through the capital of each of the three entry modes, respectively. I also use the equity joint venture share, the cooperative joint venture share and the wholly owned subsidiary share in tangible assets and intangible assets of an industrial sector to capture the effect of FDI technology spillovers on local firms through the tangible assets and the intangible assets of each of the three entry modes, respectively. Furthermore, I use the foreign affiliate share in total capital, tangible assets and intangible assets of an industrial sector to estimate the effect of FDI technology spillovers on local firms through the total capital, the tangible assets and the intangible assets of all foreign affiliates, respectively.

Second, I use the equity joint venture share, the cooperative joint venture share and the wholly owned subsidiary share in total employment of an industrial sector to capture the effect of FDI technology spillovers on local firms through the total workforce employed in each of the three entry modes, respectively. I use the employment shares of equity joint ventures, cooperative joint ventures and wholly owned subsidiaries with skilled workers in an industrial sector to capture the effect of FDI technology spillovers on local firms through skilled workers employed in each of the three entry modes, respectively.[10] I also use the employment shares of equity joint ventures, cooperative joint ventures and wholly owned subsidiaries with unskilled workers to capture the effect of FDI technology spillovers on local firms through unskilled workers employed in each of the three entry modes, respectively. Furthermore, I use the foreign affiliate share in total employment of an industrial sector, the employment share of foreign affiliates with skilled workers in an industrial sector and the employment share of foreign affiliates with unskilled workers in an industrial sector to estimate the effect of FDI technology spillovers on local firms through the total workforce, the skilled workers and the unskilled workers employed in all foreign affiliates, respectively.

Finally, I use the equity joint venture share, the cooperative joint venture share and the wholly owned subsidiary share in total sales of an industrial sector to capture the effect of FDI technology spillovers on local firms through the products of each of the three entry modes, respectively. I also use the equity joint venture share, the cooperative joint venture share and the wholly owned subsidiary share in exports, domestic sales, new products and traditional products of an industrial sector to capture the effect of FDI technology spillovers on local firms through the exported products, the locally sold products, the newly developed products and the traditional products of each of the three entry modes, respectively.[11] Furthermore, I use the foreign affiliate share in total sales, exports, domestic sales, new products and traditional products of an industrial sector to estimate the effect of FDI technology spillovers on local firms through the total products, the exported products, the locally sold products, the newly developed products and the traditional products of all foreign affiliates, respectively. The summary statistics of these variables are reported in Table 1.

(Insert Table 1 about here)

## RESULTS

Following Aitken and Harrison (1999) and Tian (2007), I use the ordinary least square approach in the regression analysis. As the variables representing foreign presence in capital, product and employment of an industrial sector are highly correlated, I do not include them in the same regression to avoid multicollinearity. In what follows, I report the empirical findings from the regression analysis on FDI technology spillovers via capital, employment and product in the three entry modes, respectively. We should bear in mind that the effects of technology spillovers through capital input, labour input, and product are, as indicated in Figure 1, dependent on the combined effects of technology spillovers through individual components of each of the three aggregate channels. We treat these individual components as disagregate channels of technology spillovers, and examine each of them in the empirical tests.

### Spillover Effect via Capital and Labor Inputs

I first estimate the effect of FDI technology spillovers on local firms through capital and labour inputs in the three entry modes, and report the results in Table 2. With regards to capital input, as shown in column 1, the coefficient on the share of equity joint ventures in the capital of an industrial sector and the coefficient on the share of cooperative joint ventures in the capital of an industrial sector are both positive and statistically significant, indicating that local firms in industrial sectors with more foreign participation in capital in the form of joint ventures are significantly more productive than those in sectors with less foreign participation in capital in the form of equity joint ventures and cooperative joint ventures. By contrast, the coefficient on the share of wholly owned subsidiaries in the capital of an industrial sector is positive but statistically insignificant, indicating that local firms in industrial sectors with more foreign participation in capital in the form of wholly owned subsidiaries are not significantly more productive than those in sectors with less foreign participation in capital in the form of wholly owned subsidiaries. The results support hypothesis 1, and are consistent with what were found in Javorcik (2004).

