Knowledge Spillovers from Foreign Direct Investment in R&D: Evidence from a Chinese Science Park*

Yasuyuki Todo† Weiying Zhang‡ Li-An Zhou§

June 16, 2006

Abstract

This study examines whether foreign direct investment generates knowledge spillovers to domestically-owned firms, using firm-level panel data from a Chinese science park. The analysis find positive effects of R&D stocks of foreign-owned firms on the productivity of domestic firms, while effects of capital stocks of foreign firms are absent. These results suggest that knowledge of foreign firms spills over through their R&D activities, but not through their production activities. In addition, we find that spillovers from firms from Hong Kong, Macau, and Taiwan are absent, suggesting that the size of FDI spillovers is smaller when the technology gap between foreign and domestic firms is smaller.

Keywords: knowledge spillovers, foreign direct investment, R&D activities, China

JEL classifications: F23, O12, O30

---

*The authors would like to thank Kyoji Fukao, Kozo Kiyota, Sadayuki Takii, and seminar participants at Aoyama Gakuin University and the annual meetings of the Japanese Economic Association for helpful comments, and Linn Gu for excellent research assistance. Todo is grateful to the New Energy and Industrial Technology Organization for financial support. Zhou thanks the Center for Research in Private Enterprises at Zhejiang University for financial support.

†Corresponding author. School of International Politics, Economics and Business, Aoyama Gakuin University, 4-4-25, Shibuya-ku, Shibuya, Tokyo 150-8366 Japan (tel.: +81-3-3409-8549; fax: +81-3-5485-0782; e-mail: yastodo@sipeb.aoyama.ac.jp).

‡Guanghua School of Management, Peking University.

§Guanghua School of Management, Peking University.

1 Introduction

A large number of empirical studies have examined whether less developed countries (LDCs) can learn foreign knowledge through spillovers from foreign direct investment (FDI) to domestically-owned firms (hereafter, domestic firms). Existing studies that use firm-level data typically test this hypothesis by estimating the effect of the presence of foreign-owned firms (hereafter, foreign firms) in a particular industry on the productivity of domestic firms in the same industry. However, the results from the existing studies have been generally mixed in particular in the first wave of this literature in the 1990s. On the one hand, FDI was found to have a positive effect on the labor productivity of domestic firms in the Mexican (Kokko, 1994), Taiwanese (Chuang and Lin, 1999), and Indonesian (Blomström and Sjöholm, 1999; Sjöholm, 1999; Takii, 2005) manufacturing industries. On the other hand, Haddad and Harrison (1993) and Kinoshita (2001) did not find a significant spillover effect from FDI in Morocco and the Czech Republic, respectively. Furthermore, Aitken and Harrison (1999) found that FDI actually lowered local productivity in Venezuela, arguing that the negative effect of FDI may be due to the strong competition exerted by foreign companies on their domestic counterparts.[1]

More recent studies argue possible reasons for and solutions to this contradiction in the results. First, Görg and Strobl (2000) conclude using a meta analysis that the contradiction is due to whether cross-sectional or panel data are used and how the extent of FDI penetration is defined. Second, Haskel, Pereira, and Slaughter (2002) and Keller and Yeaple (2003) claim, following Aitken and Harrison (1999), that to test the presence of spillovers from FDI, one should distinguish the spillover effect of foreign firms from a negative effect of foreign firms through an increase in market competition. Thus, these studies include as regressors the market share of domestic firms at the industry level or the size of markups of domestic firms to distinguish between the two effects of foreign firms. Then, Haskel, Pereira, and Slaughter (2002) and Keller and Yeaple (2003) found a positive

[1] See Saggi (2002), Keller (2004), and Lipsey and Sjöholm (2004) for excellent surveys on this issue.

effect of FDI on local productivity in the United Kingdom and the United States, respectively.[2] For the same reason, Görg and Hijzen (2004) distinguished between the presence of foreign firms in the domestic market and export market, finding that the latter has a positive effect on the productivity of domestic firms while the former has no significant effect. This confirms that foreign firms benefit domestic firms when foreign firms do not steel the market of domestic firms. Third, Javorcik (2004), Blalock and Gertler (2004), and Kugler (2006) show that spillovers occur only through backward linkages, i.e., from foreign firms to their local suppliers in upstream industries, but not horizontally, i.e., within industries, using data from Lithuania, Indonesia, and Columbia, respectively.

Another possible reason for these mixed results addressed in Todo and Miyamoto (2006) is the role of foreign firms' R&D activities in knowledge spillovers. More specifically, it is likely that the presence of R&D activities performed by foreign firms in the host country can enhance the extent of knowledge spillovers from foreign to domestic firms. This is because local workers and engineers working in the R&D unit of foreign firms gain a greater amount of knowledge than workers in foreign firms that do not perform R&D in the host country, and the knowledge obtained by these engineers may further diffuse to domestic firms through work-related discussions, job turnover, and forward and backward linkages.[3] Todo and Miyamoto (2006) distinguish between the size of R&D-performing and non-R&D-performing foreign firms in their plant-level analysis of the Indonesian manufacturing industries, using the industry share of the two types of foreign firm separately as regressors. They show that R&D-performing foreign firms have a positive effect on the productivity growth of domestic firms, while non-R&D-performing foreign firms have no such effect.[4]

This paper also examines whether R&D activities of foreign firms in the host country enlarge the degree of knowledge spillovers from FDI, using firm-level panel data for a Chinese science park during the period 2000–2003. For this purpose, this paper modifies the method of Todo and Miyamoto

[2] Note that although these two studies use data for developed countries, their methodology can be applicable to studies on FDI spillovers to LDCs.

[3] Another possible channel of FDI spillovers is R&D activities by domestic firms, as Kinoshita (2001) and Blalock and Gertler (2004) found. In addition, Todo and Miyamoto (2002) and Blalock and Gertler (2004) found a positive effect of human resource development by foreign and by domestic firms, respectively, on FDI spillovers.

[4] Kiyota (2005) uses firm-level data from Japan and finds spillovers from R&D activities of foreign firms. However, comparison between spillovers through foreign firms' production and R&D activities is not the focus of his paper.

(2006) and distinguishes between the amount of foreign firms' physical capital stocks and R&D stocks, regarding the former as the extent of foreign firms' production activities and the latter as the extent of foreign firms' R&D activities. An advantage of our dataset over the datasets used in other previous studies that usually cover a whole country is that firms in our dataset are geographically closely located. Due to this geographical proximity, spillovers are more likely to occur among firms examined in this study than in the case of other national-level studies.[5] Our baseline regression uses the system generalized method of moments (GMM) estimation developed by Blundell and Bond (1998) in order to eliminate firm-specific time-invariant effects by first-differencing and to correct for endogeneity using lagged variables as instruments.

