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**Knowledge Spillovers from FDI  
in the People's Republic of  
China:  
The Role of Educated Labor in  
Multinational Enterprises**

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**Abstract**

This paper employs a firm-level panel data set for a high-tech cluster in the People's Republic of China to examine knowledge spillovers from multinational enterprises (MNEs) to domestic firms, focusing on the role of MNEs' employment of educated workers. We find that knowledge within MNEs spills over to domestic firms in the same industry through MNEs' employment of workers with graduate-level or overseas education. We also find that Japanese MNEs contribute less to knowledge spillovers than United States MNEs. This is most likely due to the fact that Japanese MNEs in the People's Republic of China do not employ as much educated labor.

**JEL Classification: F23, O12, O30**

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## 1. INTRODUCTION

Knowledge diffusion from developed countries has long been recognized as a critical source of productivity growth of less developed countries. A potential channel of such diffusion is knowledge spillovers from foreign direct investment (FDI) to domestically owned firms (hereafter, domestic firms). A large number of empirical studies using firm-level data have examined spillovers from FDI, typically estimating the effect of the total multinational enterprise (MNE) size in a particular industry on the productivity of domestic firms in the same industry. However, in the first wave of the literature, results were mixed: While some studies found positive effects of FDI on the productivity of domestic firms (Kokko 1994; Chuang and Lin 1999; Blomström and Sjöholm 1999; Sjöholm 1999; among many others), others failed to find any significant spillover effects from FDI (Haddad and Harrison 1993; Aitken and Harrison 1999).<sup>1</sup>

Therefore, more recent studies have tried to uncover the possible channels underlying the knowledge diffusion from FDI. These channels include technical training provided by MNEs (Larrain, Lopez-Calva, and Rodriguez-Clare 2000), social interactions, including employee mobility, between MNEs and domestic firms (Fosfuri, Motta, and Ronde 2001; Hale and Long 2006), research and development (R&D) activities of MNEs in the host country (Todo 2006; Todo and Miyamoto 2006; Todo, Zhang, and Zhou 2006), and inter-industry linkages such as backward linkages (Javorcik 2004; Kugler 2006; Blalock and Gertler 2008; Javorcik and Spatareanu 2008; Liu 2008). Others find that whether or not knowledge spills over from FDI may depend on the technology gap between MNEs and domestic firms, as well as the absorptive capacity of domestic firms (Girma 2005; Girma Gong, and Görg 2005; Hale and Long, 2006; Takii 2005).

Following the literature examining more specific channels of FDI spillovers, this study, using firm-level panel data for a science park in the People's Republic of China (PRC), focuses on the role of MNE employment of educated workers in generating knowledge spillover to domestic firms. This focus is based on two important observations. First, according to the field interviews conducted by the authors of this paper in the science park, MNE engineers and managers often change jobs and work for domestic firms or start their own firms, after gaining advanced knowledge and skills from their MNE experience. These observations suggest that MNE knowledge indeed spills over to the local economy, particularly through labor mobility of educated workers. Second, a large number of PRC students educated overseas have recently returned to the PRC. According to Zweig (2008), the number of returned students drastically rose from less than 10,000 in 2000 to 25,000 in 2004. The multicultural experience and linguistic advantage of the returnees should promote interactions between MNEs and the local economy and hence facilitate knowledge spillovers from MNEs.

The science park examined in this study, the Zhongguancun Science Park (hereafter Z-Park), provides an ideal context for examining MNE employment of educated workers as a source of FDI spillovers. As a cluster of high-technology industries, the Z-Park is known as the PRC's "Silicon Valley" and is characterized by the utilization of highly educated workers. Among the total of 400,000 workers in the Z-Park in 2003, 220,000, or more than 50%, had a bachelor's or higher degree, 42,000, more than 10%, had a master's or higher degree, and 3,600, about 1%, were educated abroad. The geographical concentration of firms in the park facilitates interpersonal interactions and turnover of those educated workers between MNEs

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<sup>1</sup> See Saggi (2002), Keller (2004), Görg & Greenaway (2004), and Lipsey & Sjöholm (2005) for excellent surveys on this issue.

and domestic firms, and thereby stimulates knowledge spillover from MNEs to domestic firms.<sup>2</sup>

To preview our results, we find that the industry aggregate of total employment at MNEs in the PRC has no significant effect on the productivity of domestic firms, concluding that MNE production activities do not unconditionally lead to knowledge spillovers to domestic firms.<sup>3</sup> By contrast, the number of educated workers at MNEs, in particular, those with graduate-level or overseas education, has a positive and statistically significant effect on domestic productivity. We interpret this evidence as showing that MNE employment of educated workers results in spillovers from MNEs to domestic firms.