(Insert Table 2 about here)

At the disaggregate level of capital input, as shown in column 2, the coefficient on the share of equity joint ventures in the tangible assets of an industrial sector and the coefficient on the share of cooperative joint ventures in the tangible assets of an industrial sector are both positive and statistically significant, while the coefficient on the share of wholly owned subsidiaries in the tangible assets of an industrial sector is positive but statistically insignificant. As shown in column 3, the coefficient on the share of equity joint ventures in the intangible assets of an industrial sector, the coefficient on the share of cooperative joint ventures in the intangible assets of an industrial sector and the coefficient on the share of wholly owned subsidiaries in the intangible assets of an industrial sector are all positive but statistically insignificant. The results suggest that the positive technology spillovers are generated by the tangible assets of joint ventures rather than the tangible assets of wholly owned subsidiaries, and

that technology spillovers are not generated at all by the intangible assets of any foreign affiliates. The results support hypotheses 3 and 4, and further back up hypothesis 1.

With regards to labor input, as shown in column 4, the coefficient on the share of equity joint ventures in the employment of an industrial sector and the coefficient on the share of cooperative joint ventures in the employment of an industrial sector are both positive but statistically insignificant, indicating that equity joint ventures and cooperative joint ventures both have no significantly positive effect of technology spillovers on local firms through employment. By contrast, the coefficient on the share of wholly owned subsidiaries in the employment of an industrial sector is negative and statistically significant, indicating that wholly owned subsidiaries have a significantly negative effect on the productivity of local firms through employment. The results support hypothesis 2.

At the disaggregate level of labor input, as shown in column 5, the coefficient on the employment share of equity joint ventures with skilled workers in an industrial sector and the coefficient on the employment share of cooperative joint ventures with skilled workers in an industrial sector are both negative but statistically insignificant, while the coefficient on the employment share of wholly owned subsidiaries with skilled workers in an industrial sector is negative and statistically significant. As shown in column 6, the coefficient on the employment share of equity joint ventures with unskilled workers in an industrial sector and the coefficient on the employment share of cooperative joint ventures with unskilled workers in an industrial sector are both positive and statistically significant, while the coefficient on the employment share of wholly owned subsidiaries with unskilled workers in an industrial sector is positive but statistically insignificant. The results suggest negative technology spillovers occur through the employment of skilled workers in wholly owned subsidiaries while positive technology spillovers take place through the employment of unskilled workers in joint ventures. The results support hypotheses 5 and 6, and further back up both hypotheses 1 and 2.

**Spillover Effect via Products**

I then compare the effects of FDI technology spillovers on local firms through products in the three entry modes, and report the results in Table 3. As shown in column 1, the coefficient on the share of equity joint ventures in the total value of sales of an industrial sector and the coefficient on the share of cooperative joint ventures in the total value of sales of an industrial sector are both positive but statistically insignificant, while the coefficient on the share of wholly owned subsidiaries in the total value of sales of an industrial sector is negative and statistically significant. The result suggests that joint ventures do not have a significantly positive effect of technology spillovers on local firms through product sales, while wholly owned subsidiaries generate a significantly negative effect on the productivity of local firms through product sales. The results further back up hypothesis 2.

(Insert Table 3 about here)

At the disaggregate level of products, as shown in column 2, the coefficient on the share of equity joint ventures in the exports of an industrial sector and the coefficient on the share of cooperative joint ventures in the exports of an industrial sector are both negative but statistically insignificant, while the coefficient on the share of wholly owned subsidiaries in the exports of an industrial sector is negative and statistically significant. As shown in column 3, the coefficient on the share of equity joint ventures in the domestically consumed products of an industrial sector and the coefficient on the share of cooperative joint ventures in the domestically consumed products of an industrial sector are both positive and statistically significant, while the coefficient on the share of wholly owned subsidiaries in the domestically consumed products of an industrial sector is negative and statistically insignificant. The results suggest that negative technology spillovers are generated by the products that wholly owned subsidiaries export to overseas markets while positive technology spillovers are generated by the products that joint ventures sell at domestic market in China. The results support hypotheses 7 and 8, and further back up hypotheses 1 and 2.

As shown in column 4, the coefficient on the share of equity joint ventures in the new products of an industrial sector and the coefficient on the share of cooperative joint ventures in the new products of an industrial sector are both positive but statistically insignificant, while the coefficient on the share of wholly owned subsidiaries in the new products of an industrial sector is negative and statistically insignificant. As shown in column 5, the coefficient on the share of equity joint ventures in the traditional products of an industrial sector and the coefficient on the share of cooperative joint ventures in the traditional products of an industrial sector are both positive and statistically significant, while the coefficient on the share of wholly owned subsidiaries in the traditional products of an industrial sector is positive but statistically insignificant. The results indicate that positive technology spillovers are generated by the traditional products that joint ventures produced, and that technology spillovers are not generated at all by the new products that any foreign affiliates produced. The results support hypotheses 9 and 10, and further back up hypothesis 1.