The results from our estimations generally indicate that the effect of foreign R&D stocks on domestic value added is positive, statistically significant, and quantitatively large, whereas the effect of foreign capital stocks is insignificant. These results suggest that foreign knowledge spills over through R&D activities of foreign firms but not through production activities of foreign firms.

In addition, we find that spillovers from firms from Hong Kong, Macau, and Taiwan are absent. Since other foreign firms are mostly from technologically advanced countries, such as Japan and the United States, this evidence suggests that the size of FDI spillovers is larger when the technology gap between foreign and domestic firms is larger.

The remainder of the paper is organized as follows. Section 2 discusses the econometric procedure employed in the analysis. Section 3 presents the dataset and the variables used in the regression, whereas the results of the estimation are discussed in Section 4. Section 5 concludes.

[5] Knowledge diffusion is geographically localized according to Jaffe, Trajtenberg, and Henderson (1993), Jaffe and Trajtenberg (1998), and Jaffe and Trajtenberg (1999); Keller (2002).

2 Estimation Procedures

2.1 Estimation Equation

To estimate the impact of the presence of foreign firms on local productivity, we use the following estimation equation based on a Cobb-Douglas production function:

$$\ln Y_{it} = \beta_K \ln K_{it} + \beta_L \ln L_{it} + \beta_R \ln RDS_{it} + \delta FDI_{j(i),t-1} + x'_{it}\gamma + \alpha_i + \nu_t + \varepsilon_{it}, \tag{1}$$

where Y_{it}, K_{it}, L_{it}, and RDS_{it} are value added, capital stocks, labor, and R&D stocks of firm i in industry j at time t, respectively. α_i, ν_t, and ε_{it} are the firm-specific constant term, the year-specific constant term, and the error term, respectively.

$FDI_{j(i),t-1}$ represents the size of foreign firms in industry j in year $t-1$. We interpret that the size of the corresponding coefficient, δ, reflects the extent of knowledge spillovers from foreign firms. Assuming a time lag between foreign firms' activities and domestic firms' acquisition of foreign knowledge through spillovers, we take a one-year lag. More specifically, we employ two measures of the aggregate size of foreign firms at the industry level: the total amount of capital and R&D stocks of foreign firms in the industry, $FK_{j(i),t-1}$ and $FRDS_{j(i),t-1}$, respectively, in logs. We presume that $FK_{j(i),t-1}$ represents the extent of foreign firms' production at the industry level, whereas $FRDS_{j(i),t-1}$ represents the extent of foreign firms' R&D activities. Thus, by employing these two measures, we can test whether FDI in production or FDI in R&D is a channel of knowledge spillovers from FDI.

Vector x_{it} denotes other regressors. In particular, we follow Haskel, Pereira, and Slaughter (2002) and Keller and Yeaple (2003) and include in x_{it} the market share of firm i in the industry, $SHARE_{it}$, to take into account that the presence of foreign firms may have a negative effect on local production, since foreign firms steal the market share and the monopoly power of domestic firms.[6]

In addition, x_{it} includes the share of exports to total sales in the industry, $EXP_{j(i),t}$, which

[6]It should be noted that since our dataset covers only firms in Zhongguancun Science Park, rather than all firms in the market, $SHARE$ in our regression is the market share of the firm in the science park. However, Zhongguancun Science Park is very large in size as we will explain later, we assume that the market share in the Science Park reflects the market share in the whole market.

is presumably correlated with the industry-specific productivity level since industries with a high productivity level may export more. Since high-productivity industries are likely to attract more FDI, the estimated impact of FDI variables on value added may reflect reverse causality. The inclusion of the industry export share can avoid this problem.

Although we employ *stocks* of foreign capital and R&D at the industry level to represent the extent of foreign firms, previous studies on FDI spillovers often use the industry *share* of foreign firms in production, employment, or capital stock.[7] One reason for our use of the stock of foreign capital and R&D, rather than foreign shares, is that the authors using foreign shares implicitly assume that the degree of knowledge spillovers from foreign firms in a particular industry to domestic firms decreases as the size of the industry expands.[8] This is because, for example, the chance for workers in domestic firms to meet workers in foreign firms is smaller in a larger industry and thus the chance for domestic workers to learn foreign knowledge is also smaller. However, this assumption may not hold in the case of this paper due to the distinct feature of the dataset employed in this paper. Our dataset covers firms in a Chinese science park located in Beijing, unlike the datasets used in the previous studies that cover a whole country. Since firms in the science park are geographically close to each other, the chance for workers in domestic firms to learn knowledge of foreign firms may not decline, as the size of industries measured by the amount of capital and R&D stocks becomes larger. As a result, the absolute amount of the industry aggregate of foreign capital and R&D stocks, rather than the corresponding industry shares, is likely to be correlated with the size of foreign knowledge that spills over to domestic firms.

2.2 Estimation Method

Two major econometric issues when estimating a production function like equation (1) are estimation biases due to the endogeneity of regressors and unobservable firm-specific effects. In particular, if

[7]Some previous studies use foreign shares in the estimation of the production function analogous to equation (1) (Kokko, 1994; Aitken and Harrison, 1999; Chuang and Lin, 1999; Haskel, Pereira, and Slaughter, 2002; Keller and Yeaple, 2003; Javorcik, 2004; Takii, 2005), whereas others (Haddad and Harrison, 1993; Sjöholm, 1999; Kinoshita, 2001; Todo and Miyamoto, 2006) estimated the effect of foreign shares on the growth rate of output or productivity in growth regression.

[8]In other words, FDI of one dollar has a smaller effect in a large industry than in a small industry.

ordinary least squares (OLS) estimation finds a positive impact of the extent of FDI on domestic output, the positive impact may reflect the fact that industries with a high productivity level attract more FDI.

To correct for these potential problems, we employ the system GMM estimation of Blundell and Bond (1998) and apply a one-step GMM estimation to the system of equation (1) and its first difference. First differencing eliminates firm-specific fixed effects, whereas GMM estimation corrects for endogeneity. More specifically, instruments used for the regressors in the level equation are $\Delta z_{i,t-1}$ and earlier Δz where $z = \ln K$, $\ln L$, $\ln RDS$, $SHARE$, EXP, $\ln FK$, $\ln FRDS$ and $\Delta z_{it} = z_{it} - z_{i,t-1}$. Similarly, instruments for the regressors in the first-differenced equation are $z_{i,t-2}$ and earlier z where z is defined as above. Since our dataset covers a four-year period, we actually use data for the period 2002-2003 as regressors and data for the earlier period as instruments.