In addition, this study examines differences in the size of spillover effects across home countries of FDI, in particular between the two largest home countries in the Z-Park, Japan and the United States (US). This examination is possible since our firm-level data set contains information on the nationality of major shareholders of each firm, which is rarely available in firm-level data sets. We find that the number of PRC workers at Japanese MNEs does not affect productivity of domestic firms in the same industry, while the number of PRC workers at US MNEs positively affects it. We further find that Japanese MNEs employ educated labor substantially less than US MNEs. Therefore, it is most likely that the absence of spillovers from Japanese MNEs is due to the small numbers of educated PRC workers employed at Japanese MNEs.

The contributions of this study are twofold. First, besides several channels of FDI spillovers found in the studies mentioned earlier, we found that MNE employment of highly educated workers is an additional channel of spillover. Second, few studies have found that the size of FDI spillovers differ substantially across the home countries of FDI. This study suggests that such differences stem from variations in firm characteristics of MNEs, such as the degree of utilization of educated labor, across home countries.

The remainder of the paper is organized as follows. Section 2 discusses the econometric procedure employed in the analysis. Section 3 presents the data set and the variables used in the regression analysis, while the results of the ordinary least squares (OLS) and generalized method of moments (GMM) estimation are discussed in Section 4. Section 5 concludes.

## **2. INSTITUTIONAL BACKGROUND OF CHINA'S "SILICON VALLEY"**

### **2.1 Description of the Z-Park**

The Zhongguancun Science Park was established in Beijing in the late 1980s as the first national-level high technology district and has been the largest science park in China since its establishment. The total revenue of firms in the Z-Park was about yuan600 billion, or approximately US\$80 billion, in 2006, contributing one seventh of the total revenue of all science parks in China and 5% of the total revenue of the industrial sector in China (Zhongguancun Science Park 2009).

The Chinese government has supported the Z-Park with the view that development of the Z-Park can be the engine of domestic innovation and the model for China's high-tech industries. To attract entry of domestic and foreign firms, the government offers several preferential benefits to firms located in the Z-Park. The most notable of these are tax

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<sup>2</sup> Jaffe, Trajtenberg, & Henderson (1993) and Keller (2002) have shown that due to the tacit nature of knowledge, face-to-face interaction is probably the most effective way of transferring knowledge, and thus knowledge diffusion tends to be geographically localized within regions and countries.

<sup>3</sup> This result is consistent with Todo, Zhang, & Zhou (2006).

incentives. For all eligible firms, the corporate income tax rate is 15%, less than half of the normal corporate income tax rate of 33%. New entrants additionally enjoy a tax waiver for the first three years of operation. In 1999, additional preferential policies were granted by the government, such as enlarging the scope of the tax waivers and deductions (e.g., reduction of sales taxes on technological transfers, consulting, and services and R&D expenditures). In order to attract strong inflows of brainpower from other parts of China as well as from overseas, the government allows PRC citizens in high-tech firms in the Z-Park to obtain Beijing residence.<sup>4</sup>

The rapid development of the Z-Park benefited enormously from the high density of nationally renowned universities and research institutions in the park. The park hosts 73 universities, including the leading universities in the nation, Peking University and Tsinghua University and 232 research institutions, including the Chinese Academy of Science. These universities and institutions provide an ample supply of educated labor to both domestic firms and MNEs in the Z-Park, and hence a significant portion of workers, including chief executive officers, in the Z-Park are alumni of the universities located in the park.

## 2.2 Channels of knowledge spillovers from FDI

MNEs have been a critical part of the high growth of the Z-Park. Our data show that the MNE share of total sales and capital stocks are about 17% in 2003. Many multinational giants are residents of the Z-Park, and more importantly, the Z-Park has become a cluster of MNE R&D centers. By the end of 2005, 43 well-known global MNEs, including IBM, Microsoft, Bell Labs, Fujitsu, Intel, Motorola, Panasonic, and Oracle, had located their PRC R&D centers in the Z-Park. MNEs also employ large numbers of educated workers: more than 10,000 workers with at least undergraduate-level education and more than 1,200 workers with graduate-level education in 2003. In general, those MNEs are technologically more advanced than domestic firms. Using the same data set as in this paper, Todo, Zhang, and Zhou (2006) found that the total factor productivity (TFP) of MNEs is about 40% higher than the TFP of domestic firms on average.<sup>5</sup> Ge and Chen (2008) also found that a larger percentage of foreign ownership is associated with higher productivity, based on a study of all large- and medium-sized joint ventures in the PRC manufacturing sector.