## DISCUSSION

As shown in the study, the effect of FDI technology spillovers differs significantly from one channel to another, from one entry mode to another, and from one type of technology to another. FDI technology spillovers are difficult, if not impossible, to be completely brought under control. However, the substantial differentials in the effect of FDI technology spillovers found in this study shed light on how TNCs may manage technology spillovers strategically in emerging markets. In this section, I discuss main findings of the study and their managerial implications, and point to limitations of the study and areas of future research.

### Findings and Their Managerial Implications

Positive FDI technology spillovers are, as suggested by internalization theory and evidenced in this study, more likely to occur in joint ventures than wholly owned subsidiaries. Whenever possible, therefore, TNCs should establish wholly owned subsidiaries to protect technology. In reality, however, TNCs often have compelling reasons to establish joint ventures rather than wholly owned subsidiaries

in emerging markets and therefore have to look for alternative approaches to cross-border technology management. Selection of technologies is, as suggested by resource-based theory and evidenced in the study by Cannice, Chen and Daniels (2003, 2004), an alternative approach. That is, TNCs can choose to use periphery, dependent and tacit technologies in the affiliates they establish in emerging markets to minimize unwanted technology appropriation.

Nevertheless, FDI technology spillovers are externalities that may take place through a variety of channels no matter what types of technologies TNCs choose to use in their foreign affiliates. To address the problem, the study develops a framework to explain how FDI technology spillovers take place through various channels under different entry modes and proposes a number of hypotheses. The study contends that these spillover channels actually represent investment priorities of TNCs in foreign markets, and that selection of investment priorities is therefore as important to TNCs in managing technology spillovers as selection of entry modes and selection of technologies. This is a significant contribution to the literature on FDI technology spillovers. In testing the hypotheses, the study reaches a number of empirical findings that have practical implications for TNCs in managing FDI technology spillovers in emerging markets.

The study finds, for instance, that positive technology spillovers occur through tangible assets rather than intangible assets, which implies that TNCs should make investments in the form of intangible assets rather than tangible assets to protect their technology in the joint ventures they establish in emerging markets. The study also finds that positive technology spillovers occur through employment of unskilled workers rather than employment of skilled workers, which implies that TNCs should focus on investment projects that require employment of skilled local workers rather than investment projects that require hiring and training of unskilled local workers in order to protect their technology in the joint ventures they establish in emerging markets. The study further finds that positive technology spillovers occur through locally sold products rather than exported products and through traditional products rather than newly developed products, which implies that TNCs should

focus on investments in development of new products that target overseas markets rather than investments in production of traditional products to be sold in the local market in order to protect their technology in the joint ventures they establish in emerging markets.

In addition, the study finds strong evidence of a negative effect of technology spillovers via the products that TNCs' wholly owned subsidiaries export abroad and via the skilled workers that TNCs' wholly owned subsidiaries employ with attractive salaries. The finding suggests that TNCs can make full use of wholly owned subsidiaries in competition with rival local firms in emerging markets if they prioritize investment projects appropriately, that is, if they focus on export-oriented projects to take advantage of the market stealing effect and/or focus on projects that require employment of skilled local workers to take advantage of the skill stealing effect. The study thus provides guidance to TNCs not only on how to minimise positive technology spillovers to local firms but also on how to take full advantage of negative technology spillovers in competition with rival local firms in emerging markets.

**Limitations and Future Research Areas**

Despite the path-breaking way of thinking, the interesting empirical findings and the important managerial implications, the study is limited in the scope of analysis and the depth of investigation. First of all, TNCs often face other pressing strategic issues in emerging markets, and have to compromise their concern over technology spillovers in order to address these issues. They may have to establish, for instance, joint ventures to please the government in emerging markets for possible support in a business project. They may have to focus on production of locally sold products and promotion of traditional products in emerging markets in order to pre-empty the market before their rivals. They may have to invest in projects that hire unskilled local workers in order to establish good relationships with the government in emerging markets that are facing a serious problem of unemployment. They may have to use core, independent and explicit technologies in the affiliates they establish in emerging markets in exchange for market entry permission. In the real business world, therefore, TNCs have to balance these strategic concerns against the concern over technology spillovers.