In addition, if the error term in equation (1) is serially correlated, the error term in the first-differenced equation is also serially correlated. To alleviate biases due to this autocorrelation, we employ White's robust standard errors, which are consistent in the presence of any pattern of heteroscedasticity and autocorrelation within panels.[9]

3 Data

3.1 Description of the Dataset

The Zhongguancun Science Park (hereafter, the Park), which was established in Beijing in 1988, is the first science park and has been the largest one in China since its establishment. Firms in the Park have enjoyed several preferential benefits, the most notable of which is a lower tax rate. In addition, since the objective of the Park is to create a cluster of high-tech firms, tax waivers and deductions are set to stimulate R&D activities, technology transfers, and technology consulting.

Firms in the Park must file an annual report on firms' management, balance sheet, human resources, and R&D activities to the Administrative Committee of the Park. The dataset used in

[9]In a robustness check of the baseline results, we include the lagged dependent variable as a regressor to further alleviate possible serial correlation.

this paper is compiled from the annual reports for the period 2000–2003.[10]

Advantages of this dataset are that most firms in the Park are high-tech firms and that the annual report includes detailed information on firms' R&D activities. Therefore, the use of this dataset enables us to more accurately estimate the size of knowledge spillovers from FDI through R&D activities of foreign firms than the use of other datasets does. In addition, since firms in the dataset are closely located in a science park, we can avoid possible estimation issues due to the effect of distance on spillovers from FDI.

The Park consists of both manufacturing and non-manufacturing industries, the latter of which include in particular industries of hardware consultancy, software consultancy and supply, and data processing. Although knowledge spillovers from FDI in those industries should be of great interest, we focus on manufacturing industries since the value of intermediate goods for non-manufacturing firms is not available for the period 2000–2001.

3.2 Construction of R&D Stocks

In this section, we describe how we construct the R&D stock of each firm and the aggregate R&D stock of foreign firms. The construction of other variables are in Appendix A.

We construct firms' own R&D stock using the following procedures.[11] First, we obtain the real R&D expenditure by dividing the nominal R&D expenditure by the investment price deflator taken from National Bureau of Statistics of China (2005). Second, we estimate firm i's growth rate of the real R&D expenditure g_i^{RD} by running an OLS regression of the log of the real R&D expenditure, RD_i, on years. Third, if firm i was established before 2000, we estimate the firm's R&D stock in 2000, $RDS_{i,\,2000}$, by

$$RDS_{i,\,2000} = \sum_{t=0}^{2000-T_i} RD_{i,\,2000}\, e^{-(0.15+g_i^{RD})\,t}.$$

0.15 denotes the depreciation ratio of the R&D stock, and T_i is firm i's year of establishment or 1995 when firm i was established before 1995. If firm i was established after 2000, the R&D stock

[10] See Li, Zhang, and Zhou (2005) for more detailed description of the Park. Note that data on intermediate goods and R&D expenditures are available only for the period 2000–2003.

[11] Similar procedures are employed in other studies such as Basant and Fikkert (1996).

in the year of establishment is equal to the real value of the R&D expenditure in that year. Finally, the R&D stock for subsequent years is constructed using the perpetual inventory method assuming a depreciation rate of 15 percent.

When we construct industry aggregate of FDI variables, we define foreign firms as firms that have a foreign capital share of 30 percent or larger. Investment from Hong Kong, Macau, and Taiwan are also defined as foreign capital. Industries are categorized according to the Industrial Classification and Codes for National Economic Activities of China at the 2-digit level.

Similarly to the construction of firms' own R&D stocks, we construct R&D stocks of foreign firms in industry j in 2000, $FRDS_{j,2000}$, by $FRDS_{j,2000} = \sum_{t=0}^{5} FRD_{j,2000} \times e^{-(0.15+g_j^{FRD})\,t}$, where FRD_{jt} is the aggregate R&D expenditure of foreign firms in industry j in year t and g_j^{FRD} is the growth rate of the aggregate foreign R&D expenditure estimated by OLS. Then, foreign R&D stocks in other years are obtained by the perpetual inventory method. It should be noted that we add one to firm-level R&D stocks and industry-level capital and R&D stocks, before we take the log of these variables.

3.3 Summary Statistics

The sample for the regression in this paper consists of domestic firms that are defined as firms with a zero foreign capital share. In addition, since we construct capital and R&D stocks by the perpetual inventory method and use the system GMM estimation, we use domestic firms that reported necessary data for at least three consecutive years during the four-year period 2000–2003.

Table 1 reports summary statistics for the firm-level variables of these domestic firms and industry-level variables used in the regression of this paper. The right four columns of Table 1 exhibit the mean of those variables by year, showing that the growth of domestic firms' R&D stocks was substantially faster than the growth of their value added, capital stocks, and employment. In addition, the size of both capital and R&D stocks of foreign firms increased throughout the period 2000–2003. Particularly, there was a substantial increase in foreign capital and R&D stocks in 2002, probably because of China's participation in the WTO in December, 2001

Table 2 shows the extent of FDI penetration in the Park by year, by industry, and in total, which is represented by the share of foreign firms in sales, capital stocks, and R&D expenditures. The average foreign share in R&D expenditures is smaller than the foreign share in sales and capital stocks in all years, indicating that foreign firms are less likely to perform R&D activities than domestic firms. In addition, we find a large variation in the extent of the FDI penetration across industries. The foreign share in capital stocks is 12.9 percent on average but more than a quarter in five industries (food processing, beverages, rubber, other basic metals, and communication and computing equipment), whereas the foreign R&D share is 7.2 percent on average and exceeds a quarter in two industries (rubber and communication and computing equipment).

We further classify foreign firms according to their source countries and show in Table 3 the share of three major source regions, Japan, the United States, and overseas China that consists of Hong Kong, Macau, and Taiwan. The amount of R&D stocks of overseas Chinese firms grew at a surprising rate, resulting in a large increase in the share of overseas Chinese firms in foreign R&D stocks from 26 percent in 2000 to 58 percent in 2003, while their share in capital stocks declined during the same period. Table 3 also shows that although Japanese firms contributed to almost half of foreign capital stocks in the Park during the period 2000-2003, their share in foreign R&D stocks was only 10 percent on average during the same period. In contrast, the share of US firms in foreign R&D stocks was always larger than their share in foreign capital stocks. This evidence indicates that overseas Chinese firms are most likely to perform R&D, while Japanese firms are least.

4 Estimation Results

4.1 Baseline Results

We estimate equation (1) by the OLS and the system GMM regression and report the results in Table 4. As we have noted in the previous section, the system GMM estimation can correct for possible biases due to endogeneity of the regressors and firm-specific fixed effects. Since the industry aggregate of foreign capital and R&D stocks in logs, $\ln FK_{jt}$ and $\ln FRDS_{jt}$, respectively, exhibit a strong correlation,[12] we use only $\ln FK_{jt}$ in specifications (1) and (2) and only $\ln FRDS_{jt}$ in (3) and (4), whereas specifications (5) and (6) employ the full set of regressors. The Hansen J statistics reported in the last row indicate that instruments are orthogonal to the error term at the 5-percent significance level in all the three GMM regressions. In other words, the use of the lagged regressors as instruments can be justified, suggesting that the system GMM estimators are most preferred and should be discussed more carefully than the OLS estimators.