There are a number of reasons to expect knowledge spillovers from such technologically advanced MNEs to domestic firms in the same industry, particularly through MNE employment of an educated labor force. The authors of this paper conducted interviews with managers of several foreign and domestic firms in the Z-Park and discern several important channels of FDI spillovers.<sup>6</sup> Most notably, local engineers and managers who work in MNEs often leave the job after several years—three years on average according to one manager of an MNE—of working and learning of foreign advanced knowledge. After that period, some of them are employed by domestic firms, and some set up their own firms. Such labor turnover between firms is an important channel for knowledge spillovers from FDI. Other possible channels of spillovers include technological cooperation between MNEs and domestic firms

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<sup>4</sup> China has long instituted a strict *hu kou* (household registration) system to regulate the mobility of people across localities. A person without a *hu kou* in a particular locality is not entitled to social benefits (e.g., schooling and housing subsidies) in that locality.

<sup>5</sup> The calculation is based on simple comparison of the average TFP between MNEs and domestic firms, without controlling for any firm characteristic. The size of the TFP differential varies across industries. For example, in the food processing, the chemical, and the pharmaceuticals industry, the MNE average TFP is more than 80% higher than that of domestic firms, whereas in the plastic products, the non-metallic mineral products, and the general equipment industries, the MNE premium is 60-70%. By contrast, in the coke and refined petroleum product, rubber, other basic metals, and transport equipment industries, in which the number of firms is relatively small, the average TFP is higher for domestic firms than for MNEs.

<sup>6</sup> The details of observations from the interviews are presented in Cai, Todo, and Zhou (2007).

and technological outsourcing from MNEs to local firms. All of these channels should involve educated workers in MNEs.

### 3. ESTIMATION PROCEDURE

#### 3.1 Estimation equation

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

$$\ln Y_{it} = \beta_K \ln K_{it} + \beta_L \ln L_{it} + \beta_R \ln R_{it} + \delta \ln FDI_{ij,t-1} + \beta_S \text{SHARE}_{it} + \alpha_i + u_t + \varepsilon_{it} \quad (1)$$

where  $Y_{it}$ ,  $K_{it}$ ,  $L_{it}$ , and  $R_{it}$  are the value added, capital stock, labor, and R&D stock of firm  $i$  in industry  $j$  at time  $t$ , respectively.  $\alpha_i$ ,  $u_t$ , and  $\varepsilon_{it}$  are the firm-specific constant term, the year-specific constant term, and the error term, respectively.

In the equation,  $\ln FDI_{ij,t-1}$  represents the extent of foreign firms' activities in industry  $j$  in year  $t-1$ . We take the size of the corresponding coefficient,  $\delta$ , to represent the extent of knowledge spillovers from MNEs. More specifically, we employ several alternative measures of MNE penetration at the industry level: the amount of total MNE labor force and their educated labor force in the industry,  $FL_{ij,t-1}$  and  $FE_{ij,t-1}$ , respectively, in logs. We assume that  $FL_{ij,t-1}$  represents the extent of foreign firm production activities at the industry level,<sup>7</sup> while by using  $FE_{ij,t-1}$  we examine whether MNE employment of educated workers is a channel of FDI spillovers.<sup>8</sup> We use a one-year lag because we assume that there is a time lag from when an MNE engages in production and when its knowledge spills over to domestic firms.

In addition, Haskel, Pereira, and Slaughter (2002) and Keller and Yeaple (2009) argue that the presence of MNEs may have a negative effect on local production, since MNEs grab market share from, and undermine the monopoly power, of domestic firms. To incorporate this effect of MNEs unrelated to spillovers, we include in the equation (1) the market share of firm  $i$  in the industry,  $\text{SHARE}_{it}$ .<sup>9</sup> If we had failed to incorporate this variable, then the coefficient on the FDI variable would capture the MNE positive spillover effect as well as the negative effects of their increasing market share, and thus could become negative even in the presence of the positive spillover effect, as Aitken and Harrison (1999) suggest.

#### 3.2 Estimation method

There are two major econometric issues when estimating equations such as production functions: estimation biases, due to the endogeneity of regressors, and unobservable firm-specific effects. In particular, an estimation using OLS may suggest that the extent of FDI has a positive impact on domestic output, when in fact the correlation reflects the fact that industries with a high productivity level attract more FDI.

<sup>7</sup> Alternatively, we used MNE capital stock and sales totals to represent the extent of foreign firms' production activities. The results from using these alternative variables are very similar to the benchmark results from using total MNE labor.