Further efforts need to be made to examine how TNCs may manage FDI technology spillovers under these circumstances.

Due to data constraints, moreover, the study does not distinguish between foreign affiliates that use different technologies, and thus cannot empirically test hypotheses about selection of technologies. Future research may move in this direction. Surveys can be, for instance, carried out to collect information on the technologies TNCs use in their foreign affiliates. With the survey data, foreign affiliates can be divided into those that use periphery technologies and those that use core technologies, those that use dependent technologies and those that use independent technologies, and those that use tacit technologies and those that use explicit technologies. The regression model of this study can be applied to these foreign affiliates to investigate how the differences in the technologies used in the foreign affiliates may affect FDI technology spillovers to local firms. As technology data are sensitive, however, collection of the survey data could be a very difficult process.

Furthermore, FDI technology spillovers are a complicated process, and the discussion of FDI technology spillovers in this study is by no mean exclusive. Further efforts need to be made to examine other possible factors in the process of FDI technology spillovers. A number of interesting research questions can be raised in this regard. How do FDI technology spillovers affect different types of local firms in a host country? How do FDI technology spillovers differ between one type of host countries and another type of host countries? How do FDI technology spillovers differ between the early stage of foreign entry and the late stage of foreign entry? Does cultural distance affect FDI technology spillovers? How do TNCs take corporate social responsibility into consideration in managing FDI technology spillovers in emerging markets? Research on these questions is quite demanding in data collection and technical analysis, but is very rewarding as answers to the questions are doomed to deepen our understanding of FDI technology spillovers and offer TNCs new insights into how to manage FDI technology spillovers in emerging markets.

## CONCLUSION

In conclusion, the study takes the initiative to discuss how TNCs may deal with the challenge of managing FDI technology spillovers in emerging markets. In order to exploit as well as protect technology, the study argues, TNCs can choose between different entry modes, between different technologies, and between different investment priorities when they enter emerging markets. TNCs may use any of the three approaches or any combination of them in consideration of the particular circumstances they face. There are, however, some limitations in the study that need to be overcome in future research.

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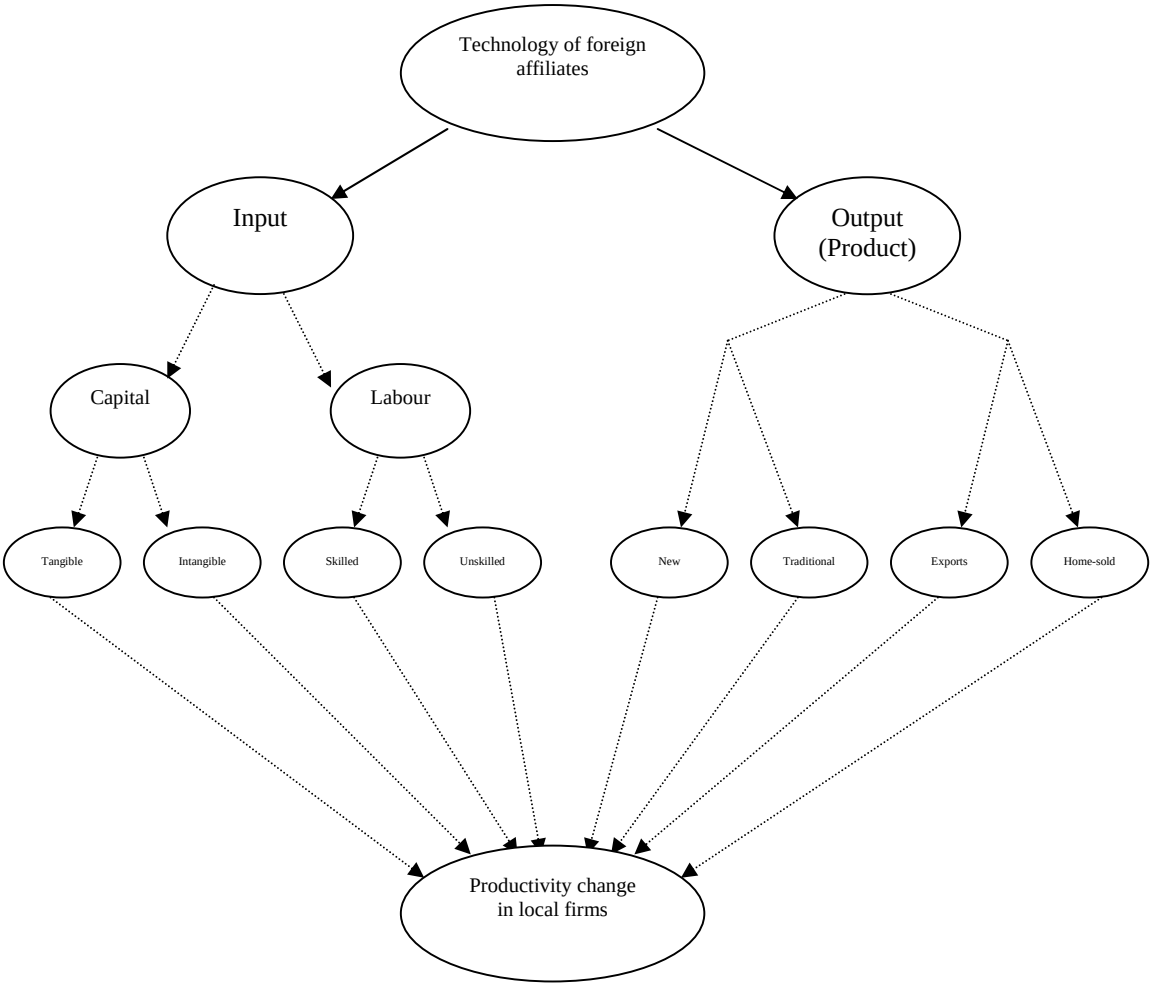
# Figures and Tables