The result on the impact of the industry aggregate of foreign capital stocks, FK, is clear. In any specification in Table 4, the industry aggregate of foreign capital stocks has no significant impact on value added of domestic firms. This result suggests that knowledge of foreign firms does not spill over to domestic firms through production activities of foreign firms.

In contrast, the industry aggregate of foreign R&D stocks has a positive and significant impact on domestic output according to the results in the OLS estimation reported in columns (3) and (5) and the system GMM estimation in (4). This result suggests that contrary to foreign production activities, R&D activities of foreign firms in the host country stimulate spillovers of foreign knowledge to domestic firms.[13]

How large is this impact of R&D by foreign firms? According to Table 1, $\ln FRDS$ increased by 2.88 from 2000 to 2003 on average across industries. Thus, the estimation result in column (4) indicates that the increase in foreign R&D stocks raised the average productivity and output of domestic firms by roughly 22 percent. Therefore, we conclude that the spillover effect of foreign firms' R&D is substantial in size.

4.2 Robustness Checks

To check the robustness of the results in the previous section, we conduct several alternative estimations. First, we implement a two-step procedure in which we first estimate firms' productivity level

[12] The correlation coefficient of the two is 0.824.

[13] The insignificant effect of the industry R&D stocks of foreign firms in column (6) may be due to multicollinearity discussed above.

and then estimate the effect of the FDI variables on the productivity level. Similar methods are employed in Keller and Yeaple (2003) and Javorcik (2004). In particular, to estimate the productivity level, we employ a method developed by Buettner (2003) who incorporates R&D investment into the method of Olley and Pakes (1996). In short, we assume a Cobb Douglas production function, estimate the elasticity of capital and labor, correcting for endogeneity, and measure the productivity level by total factor productivity (TFP) (See Appendix B for details). The elasticity of capital and labor estimated by this method is 0.232 and 0.743, respectively.

Second, to take into account a possibility that foreign knowledge immediately spills over to domestic firms without a time lag, we employ stocks of current foreign capital and R&D as regressors, rather than one-year lags used in the baseline regression.

Third, in the baseline regression we define the industry aggregate of capital and R&D stocks of foreign firms as the simple aggregation over the industry. To incorporate the variation in the foreign capital share, we follow Javorcik (2004) and define the industry aggregate of foreign capital and foreign R&D stocks as the weighted sum of capital and R&D stocks of foreign firms, using the foreign capital share as weights: $FK(FRDS)_{jt} = \sum_{k \in j} K(RDS)_{kt} \times FS_{kt}$, where FS_{kt} denotes the foreign capital share of firm k.

Fourth, we define foreign firms as firms with a positive foreign capital share, rather than firms with a foreign capital share of 30 percent or more as in the baseline regression.

Finally, we include as a regressor the first lag of the dependent variable to alleviate possible serial correlation.

The results from the first alternative specification using the two-step approach are presented in Table 5, whereas the results from other four alternative specifications are in Table 6. In most alternative specifications, the results from the OLS and the system GMM estimation are consistent with the baseline results: capital stocks of foreign firms have no significant effect on the productivity of domestic firms, whereas R&D stocks of foreign firms have a positive and significant effect.

4.3 Differences in Spillover Effects among Source Countries

We further investigate whether the size of spillovers from foreign firms' R&D activities differ depending on the source country of foreign firms. This investigation is inspired by a large discrepancy in characteristics of foreign firms across source countries, as indicated in Table 3 For example, the size of R&D activities by overseas Chinese firms, i.e., firms from Hong Kong, Macau, and Taiwan, was rapidly increasing, while Japanese firms were not likely to engage in R&D activities in the Park.

In addition, foreign firms from different countries are different in the productivity level. Table 7 shows that the average labor productivity and TFP of foreign firms are 60- and 40-percent higher than those of domestic firms, respectively, indicating that foreign firms embody substantially higher technology than domestic firms. Table 7 also show that among foreign firms, the TFP of overseas Chinese firms is lower by 13 percent than that of other foreign firms, while being higher than that of domestic firms. In particular, the average TFP of Japanese and US firms is 20- and 15-percent higher, respectively, than the average TFP of overseas Chinese firms.

We thus investigate whether the spillover effect of overseas Chinese firms that are technologically less advanced is smaller in size than the effect of other foreign firms, by modifying equation (1) to obtain the following two alternative specifications:

$$\begin{aligned}\ln Y_{it} &= \beta_K \ln K_{it} + \beta_L \ln L_{it} + \beta_R \ln RDS_{it} + \beta_S SHARE_{it} + \beta_E EXP_{j(i)t} \\ &\quad + \delta_1 \ln FRDS^{c}_{j(i),t-1} + \delta_2 \ln FRDS^{-c}_{j(i),t-1} + x'_{it}\gamma + \alpha_i + \nu_t + \varepsilon_{it}, \qquad (2)\end{aligned}$$

and

$$\begin{aligned}\ln Y_{it} &= \beta_K \ln K_{it} + \beta_L \ln L_{it} + \beta_R \ln RDS_{it} + \beta_S SHARE_{it} + \beta_E EXP_{j(i)t} \\ &\quad + \delta \ln \left(\theta FRDS^{c}_{j(i),t-1} + FRDS^{-c}_{j(i),t-1}\right) + x'_{it}\gamma + \alpha_i + \nu_t + \varepsilon_{it}, \qquad (3)\end{aligned}$$

where $FRDS^{c}$ and $FRDS^{-c}$ denote R&D stocks of overseas Chinese firms and of all other foreign firms, respectively, and θ is a constant parameter. In equation (3), $\theta <$ ($>$) 1 indicates that the effect of industry R&D stocks of overseas Chinese firms is smaller (larger) than that of other foreign firms. Defining the share of overseas Chinese firms in industry foreign R&D stocks as $S_{jt} \equiv \frac{FRDS^c_{jt}}{FRDS_{jt}}$, we use the first-order Taylor expansion around $S = 0$ and obtain $\ln(\theta FRDS^c + FRDS^{c-}) \approx \ln(FRDS) + (\theta - 1)S$. Thus, we can rewrite equation (3) as

$$\begin{aligned} \ln Y_{it} &= \beta_K \ln K_{it} + \beta_L \ln L_{it} + \beta_R \ln RDS_{it} + \beta_S SHARE_{it} + \beta_E EXP_{j(i)t} \\ &\quad + \delta \ln FRDS_{j(i),t-1} + \sigma S_{j(i),t-1} + x'_{it}\gamma + \alpha_i + \nu_t + \varepsilon_{it}, \qquad (4) \end{aligned}$$

where σ approximates $(\theta - 1)\delta$, which is a constant, assuming that S is sufficiently close to zero. Therefore, $\sigma < (>)\ 0$ if $\theta < (>)\ 1$, or if the effect of R&D stocks of overseas Chinese firms is smaller (larger) than that of other foreign firms.