<sup>8</sup> Buckley, Clegg, and Wang (2007) find that the effect of the percentage of foreign-owned firms on labor productivity of locally-owned firms (not in logs) is nonlinear, using industry-level cross-section data for the PRC. Since our estimation uses logs as variables, non-linearity is incorporated to some extent. Further, when we included the square of the natural logarithm of FDI as an additional independent variable, we found that its effect is always insignificant.

<sup>9</sup> It should be noted that since our data set covers only firms in the Z-Park rather than all firms in the market,  $\text{SHARE}$  in our regression is the market share of the firm in the science park. However, as we explained earlier, the Z-Park is very large in size and we therefore assume that the market share in the science park reflects the market share in the whole market.

To correct for these potential problems, we employ the system GMM estimation as detailed in Blundell and Bond (1998) and apply the estimation method to equation (1) and its first difference. Using first differences eliminates firm-specific fixed effects, whereas GMM estimation corrects for endogeneity. In the system GMM, we estimate equation (1) in addition to its first-difference, because instruments are weak if the regressors have very similar unit root properties. More specifically, instruments used for the regressors in the level equation are  $\Delta z_{i,t-1}$  and earlier  $\Delta z_i$  where  $z = \ln K, \ln L, \ln R, SHARE, \ln FDI$ , and  $\Delta z_{it} = z_{it} - z_{i,t-1}$ . Similarly, instruments for the regressors in the first-difference equation are  $z_{i,t-2}$  where  $z$  is defined as above. Since our data set covers a four-year period, we actually use data for the period 2002–2003 as regressors and data for the earlier period as instruments.

We apply two-step estimations of the GMM system to obtain higher levels of efficiency. In addition, we use the methodology of robust standard errors developed by Windmeijer (2005), which are consistent in the presence of any pattern of heteroskedasticity and autocorrelation, and correct for finite sample biases found in the two-step estimations.

## 4. DATA

### 4.1 Description of the data set and variables

Firms in the Z-Park must file an annual report with the Administrative Committee of the Z-Park containing balance sheet information as well as information on their ownership, human resources, and R&D activities. The data set used in this paper is compiled from the annual reports for the period 2000–2003.<sup>10</sup> The advantages of this data set are that most firms in the Z-Park are high-tech firms and that the annual report includes detailed information on firm employment by educational level. Therefore, the use of this data set enables us to estimate the size of knowledge spillovers from FDI through employment of educated labor in MNEs more accurately than other data sets. In addition, since firms in the data set are located close to each other in the science park, we do not have to take into account estimation issues that may arise as a result of the effect of distance on spillovers from FDI. Firms from both the manufacturing and the non-manufacturing sector are located in the Z-Park. Non-manufacturing firms include those involved in hardware consultancy, software consultancy and supply, and data processing. Although knowledge spillovers from FDI in these activities would be of great interest, we focus on the manufacturing sector since the value of intermediate goods for non-manufacturing firms is not available for the period 2000–2001.

In the data set, we define MNEs as firms that have a foreign ownership ratio of 30% or more. Since each respondent firm reported nationality of the largest investor of the firm, we can identify the home country of each MNE. Investments from Hong Kong, China; Macau, China; or Taipei, China are not defined as foreign capital, since characteristics of those investments are different from investments from other countries, mostly developed countries such as Japan and the US.<sup>11</sup> When we construct the aggregate of FDI variables within each

<sup>10</sup> See Li, Zhang, and Zhou (2005) for a more detailed description of the Z-Park. Note that data on intermediate goods and R&D expenditures are not available in 1999 or earlier.

<sup>11</sup> Huang (2003) claims that a considerable proportion of FDI in the PRC from Hong Kong, China is round-trip FDI, i.e., the investment actually originated from domestic sources and was undertaken to take advantage of the tax, and other, benefits enjoyed by foreign-funded firms. Using the same data set as in this paper, Todo, Zhang, and Zhou (2006) find no spillovers from FDI in R&D from Hong Kong, China; Macau; or Taipei, China. Using the framework in this paper, we found that the effect that MNEs from Hong Kong, China; Macau; or Taipei, China had on local productivity is always insignificant. In addition, using industry-level data, Buckley, Clegg, and Wang (2002) find no productivity spillovers from FDI from Hong Kong, China; Macau; or Taipei, China firms, and Buckley, Wang, and Clegg (2007) find that this is particularly the case for technology-intensive industries which are the focus of this paper. Todo, Zhang, and Zhou (2006) and Ge and Chen (2008) find that MNEs from Hong Kong, China; Macau; or Taipei, China are less productive than other MNEs. This

"industry," "industries" are categorized according to the Industrial Classification and Codes for National Economic Activities of China at the two-digit level. Details on the construction of variables used in the estimation are presented in the Appendix.