## Figure 1: Channels of FDI Technology Spillovers



## Table 1. Summary statistics

| Name of variables | Observation | Mean | Standard deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| *Log Y* | 36220 | 9.46 | 1.48 | 2.21 | 16.53 |
| *Log K* | 36220 | 11.12 | 1.18 | 2.88 | 17.74 |
| *Log L* | 36220 | 6.89 | 1.02 | 1.96 | 12.25 |
| *EJV share in capital* | 36220 | 0.12 | 0.10 | 0.00 | 0.64 |
| *CJV share in capital* | 36220 | 0.05 | 0.03 | 0.00 | 0.12 |
| *WOS share in capital* | 36220 | 0.03 | 0.05 | 0.00 | 0.38 |
| *All-FA share in capital* | 36200 | 0.14 | 0.12 | 0.00 | 0.95 |
| *EJV share in tangible assets* | 36220 | 0.12 | 0.10 | 0.00 | 0.63 |
| *CJV share in tangible assets* | 36220 | 0.05 | 0.03 | 0.00 | 0.12 |
| *WOS share in tangible assets* | 36220 | 0.03 | 0.05 | 0.00 | 0.39 |
| *All-FA share in tangible assets* | 36200 | 0.15 | 0.14 | 0.00 | 0.74 |
| *EJV share in intangible assets* | 36220 | 0.15 | 0.13 | 0.00 | 0.87 |
| *CJV share in intangible assets* | 36220 | 0.06 | 0.16 | 0.00 | 0.18 |
| *WOS share in intangible assets* | 36220 | 0.04 | 0.07 | 0.00 | 0.39 |
| *All-FA share in intangible assets* | 36200 | 0.20 | 0.17 | 0.00 | 0.95 |
| *EJV share in sales* | 36220 | 0.14 | 0.11 | 0.00 | 0.59 |
| *CJV share in sales* | 36220 | 0.03 | 0.04 | 0.00 | 0.12 |
| *WOS share in sales* | 36220 | 0.04 | 0.07 | 0.00 | 0.48 |
| *All-FA share in sales* | 36200 | 0.18 | 0.15 | 0.00 | 0.92 |
| *EJV share in exports* | 18110 | 0.21 | 0.24 | 0.00 | 0.95 |
| *CJV share in exports* | 18110 | 0.02 | 0.04 | 0.00 | 0.47 |
| *WOS share in exports* | 18110 | 0.10 | 0.17 | 0.00 | 0.85 |
| *All-FA share in exports* | 18110 | 0.32 | 0.29 | 0.00 | 0.96 |
| *EJV share in domestic sales* | 18110 | 0.13 | 0.12 | 0.00 | 0.56 |
| *CJV share in domestic sales* | 18110 | 0.03 | 0.04 | 0.00 | 0.10 |
| *WOS share in domestic sales* | 18110 | 0.02 | 0.05 | 0.00 | 0.40 |
| *All-FA share in domestic sales* | 18110 | 0.15 | 0.14 | 0.00 | 0.69 |
| *EJV share in new products* | 18110 | 0.15 | 0.17 | 0.00 | 0.95 |
| *CJV share in new products* | 18110 | 0.02 | 0.07 | 0.00 | 0.55 |
| *WOS share in new products* | 18110 | 0.01 | 0.03 | 0.00 | 0.36 |