We estimate equations (2) and (4) and report the results in Table 8. Columns 1-2 indicate that the effect of R&D stocks of overseas Chinese firms is negative and insignificant, while the effect of other foreign firms' R&D stocks is positive and significant in the OLS results but insignificant in the GMM. Columns 3-4 show that the share of overseas Chinese firms in foreign R&D stocks has a negative and significant effect, implying that spillovers from R&D stocks of overseas Chinese firms are smaller in size than spillovers from other foreign firms. Using $\sigma \approx (\theta - 1)\delta$, or $\theta \approx \frac{\sigma}{\delta} + 1$, and the results from the GMM estimation, the estimated θ is -4.8 $(= \frac{-0.582}{0.100} + 1)$. However, we should not conclude from this evidence that the effect of R&D activities of overseas Chinese firms on domestic firms' productivity is *negative*, since this estimation of θ is based on the assumption that S is close to zero, which is not the case for the share of overseas Chinese firms in foreign R&D stocks.

Therefore, combining these results in columns 1-4 of Table 8, we may conclude that overseas Chinese firms have no positive spillover effect on domestic firms, while other foreign firms have a positive effect. This evidence suggests that a larger technology gap between foreign and domestic firms leads to larger knowledge spillovers from foreign to domestic firms.

Finally, we investigate whether the two major source countries in the Park, Japan and the United States, have distinct spillover effects. Japanese firms are particularly different from other foreign firms in that Japanese firms are least likely to perform R&D in the Park (Table 3), although they embody the highest technology on average (Table 7). To examine possible differences in spillover effects among Japanese, US, and other non-overseas Chinese firms, we include in equation (4) the share of Japanese and US firms in foreign R&D stocks as regressors. The results presented in columns 5-6 of Table 8 show that Japanese or US firms have no significant additional effect compared with other non-overseas Chinese foreign firms. Thus, despite the distinct characteristics of Japanese firms, the size of knowledge spillovers from Japanese firms does not seem to be very different from the size of spillovers from other foreign firms.

5 Conclusion

A large number of studies have used firm-level data to examine if FDI generates knowledge spillovers to domestically-owned firms. However, the results are mixed. In this study, panel data from a Chinese science park are used to test whether the often-ignored local R&D activities of foreign-owned firms in the host country enhance knowledge spillovers from FDI. The analysis found positive effects of R&D stocks of foreign-owned firms on the productivity of domestic firms, while effects of capital stocks of foreign firms were absent. These results suggest that knowledge of foreign firms spills over through their R&D activities, but not through their production activities. In addition, we found that spillovers from firms from Hong Kong, Macau, and Taiwan are absent, concluding that the size of FDI spillovers is larger when the technology gap between foreign and domestic firms is larger.

References

Aitken, B. J., and A. E. Harrison (1999): "Do Domestic Firms Benefit from Direct Foreign Investment? Evidence from Venezuela," *American Economic Review*, 89(3), 605–618.

Basant, R., and B. Fikkert (1996): "The Effects of R&D, Foreign Technology Purchase, and Domestic and International Spillovers on Productivity in Indian Firms," *Review of Economics and Statistics*, 78(2), 187–199.

Blalock, G., and P. Gertler (2004): "Welfare Gains from Foreign Direct Investment through Technology Transfer to Local Suppliers," unpublished, Department of Applied Economics and Management, Cornell University.

Blomström, M., and F. Sjöholm (1999): "Technology Transfer and Spillovers: Does Local Participation with Multinationals Matter?," *European Economic Review*, 43(4-6), 915–923.

Blundell, R., and S. Bond (1998): "Initial Conditions and Moment Restrictions in Dynamic Panel Data Models," *Journal of Econometrics*, 87(1), 115–143.

Buettner, T. (2003): "R&D and the Dynamics of Productivity," unpublished, London School of Economics.

Chuang, Y.-C., and C.-M. Lin (1999): "Foreign Direct Investment, R&D and Spillover Efficiency: Evidence from Taiwan's Manufacturing Firms," *Journal of Development Studies*, 35(4), 117–137.

Görg, H., and A. Hijzen (2004): "Multinationals and Productivity Spillovers," GEP Research Paper, No. 04/41.

Görg, H., and E. Strobl (2000): "Multinational Companies, Technology Spillovers and Firm Survival: Evidence from Irish Manufacturing," GLM Research Paper, No. 12, School of Economics, University of Nottingham.

Haddad, M., and A. Harrison (1993): "Are There Positive Spillovers from Direct Foreign Investment? Evidence from Panel Data for Morocco," *Journal of Development Economics*, 42(1), 51–74.

Haskel, J. E., S. C. Pereira, and M. J. Slaughter (2002): "Does Inward Foreign Direct Investment Boost the Productivity of Domestic Firms?," NBER Working Paper, No. 8724.

Jaffe, A. B., and M. Trajtenberg (1998): "Flows of Knowledge from Universities and Federal Labs: Modeling the Flow of Patent Citations Over Time and Across Institutional and Geographic Boundaries," NBER Working Paper, No. 6507.

——— (1999): "International Knowledge Flows: Evidence from Patent Citations," *Economics of Innovation and New Technology*, 8(1-2), 105–136.

Jaffe, A. B., M. Trajtenberg, and R. Henderson (1993): "Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations," *Quarterly Journal of Economics*, 108(3), 577–598.

Javorcik, B. S. (2004): "Does Foreign Direct Investment Increase the Productivity of Domestic Firms? In Search of Spillovers Through Backward Linkages," *American Economic Review*, 94(3), 605–627.

Keller, W. (2002): "Geographic Localization of International Technology Diffusion," *American Economic Review*, 92(1), 120–142.

——— (2004): "International Technology Diffusion," *Journal of Economic Literature*, 42(3), 752–782.

Keller, W., and S. Yeaple (2003): "Multinational Enterprises, International Trade, and Productivity Growth: Firm-Level Evidence from the United States," NBER Working Paper, No. 9504.

Kinoshita, Y. (2001): "R&D and Technology Spillovers via FDI: Innovation and Absorptive Capacity," CEPR Discussion Paper, No. 2775.

Kiyota, K. (2005): "Reconsidering the Effects of Intranational and International R&D Spillovers: Firm-level Evidence from Japan," MMRC Discussion Paper, No. 44, Manufacturing Management Research Canter, the University of Tokyo.