## 4.2 Summary statistics

The sample for the regression in this paper consists of domestic firms that are defined as firms with a zero foreign ownership share. In addition, since we calculate capital and R&D stocks by the perpetual inventory method and use the GMM system to calculate our estimate, we include only domestic firms that reported the necessary data for at least three consecutive years during the four-year period 2000–2003. This selection process results in a sample of 798 firms and 1,504 firm-year observations. Table 1 reports summary statistics for the firm-level variables for these domestic firms and the industry-level variables relating to MNE capital and educated labor used in the regression. Table 2 shows the mean of the industry-level FDI variables by year, pointing to a drastic increase of MNEs in the Z-Park from 2001 to 2002. This increase is probably because of the PRC's accession to the World Trade Organization in December 2001.

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productivity differential may be the reason for the absence of knowledge spillovers from overseas Chinese MNEs from Hong Kong, China; Macau, China; or Taipei, China. Since a comparison between Hong Kong, China; Macau, China; or Taipei, China MNEs and those of other economies is not the main focus in this paper, we completely exclude Hong Kong, China; Macau, China; or Taipei, China MNEs from our definition of MNEs.

**Table 1: Summary Statistics of Variables Used in Estimations**

	Item	Mean	Standard Deviation	Min.	Max.
<i>Firm-level variables (N = 1,504)</i>					
InY	Log of output	7.526	2.036	-1.637	13.687
InK	Log of capital stock	6.360	2.425	-3.159	13.670
InL	Log of labor	3.399	1.363	0.000	7.820
InR	Log of R&D stock	6.646	1.952	0.000	13.502
SHARE	Market share	0.008	0.041	0.000	0.783
<i>Industry-level variables (N = 38)</i>					
InFL	Log of the industry aggregate of MNEs' workers	5.094	2.977	0.000	9.933
InFE1	Log of the industry aggregate of MNEs' workers with a master's or higher degree	2.483	1.979	0.000	7.285
InFE2	Log of the industry aggregate of MNEs' workers with a bachelor's or higher degree	4.075	2.540	0.000	9.011
InFE3	Log of the industry aggregate of MNEs' workers with overseas education	1.437	1.426	0.000	4.477

Note: The mean is based on the data for the period 2002–2003 used for the regressions.

Source: Author's calculations based on the firm-level data for Zhongguancun Science Park.

**Table 2: The mean of industry aggregate of MNE variables by year**

		2000	2001	2002	2003
InFL	Log of the industry aggregate of MNE workers	3.87	3.86	5.09	5.10
InFE1	Log of the industry aggregate of MNE workers with a master's or higher degree	1.73	1.76	2.51	2.46
InFE2	Log of the industry aggregate of MNE workers with a bachelor's or higher degree	3.15	3.20	4.05	4.10
InFE3	Log of the industry aggregate of MNE workers with overseas education	0.78	0.84	1.46	1.41

Source: Author's calculations based on the firm-level data for Zhongguancun Science Park.

Table 3 presents the extent of FDI penetration in the Z-Park by year, by industry, and in total, represented by the MNE share of sales, total employment, and employment of workers, with a master's or higher degree. The average share of MNEs in the total employment of workers with a master's or higher degree is smaller than the share of MNEs in sales or total employment in every year, indicating that MNEs are less likely to hire educated labor than domestic firms. In addition, we find a large variation in the extent of FDI penetration across industries. The MNE share of total sales mean value average is 10.3%, but more than 20% in four industries (rubber, electrical machinery, communication and computing equipment, and precision and optical instruments). The foreign share of educated labor mean value average, however, is 4.6% and exceeds 10% in the pharmaceuticals and medicinal chemicals, and the communication and computing equipment industries.