| | | | | | |
|---|---|---|---|---|---|
| *All-FA share in new products* | 18110 | 0.17 | 0.19 | 0.00 | 0.95 |
| *EJV share in traditional products* | 18110 | 0.13 | 0.11 | 0.00 | 0.58 |
| *CJV share in traditional products* | 18110 | 0.03 | 0.04 | 0.00 | 0.12 |
| *WOS share in traditional products* | 18110 | 0.05 | 0.08 | 0.00 | 0.64 |
| *All-FA share in traditional products* | 18110 | 0.18 | 0.16 | 0.00 | 0.93 |
| *EJV share in employment* | 36220 | 0.07 | 0.08 | 0.00 | 0.54 |
| *CJV share in employment* | 36220 | 0.01 | 0.02 | 0.00 | 0.42 |
| *WOS share employment* | 36220 | 0.06 | 0.8 | 0.00 | 0.46 |
| *All-FA share in employment* | 36200 | 0.08 | 0.19 | 0.00 | 0.57 |
| *EJV share in skilled workers* | 36220 | 0.07 | 0.07 | 0.00 | 0.49 |
| *CJV share in skilled workers* | 36220 | 0.01 | 0.02 | 0.00 | 0.07 |
| *WOS share in skilled workers* | 36220 | 0.06 | 0.06 | 0.00 | 0.47 |
| *All-FA share in skilled workers* | 36200 | 0.08 | 0.08 | 0.00 | 0.53 |
| *EJV share in unskilled workers* | 36220 | 0.06 | 0.7 | 0.00 | 0.50 |
| *CJV share in unskilled workers* | 36220 | 0.05 | 0.6 | 0.00 | 0.08 |
| *WOS share in unskilled workers* | 36220 | 0.01 | 0.01 | 0.00 | 0.35 |
| *All-FA share in unskilled workers* | 36200 | 0.07 | 0.08 | 0.00 | 0.54 |
| *F/D gap* | 36220 | 24.67 | 169.38 | 0.01 | 9312.91 |

## Table 2. Spillover effect via capital and Labor inputs

| Variables | Regressions | | | | | |
|---|---|---|---|---|---|---|
| | Capital inputs | | | Labor inputs | | |
| | (1) Capital | (2)Tangible assets | (3) Intangible assets | (4) Employment | (5) Skilled workers | (6) Unskilled workers |
| *Constant* | -0.64<br>(-1.33) | -0.66<br>(-1.35) | -0.67<br>(-1.35) | -0.72<br>(-1.41) | -0.73<br>(-1.46) | -0.69<br>(-1.41) |
| *K* | 0.70<br>(94.66)*** | 0.71<br>(94.72)*** | 0.70<br>(94.74)*** | 0.70<br>(94.05)*** | 0.70<br>(94.72)*** | 0.70<br>(94.71)*** |
| *L* | 0.29<br>(33.26)*** | 0.28<br>(33.12)*** | 0.29<br>(33.21)*** | 0.29<br>(33..26)*** | 0.29<br>(33.19)*** | 0.29<br>(33.18)*** |
| *F/D gap* | -0.0011<br>(-12.05)*** | -0.0012<br>(-12.12)*** | -0.0011<br>(-12.09)*** | -0.0011<br>(-12.11)*** | -0.0011<br>(-12.06)*** | -0.0011<br>(-12.11)*** |
| *EJV share* | 0.53<br>(2.28)** | 0.56<br>(2.36)** | 0.15<br>(1.08) | 0.26<br>(1.51) | -0.17<br>(-1.53) | 0.26<br>(2.28)** |
| *CJV share* | 0.56<br>(2.27)** | 0.49<br>(2.14)** | 0.19<br>(1.26) | 0.27<br>(1.54) | -0.15<br>(-1.26) | 0.42<br>(2.44)** |
| *WOS share* | 0.12<br>(0.27) | 0.10<br>(0.22) | 0.03<br>(0.08) | -0.41<br>(-1.74)* | -0.46<br>(-2.57)** | 0.16<br>(0.97) |
| Adjusted $R^2$ | 0.56 | 0.55 | 0.55 | 0.55 | 0.53 | 0.54 |

Notes: 1) All specifications include annual time dummies and four-digit ISIC industry dummies. Numbers in parentheses under the coefficient estimates are White heteroscedasticity consistent T ratios; 2) * p < 0.10; ** p < 0.5; and *** p < 0.1.