Kokko, A. (1994): "Technology, Market Characteristics, and Spillovers," *Journal of Development Economics*, 43(2), 279–293.

Kugler, M. (2006): "Spillovers from Foreign Direct Investment: Within or Between Industries?," *Journal of Development Economics*, 80(2), 444–477.

Li, H., W. Zhang, and L.-A. Zhou (2005): "Ownership, Efficiency, and Firm Survival in Economic Transition: Evidence from a Chinese Science Park," unpublished, Department of Economics, the Chinese University of Hong Kong.

Lipsey, R. E., and F. Sjöholm (2004): "Host Country Impacts of Inward FDI: Why such Different Answers?," EIJS Working Paper, No. 192, Stockholm School of Economics.

National Bureau of Statistics of China (2005): "Yearly Data," available at http://www.stats.gov.cn/.

Olley, S. G., and A. Pakes (1996): "The Dynamics of Productivity in the Telecommunications Equipment Industry," *Econometrica*, 64(6), 1263–1297.

Saggi, K. (2002): "Trade, Foreign Direct Investment, and International Technology Transfer: A Survey," *World Bank Research Observer*, 17(2), 191–235.

Sjöholm, F. (1999): "Productivity Growth in Indonesia: The Role of Regional Characteristics and Direct Foreign Investment," *Economic Development and Cultural Change*, 47(3), 559–584.

Takii, S. (2005): "Productivity Spillovers and Characteristics of Foreign Multinational Plants in Indonesian Manufacturing 1990-1995," *Journal of Development Economics*, 76(2), 521–542.

Todo, Y., and K. Miyamoto (2002): "Knowledge Diffusion from Multinational Enterprises: The Role of Domestic and Foreign Knowledge-Enhancing Activities," Technical Paper, No. 196, OECD Development Centre.

——— (2006): "Knowledge Spillovers from Foreign Direct Investment and the Role of R&D Activities: Evidence from Indonesia," *Economic Development and Cultural Change*, forthcoming.

Appendix A: Construction of Variables

Firms' value added Y is defined as the real value of "industrial output" minus the real value of "industrial input." The nominal value of industrial output and input is reported in the annual reports filed by firms in the Park, which are then deflated by industry-specific price deflators for output and input taken from National Bureau of Statistics of China (2005) [Statistical Yearbook of China].

The capital stock K is constructed by the following procedures. First, nominal investment is defined as the book value of current fixed assets minus the book value of fixed assets in the previous year plus the value of depreciation. Second, nominal investment is deflated by the price deflator for investment to create real investment. The investment price deflator is again taken from National Bureau of Statistics of China (2005). Third, the initial stock is defined as either the deflated book value of fixed assets in 1995 for firms that were established before 1995 or the deflated book value of fixed assets in the year of establishment for other firms. Finally, the capital stock is constructed by the perpetual inventory method.

Labor L is the total labor minus labor engaging in R&D activities. We subtract labor in R&D to avoid double counting, since our value-added equation includes the R&D stock as another input.

Firms' market share $SHARE$ is represented by the share of the firm's sales in total sales of the industry to which the firm is classified. The industry-level export-sales ratio EXP is the ratio of total exports in the industry to total sales in the industry. The industry aggregate of foreign capital stocks, FK, is defined as the aggregation of capital stocks of all foreign firms in the industry.

Appendix B: Buettner's (2003) Method for Productivity Measurement

Buettner (2003) incorporates R&D investment into the method of Olley and Pakes (1996) for productivity measurement and presents several alternative methods. In what follows, we explain a particular type of those methods that assumes no exit of firms (type "k" in his notation), which adopted in this paper.

We begin with the following Cobb-Douglas production function for firm i at time t:

$$y_{it} = \beta_0 + \beta_K k_{it} + \beta_L l_{it} + \omega_{it} + \eta_{it}, \tag{5}$$

where $x \equiv \ln X$ for any variable X, Y_{it}, K_{it}, and L_{it} are value added, capital stocks, and labor of firm i at time t, respectively. ω_{it} represent the productivity level, and η_{it} a productivity shock. It is assumed that the distribution of ω_{it} is governed by a single parameter, ψ_{it}. At the beginning of time $t+1$, firm i observes k_{it} and ω_{it} and chooses $k_{i,t+1}$ and $\psi_{i,t+1}$. This choice requires R&D expenditure of $RD_{i,t+1} = RD(\psi_{i,t+1},\ \omega_{it})$, where $\partial RD/\partial\psi > 0$ and $\partial RD/\partial\omega < 0$. In other words, the distribution of the productivity in the next period is a function of the current productivity level and the current R&D investment.[14]

Given these assumptions, firm i's optimal choice of investment at time t, I_{it}, depends on the current productivity level ω_{it} and the current capital stock k_{it}: $i_{it} = i_t(\omega_{it}, k_{it})$. We this equation to obtain $\omega_{it} = \tilde{\omega}_{it}(i_{it},\ k_{it})$. Substituting this to the production function (5) gives

$$y_{it} = \beta_L l_{it} + \phi_{it}(i_{it},\ k_{it}) + \eta_{it},$$

where $\phi_{it} = \beta_0 + \beta_K k_{it} + \omega_{it}$. Semi-parametric estimation of this equation by OLS assuming that ϕ is a polynomial series expansion of the arguments leads to a consistent estimation of β_L.

To estimate β_K in the second stage, we rearrange equation (5) as

$$y_{it} - \beta_L l_{it} = \beta_0 + \beta_K k_{it} + \omega_{it} + \eta_{it}. \tag{6}$$

We assume a Markov process in ω: $\omega_{it} = E[\omega_{it}|\psi_{it}] + \xi_{it} + \eta_{it}$, where ξ_{it} is productivity innovation and unrelated with k_{it}. Thus, equation (6) can be rewritten as

$$y_{it} - \beta_L l_{it} = \beta_0 + \beta_K k_{it} + E[\omega_{it}|\psi_{it}] + \xi_{it} + \eta_{it}. \tag{7}$$

The optimal choice of the distribution parameter $\psi_{i,t+1}$ can be written as a function of ω_{it} and

[14] In the Olley-Pakes method, $\psi_{i,t+1}$ equals ω_{it} and does not depend on R&D investment.

$k_{i,t+1}$:

$$\psi_{i,t+1} = \bar{\psi}(\omega_{it}, k_{i,t+1}). \tag{8}$$

Combining equations (7) and (8), we obtain

$$\begin{aligned} y_{it} - \beta_L l_{it} &= \beta_0 + \beta_K k_{it} + g(\bar{\psi}(\omega_{i,t-1},\, k_{it})) + \xi_{it} + \eta_{it} \\ &= f(\phi_{i,t-1} - \beta_K k_{i,t-1},\, k_{it}) + \xi_{it} + \eta_{it}. \end{aligned} \tag{9}$$

We estimate equation (9) by nonlinear least squares, approximating function f by a polynomial series expansion, to obtain a consistent estimate of β_K.