**Table 3: The MNE share of the Z-Park totals by year and by industry (%)**

Item	Code	MNE share of Z-Park Total Sales	MNE share of Z-Park Total Workers	MNE share of Z-Park Total Workers with graduate education
<i>Year</i>				
2000		5.0	3.9	3.5
2001		2.8	3.0	2.7
2002		16.3	9.9	6.4
2003		16.9	10.3	5.6
<i>Industry (Mean value average for years 2000–3)</i>				
Food processing	13	14.0	9.5	8.2
Food products	14	0.0	0.0	0.0
Coke, refined petroleum products and nuclear fuel	25	0.0	0.2	0.0
Chemicals and chemical products	26	7.4	3.1	5.4
Pharmaceuticals and medicinal chemicals	27	10.2	8.1	10.1
Man-made fibers	28	0.0	0.0	0.0
Rubber	29	38.0	22.6	8.7
Plastic products	30	6.1	5.9	4.4
Non-metallic mineral products	31	7.5	6.3	3.4
Iron and steel	32	0.0	0.0	0.0
Other basic metals	33	4.8	9.1	2.1
Metal products except machinery and equipment	34	2.8	2.6	1.4
Machinery	35	10.4	6.2	2.6
General equipment	36	18.9	5.3	7.6
Transport equipment	37	5.2	1.7	2.6
Electrical machinery	39	21.1	11.3	6.7
Communication and computing equipment	40	25.8	19.3	13.9
Precision and optical instruments	41	21.7	10.6	7.2
Others	42	1.0	6.8	2.5
Mean Value Average MNE Share of the Z-Park Total		10.3	6.8	4.6

Note: Industries are categorized according to the Industrial Classification and Codes for National Economic Activities of China.

Source: Author's calculations based on the firm-level data for Zhongguancun Science Park.

### 4.3 Differences in MNEs across home countries

Since our data set contains information on the nationality of the largest shareholder of each firm, we use that information to classify MNEs by home country. Table 4 presents the number of MNEs by year and in total for selected home countries. This table indicates that in terms of the number of MNEs, the United States is the largest home country of FDI to the Z-Park, followed by Japan.

**Table 4: The number of MNEs by home country**

Home country	2000	2001	2002	2003	Total
Canada	3	7	14	14	38
Germany	5	5	17	20	47
France	1	3	8	8	20
Japan	24	25	48	49	146
Singapore	16	15	15	15	61
Korea	2	3	8	10	23
United Kingdom	8	9	7	8	32
US	60	66	98	93	317
Total	156	173	301	303	933

Source: Author's calculations based on the firm-level data for Zhongguancun Science Park.

Further, Table 5 presents the amount of capital stock and the number of workers for Japanese, US, and other MNEs in the Z-Park, as well as the share of each group of total MNEs. The table indicates that Japanese MNEs have the largest shares in both capital stocks and employment. The share of Japanese MNEs in foreign capital stock mean value average exceeded 60% during the period 2000–2003, whereas their share in foreign employment was about 40%. The table also shows that Japanese MNE share in foreign capital stock is larger than their share in foreign employment, while the relation is the opposite for US and other MNEs. This evidence suggests that Japanese MNEs are more capital intensive than non-Japanese MNEs.

**Table 5: Characteristics of MNEs by home country**

	Japanese MNEs	US MNEs	Other MNEs	All MNEs	Share of MNE totals (%)		
					Japanese MNEs	US MNEs	Other MNEs
Capital stock	Amount (million RMB)						
2000	783.2	93.9	207.8	1,084.8	72.2	8.7	19.2
2001	678.0	120.4	300.0	1,098.4	61.7	11.0	27.3
2002	3,792.1	562.4	2,379.6	6,734.2	56.3	8.4	35.3
2003	4,127.9	777.0	2,280.3	7,185.2	57.4	10.8	31.7
Average of the columns	2,345.3	388.4	1,291.9	4,025.7	61.9	9.7	28.4
Employment	Number of workers						
2000	3,719	1,658	2,984	8,361	44.5	19.8	35.7
2001	3,435	2,696	2,983	9,114	37.7	29.6	32.7
2002	13,412	5,534	14,464	33,410	40.1	16.6	43.3
2003	16,200	3,716	15,006	34,922	46.4	10.6	43.0
Average of the columns	9,191.5	3,401.0	8,859.3	21,451.8	42.2	19.2	38.7

Source: Author's calculations based on the firm-level data for Zhongguancun Science Park.

Table 6 shows the share of Japanese, US, and other MNEs in total employment by industry. This indicates that MNE employment patterns differ substantially across industries. The Japanese MNE share is large in the machinery, the electrical machinery, communication and computing equipment industries, as well as in the other (i.e. not steel or iron) basic metal industry.. Japanese and US MNE shares are similar in some industries, such as the plastics, communication and computing equipment, and precision and optical instruments industries. The share for either Japanese or US MNEs, however, is high while the other is low in some other industries, such as the food processing, machinery, transport equipment, and other basic metals industries.