## Table 3. Spillover effect via products

| Variables | Regressions | | | | |
|---|---|---|---|---|---|
| | (1) Sales | (2) Exports | (3) Domestic sales | (4) New products | (5) Traditional products |
| *Constant* | -0.45<br>(-1.08) | -0.44<br>(-1.02) | -0.46<br>(-1.14) | -0.58<br>(-1.28) | -0.54<br>(-1.25) |
| *K* | 0.70<br>(94.088)*** | 0.70<br>(94.19)*** | 0.70<br>(94.25)*** | 0.70<br>(94.15)*** | 0.70<br>(94.13)*** |
| *L* | 0.29<br>(33.24)*** | 0.28<br>(33.15)*** | 0.29<br>(33.23)*** | 0.28<br>(33.17)*** | 0.28<br>(33.18)*** |
| *F/D gap* | -0.0013<br>(-12.15)*** | -0.0011<br>(-12.05)*** | -0.0013<br>(-12.14)*** | -0.0011<br>(-12.07)*** | -0.0013<br>(-12.13)*** |
| *EJV_share* | 0.21<br>(1.64) | -0.14<br>(-1.24) | 0.35<br>(1.84)* | 0.11<br>(1.12) | 0.32<br>(1.88)* |
| *CJV_share* | 0.22<br>(1.58) | -0.17<br>(-1..46) | 0.43<br>(1.91)* | 0.15<br>(0.84) | 0.46<br>(1.94)* |
| *WOS_share* | -0.30<br>(-1.83)* | -0.76<br>(-3.88)** | -0.18<br>(-0.72) | -0.07<br>(-0.21) | 0.14<br>(0.82) |
| Adjusted $R^2$ | 0.56 | 0.55 | 0.56 | 0.55 | 0.56 |

Notes: 1) All specifications include annual time dummies and four-digit ISIC industry dummies. Numbers in parentheses under the coefficient estimates are White heteroscedasticity consistent T ratios; 2) * p < 0.10; ** p < 0.5; and *** p < 0.1.

**Notes**

[*] I would like to thank Professor Peter W. Liesch, Editor of *Journal of World Business* and two anonymous reviewers for their helpful comments, suggestions and advice. I would also like to thank Wenjun Li for technical assistance.

[1] See United Nations: *World Investment Report*, 2005-2008.

[2] I would like to thank an anonymous reviewer for recommending some of the references to the author.

[3] In fact, it is very difficult to gain information about the types of technologies that TNCs use in their foreign affiliates. Consequently, prior research on technology selection had to use subjective measures gathered from interviews with executives of TNCs, which is very hard to be conducted at a large scale and is unreliable because technology issues are normally treated as top secret in TNCs.

[4] I would like to thank an anonymous reviewer for advice on formulating these hypotheses.

[5] The three entry modes account for about 99% of all FDI in China. The difference between equity joint venture and cooperative joint venture lies in that foreign and domestic partners share the benefits and liabilities of the joint venture on the basis of respective equity shares in the former, but on the basis of an agreed contract in the later.

[6] I also use an autocorrelation and heteroscedasticity robust estimation based on the Newey-West method to achieve consistent estimates in the presence of generally unspecified autocorrelation, and the results remain virtually unchanged. I would like to thank an anonymous reviewer for advice on this method.

[7] It is argued that the GMM method may be an alternative to the OLS method to deal with the problem. I also tried the GMM estimations and the results hardly change. I would like to thank an anonymous reviewer for pointing out this alternative method.

[8] I would like to thank an anonymous reviewer for pointing to this possibility.

[9] Please also refer to Levinsohn and Petrin (2003) and Javorcik (2004).

[10] All foreign affiliates are classified into high-salary and low-salary groups according to the average level of annual salary of the employees, with the benchmark being the firm with the medium salary level. Generally speaking, the level of salary represents the level of skills of workers.

[11] Domestic sales are calculated as the total sales minus exports, while traditional products are calculated as the total sales minus new products.