Given the consistent estimates of β_K and β_L, we measure the log of the TFP level of firm i at time t as $y_{it} - \beta_L l_{it} - \beta_K k_{it}$.

Table 1: Summary Statistics

	Mean	Standard Deviation	Mean by year			
			2000	2001	2002	2003
Firm-level variables						
ln$Y$	7.43	2.02	7.40	7.22	7.46	7.66
ln$K$	6.19	2.42	6.00	6.05	6.26	6.51
ln$L$	3.38	1.34	3.39	3.41	3.37	3.36
lnRDS	5.91	2.78	3.84	5.70	6.59	7.14
$SHARE$	0.009	0.042	0.010	0.010	0.009	0.008
Industry-level variables						
EXP	0.051	0.078	0.059	0.045	0.052	0.049
lnFK	7.69	4.82	6.35	6.56	8.83	9.00
ln$FRDS$	5.50	4.45	3.94	5.08	6.15	6.82

Notes: Y: value added; K: capital stock; L: labor; RDS: R&D stock; $SHARE$: market share in the industry (raw ratios); EXP: industry's share of exports in output (raw ratios); FK: industry's capital stock of foreign firms; $FRDS$: industry's capital stock of foreign firms. The overall mean of the firm-level variables is based on the data for the period 2000-2003.

Table 2: The Extent of FDI Penetration in the Zhongguancun Science Park by Year and by Industry

		Share of foreign firms (percentage)		
		Sales	Capital stocks	R&D expenditures
Year				
2000		5.8	5.5	3.9
2001		4.7	4.8	3.5
2002		20.1	20.8	9.7
2003		21.2	20.8	11.8
Industry	*(Code)*			
Food processing	13	14.1	26.0	11.1
Food products	14	1.1	0.2	0.1
Beverages	15	44.8	48.1	0.0
Textile	17	0.2	0.2	0.0
Furniture	21	0.0	0.0	0.0
Publishing and printing	23	2.3	4.8	0.0
Stationery and musical instruments	24	18.2	14.3	19.2
Coke, refined petroleum products and nuclear fuel	25	0.6	0.6	3.0
Chemicals and chemical products	26	9.4	4.2	5.1
Pharmaceuticals and medicinal chemicals	27	11.9	13.0	14.2
Man-made fibres	28	0.0	0.0	0.0
Rubber	29	38.0	44.5	40.6
Plastic products	30	6.1	4.5	1.1
Non-metallic mineral products	31	11.5	7.5	4.2
Iron and steel	32	0.0	0.0	0.0
Other basic metals	33	6.3	31.4	0.8
Metal products except machinery and equipment	34	4.1	8.8	2.3
Machinery	35	16.8	17.2	13.3
General equipment	36	20.7	15.5	7.5
Transport equipment	37	14.3	4.2	0.3
Electrical machinery	39	21.5	14.8	9.9
Communication and computing equipment	40	52.9	31.3	33.6
Precisions and optical instruments	41	27.4	21.6	9.4
Other	42	1.5	11.5	4.1
Recycling	43	0.0	0.3	0.0
Total		12.9	13.0	7.2

Notes: The share of foreign firms as a percentage of the aggregate figure by year, by industry, or in total is presented. Industries are categorized according to the Industrial Classification and Codes for National Economic Activities of China.

Table 3: The Share of Japanese, US, and overseas Chinese FDI

	Capital stocks			R&D stocks		
	Japanese firms	US firms	Overseas Chinese firms	Japanese firms	US firms	Overseas Chinese firms
Amount (million RMB)						
2000	783.2	93.4	486.9	53.1	119.5	59.8
2001	678.0	119.6	762.2	92.4	277.9	117.0
2002	3792.1	556.8	1272.1	166.6	303.0	1207.3
2003	4127.9	776.3	1650.6	403.3	382.0	2415.1
Total	9381.2	1546.1	4171.9	715.4	1082.3	3799.1
Share in total of all foreign firms (percentage)						
2000	50.1	6.0	31.2	23.2	52.1	26.1
2001	36.5	6.4	41.1	16.7	50.1	21.1
2002	47.0	6.9	15.8	7.2	13.0	51.9
2003	46.4	8.7	18.6	9.7	9.2	58.0
Total	46.0	7.6	20.5	9.8	14.9	52.2

Notes: Overseas Chinese firms are defined as those from Hong Kong, Macau, and Taiwan.

Table 4: Spillover Effects from Foreign Firms: Baseline Results

		Dependent variable: log of value added					
		(1)	(2)	(3)	(4)	(5)	(6)
		OLS	GMM	OLS	GMM	OLS	GMM
ln*K*	log of capital stock	0.127	0.355	0.128	0.275	0.130	0.287
		(0.017)**	(0.102)**	(0.017)**	(0.090)**	(0.017)**	(0.092)**
ln*L*	log of labor	0.645	0.677	0.647	0.879	0.648	0.841
		(0.042)**	(0.203)**	(0.042)**	(0.182)**	(0.042)**	(0.185)**
ln*RDS*	log of R&D stock	0.267	0.240	0.262	0.143	0.261	0.157
		(0.023)**	(0.058)**	(0.022)**	(0.056)*	(0.021)**	(0.053)**
SHARE	Market share	3.670	2.197	3.869	3.386	3.730	2.443
		(1.205)**	(2.199)	(1.260)**	(2.912)	(1.273)**	(2.263)
EXP	Industry export-sales ratio	0.083	-1.341	-0.125	-2.969	0.050	-1.606
		(0.624)	(1.794)	(0.492)	(2.015)	(0.541)	(1.324)
ln*FK*	log of industry capital stock of foreign firms	0.023	-0.047			-0.054	-0.015
		(0.020)	(0.044)			(0.043)	(0.046)
ln*FRDS*	log of industry R&D stock of foreign firms			0.033	0.075	0.076	0.058
				(0.015)*	(0.036)*	(0.033)*	(0.035)
No. of observations		1427	1427	1427	1427	1427	1427
R-squared		0.60		0.61		0.61	
Hansen *J* statistic			0.14		0.09		0.06

Notes: Standard errors are in parentheses. **, *, and + signify statistical significance at the 1%, 5%, and 10% levels, respectively. Year dummies are included in all specification. GMM estimation is based on the system GMM estimation developed by Blundell and Bond (1998). *P* values are reported for the Hansen *J* statistics.