**Table 6: MNE share of industry total employment, by home country from 2000 to 2003 (%)**

Industry	(Code)	Japanese MNEs	US MNEs	Other MNEs
Food processing	13	0.7	4.0	4.8
Food products	14	0.0	0.0	0.0
Coke, refined petroleum products, and nuclear fuel	25	0.0	0.0	0.2
Chemicals and chemical products	26	0.0	0.8	2.3
Pharmaceuticals and medicinal chemicals	27	1.1	1.0	6.0
Man-made fibers	28	0.0	0.0	0.0
Rubber	29	0.0	0.0	22.6
Plastic products	30	2.4	2.1	1.4
Non-metallic mineral products	31	4.7	1.2	0.4
Iron and steel	32	0.0	0.0	0.0
Other basic metals	33	9.0	0.1	0.0
Metal products except machinery and equipment	34	1.2	1.1	0.3
Machinery	35	4.9	0.5	0.9
General equipment	36	0.3	1.6	3.4
Transport equipment	37	0.0	1.1	0.5
Electrical machinery	39	7.6	1.1	2.6
Communication and computing equipment	40	9.4	3.0	6.9
Precision and optical instruments	41	1.5	1.8	7.3
Others	42	1.1	0.7	5.0

*Note:* Industries are categorized according to the Industrial Classification and Codes for National Economic Activities of China.

Source: Author's calculations based on the firm-level data for Zhongguancun Science Park.

Differences between Japanese and non-Japanese MNEs can also be seen in their utilization of educated labor. Table 7 presents the number of employees with a master's or higher degree, those with a bachelor's or higher degree, and those with overseas education (i.e., outside the PRC) for Japanese, US, and other MNEs. The three right hand columns in the table show the share of the total number of educated workers in the Z-Park for MNEs from Japan, the US and elsewhere. Table 7 clearly indicates that the share of both educated and overseas workers is much smaller at Japanese MNEs compared with non-Japanese MNEs. For example, the mean value average of the ratio of Japanese MNE employees to total MNE employees with a master's or higher degree was only 8.7%, in contrast with the share of the total capital for MNEs operating in the Z-Park that Japanese MNEs provided—the mean value average of which exceeded 60% (Table 5). The mean value average of the share of total educated employees for US MNEs was above 30%, as compared with the US share of total foreign capital of 19%. Table 8 looks at the utilization of educated workers by home country from another perspective, showing the ratio of educated employees to total employees for the three types of MNE. For Japanese MNEs, the mean value average of all workers held a bachelor's, or higher, degree was only 12%, while in the case of non-Japanese MNEs, the share ranged from 47% to 79%. Similarly, Japanese MNEs employ many fewer PRC returnees from overseas than non-Japanese MNEs.

**Table 7: MNE employment by home country and education level**

Education level	Number of employees				Share of All MNEs Total (%)		
	Japanese MNEs	US MNEs	Other MNEs	All MNEs	Japanese MNEs	US MNEs	Other MNEs
<b>Master's or higher degree</b>							
2000	51	171	376	598	8.5	28.6	62.9
2001	37	285	420	742	5.0	38.4	56.6
2002	181	874	1,001	2,056	8.8	42.5	48.7
2003	194	319	1,052	1,565	12.4	20.4	67.2
Average of the columns	115.8	412.3	712.3	1,240.3	8.7	32.5	58.8
<b>Bachelor's or higher degree</b>							
2000	465	1,226	1,868	3,559	13.1	34.4	52.5
2001	457	1,928	2,368	4,753	9.6	40.6	49.8
2002	1,439	3,949	6,757	12,145	11.8	32.5	55.6
2003	1,721	1,752	7,190	10,663	16.1	16.4	67.4
Average of the columns	1,020.5	2,213.8	4,545.8	7,780.0	12.7	31.0	56.3
<b>Overseas education</b>							
2000	13	44	22	79	16.5	55.7	27.8
2001	5	31	41	77	6.5	40.3	53.2
2002	56	41	116	213	26.3	19.2	54.5
2003	65	59	82	206	31.6	28.6	39.8
Average of the columns	34.8	43.8	65.3	143.8	20.2	36.0	43.8

Source: Author's calculations based on the firm-level data for Zhongguancun Science Park.

**Table 8: Share of educated workers in the total MNE labor force by home country (%)**

Education level	Japanese MNEs	US MNEs	Other MNEs
Master's or higher degree			
2000	1.4	10.3	12.6
2001	1.1	10.6	14.1
2002	1.3	15.8	6.9
2003	1.2	8.6	7.0
Mean Value Average	1.2	11.3	10.2
Bachelor's or higher degree			
2000	12.5	73.9	62.6
2001	13.3	71.5	79.4
2002	10.7	71.4	46.7
2003	10.6	47.1	47.9
Mean Value Average	11.8	66.0	59.2
Overseas education			
2000	0.3	2.7	0.7
2001	0.1	1.1	1.4
2002	0.4	0.7	0.8
2003	0.4	1.6	0.5
Mean Value Average	0.3	1.5	0.9

Source: Author's calculations based on the firm-level data for Zhongguancun Science Park.