Table 5: Robustness of the Baseline Results (1)

		Dependent variable: log of TFP					
		(1)	(2)	(3)	(4)	(5)	(6)
		OLS	GMM	OLS	GMM	OLS	GMM
ln*RDS*	log of R&D stock	0.145	0.257	0.141	0.160	0.142	0.179
		(0.014)**	(0.054)**	(0.013)**	(0.050)**	(0.013)**	(0.047)**
SHARE	Market share	2.490	2.555	2.783	3.774	2.612	2.821
		(0.835)**	(2.062)	(0.887)**	(2.836)	(0.904)**	(2.158)
EXP	Industry export-sales ratio	0.343	-1.354	0.051	-2.675	0.291	-1.341
		(0.769)	(1.784)	(0.608)	(2.023)	(0.666)	(1.292)
ln*FK*	log of industry capital stock of foreign firms	0.025	-0.032			-0.076	-0.020
		(0.020)	(0.039)			(0.044)+	(0.043)
ln*FRDS*	log of industry R&D stock of foreign firms			0.039	0.068	0.098	0.053
				(0.015)*	(0.036)+	(0.034)**	(0.034)
No. of observations		1427	1427	1427	1427	1427	1427
R-squared		0.06		0.06		0.07	
Hansen *J* statistic			0.07		0.08		0.06

Notes: Standard errors are in parentheses. **, *, and + signify statistical significance at the 1%, 5%, and 10% levels, respectively. The TFP level is estimated by the method of Buettner (2003). Year dummies are included in all specification. GMM estimation is based on the system GMM estimation developed by Blundell and Bond (1998). *P* values are reported for the Hansen *J* statistics.

Table 6: Robustness of the Baseline Results (2)

		Dependent variable: log of value added							
		A. Current FDI variables				B. Alternative definition of FDI variables			
		(1) OLS	(2) GMM	(3) OLS	(4) GMM	(5) OLS	(6) GMM	(7) OLS	(8) GMM
ln*FK*	log of industry capital	0.036	0.000			0.020	-0.051		
	stock of foreign firms	(0.018)+	(0.043)			(0.017)	(0.040)		
ln*FRD*	log of industry R&D			0.035	0.081			0.037	0.092
	stock of foreign firms			(0.017)*	(0.041)+			(0.014)*	(0.040)*
Observations		1427	1427	1427	1427	1427	1427	1427	1427
R-squared		0.60		0.61		0.60		0.61	
Hansen *J*			0.10		0.07		0.09		0.08

		C. Alternative definition of foreign firms				D. Including the lagged dependent variable			
		(9) OLS	(10) GMM	(11) OLS	(12) GMM	(13) OLS	(14) GMM	(15) OLS	(16) GMM
Lagged ln*Y*	lagged log of value added					0.460	0.233	0.460	0.233
						(0.040)**	(0.055)**	(0.039)**	(0.056)**
ln*FK*	log of industry capital	0.028	-0.050			0.021	-0.003		
	stock of foreign firms	(0.021)	(0.048)			(0.015)	(0.047)		
ln*FRD*	log of industry R&D			0.038	0.082			0.028	0.070
	stock of foreign firms			(0.015)*	(0.043)+			(0.011)*	(0.035)*
Observations		1427	1427	1427	1427	1427	1427	1427	1427
R-squared		0.60		0.61		0.69		0.69	
Hansen *J*			0.12		0.10		0.48		0.33

Notes: Standard errors are in parentheses. **, *, and + signify statistical significance at the 1%, 5%, and 10% levels, respectively. GMM estimation is based on the system GMM estimation developed by Blundell and Bond (1998). *P* values are reported for the Hansen *J* statistics. The capital stock, labor, R&D stocks, the market share in the industry, the industry's ratio of exports to total sales, and year dummies are included as regressors in all specifications, but their estimated coefficients are not reported for brevity. In columns 1-4, current *FK* and *FRDS* are employed. In columns 5-8, *FK* and *FRDS* are defined as the weighted sum of capital and R&D stocks, respectively, of foreign firms at the industry level, where weights are the foreign share in capital of each foreign firm. In columns 9-12, foreign firms are defined as firms with a positive foreign share in capital. In columns 13-16, the lagged dependent variable is included as a regressor.

Table 7: Productivity Differences between Domestic and Foreign Firms

		Foreign firms	*Of which*			
	Domestic Firms		Overseas Chinese firms	Non-overseas Chinese firms	*Of which*	
Mean of					Japanese firms	US firms
ln(value added)	7.067	7.865	7.608	8.024	9.050	7.546
	(2.136)	(2.364)	(2.238)	(2.426)	(2.336)	(2.186)
ln(labor productivity)	3.846	4.448	4.337	4.516	4.687	4.475
	(1.566)	(1.594)	(1.565)	(1.610)	(1.433)	(1.609)
ln(TFP)	3.285	3.678	3.599	3.726	3.809	3.752
	(1.511)	(1.527)	(1.509)	(1.537)	(1.359)	(1.560)

Notes: The mean of log of value added, labor productivity, and TFP for different types of firm during the period 2000-2003 is presented. We construct TFP levels using Buettner's (2003) method. Overseas Chinese firms are defined as those from Hong Kong, Macau, and Taiwan.

Table 8: Spillover Effects from Japanese, US, and overseas Chinese FDI

		Dependent variable: log of value added					
		(1)	(2)	(3)	(4)	(5)	(6)
		OLS	GMM	OLS	GMM	OLS	GMM
ln*FRDS*	log of industry R&D stocks of all foreign firms			0.031	0.100	0.032	0.070
				(0.014)*	(0.034)**	(0.017)+	(0.023)**
$\ln FRDS^{C}$	log of industry R&D stocks of overseas Chinese firms	-0.019	-0.000				
		(0.012)	(0.016)				
$\ln FRDS^{C-}$	log of industry R&D stocks of non-overseas Chinese foreign firms	0.044	0.028				
		(0.009)**	(0.022)				
Share in foreign R&D stocks							
Overseas Chinese firms				-0.302	-0.582	-0.349	-0.553
				(0.083)**	(0.204)**	(0.142)*	(0.239)*
Japanese firms						-0.093	-0.087
						(0.193)	(0.257)
US firms						-0.077	-0.182
						(0.299)	(0.195)
Observations		1427	1427	1427	1427	1427	1427
R-squared		0.61		0.61		0.61	
Hansen *J* statistic			0.18		0.41		0.29

Notes: Standard errors are in parentheses. ** and * signify statistical significance at the 1% and 5% levels, respectively. GMM estimation is based on the system GMM estimation developed by Blundell and Bond (1998). *P* values are reported for the Hansen *J* statistics. The capital stock, labor, R&D stocks, the market share in the industry, the industry's ratio of exports to total sales, and year dummies are included as regressors in all specifications, but their estimated coefficients are not reported for brevity.