## 5. ESTIMATION RESULTS

### 5.1 Spillovers through production activities

We start with estimating equation (1) in which we assume that MNE knowledge spills over through production activities, using the MNE industry labor force aggregate as a proxy for the size of their production activities. Columns (1) and (2) in Table 9 show results from the OLS and the system GMM estimations. As we noted in the previous section, the system GMM approach can correct for possible biases due to the endogeneity of the regressors and firm-specific fixed effects. According to the  $p$  value of the Hansen  $J$  statistics reported in the last row, we cannot reject the hypothesis that the instruments are orthogonal to the error term at the 5% significance level. This is actually the case in all other estimations presented later. In other words, the use of the lagged regressors as instruments can be justified in all estimations, suggesting that the system GMM is the preferred estimator.

**Table 9: Spillover Effects from MNE Production Activities**

Regressor	Description	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
		OLS	GMM	OLS	GMM	OLS	GMM	OLS	GMM
<i>lnK</i>	Capital stock	0.131*** (0.019)	0.282*** (0.100)	0.131*** (0.020)	0.312*** (0.111)	0.132*** (0.0194)	0.284*** (0.104)	0.133*** (0.019)	0.278** (0.119)
<i>lnL</i>	Labor	0.615*** (0.0385)	0.781*** (0.200)	0.612*** (0.0384)	0.738*** (0.211)	0.616*** (0.0386)	0.818*** (0.205)	0.615*** (0.039)	0.835*** (0.230)
<i>lnR</i>	R&D stock	0.283*** (0.028)	0.236*** (0.077)	0.287*** (0.028)	0.210** (0.082)	0.281*** (0.0274)	0.242*** (0.0780)	0.282*** (0.027)	0.222*** (0.077)
<i>SHARE</i>	Market share	6.119*** (0.817)	4.562 (3.941)	5.844*** (0.828)	4.622 (3.202)	6.181*** (0.823)	4.461 (3.644)	6.143*** (0.812)	7.677 (6.500)
<i>lnFL</i>	Industry aggregate of MNE labor	0.048*** (0.016)	0.050 (0.054)						
<i>lnJL</i>	Industry aggregate of Japanese MNE labor			0.018* (0.011)	-0.005 (0.031)				
<i>lnUL</i>	Industry aggregate of US MNE labor					0.054*** (0.015)	0.065** (0.032)		
<i>lnOL</i>	Industry aggregate of other MNE labor							0.049*** (0.016)	0.060 (0.037)
Number of observations		1504	1504	1504	1504	1504	1504	1504	1504
$R^2$		0.616	.	0.615	.	0.617	.	0.617	.
Hansen <i>J</i> statistic			0.089		0.225		0.198		0.143

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

Source: Author's calculations based on the firm-level data for Zhongguancun Science Park.

Columns (1) and (2) of Table 9 indicate that although the effect of the industry aggregate of MNE labor is positive and statistically significant in the OLS results, its effect is insignificant in the GMM results. The difference between the OLS and the GMM results suggests that MNEs are more attracted to more productive industries, but that MNE production activities do not improve domestic firm productivity due to knowledge spillovers.

## 5.2 Differences in FDI spillovers across home countries

In Section 5.1, we assumed that the spillover effect does not vary in size depending on the MNE home country. However, since MNE characteristics substantially differ across home countries, as we have seen in Section 4, this assumption may not hold in practice. Therefore, we estimate the effect of spillovers from Japanese, US, and other MNEs separately, by incorporating the total labor force for each of the three types of MNE in equation (1). The results from the OLS and the GMM estimation are presented in columns (3)–(8) of Table 9. The GMM results indicate that the coefficient on US MNEs is positive and significant, while Japanese and other MNEs do not have a significant effect on local productivity. These results suggest that although Japanese MNE employment does not lead to knowledge spillovers to domestic firms, knowledge spillovers from US MNEs in fact take place.

The size of the spillover effect of non-Japanese MNEs is large. The average across industries of the log of industry labor force of US MNEs increased from 2.97 in 2000 to 3.47 in 2003. Thus, the estimation result in column (6) of Table 9 indicates that the increase in US MNEs raised the average productivity and output of domestic firms by roughly 3.3% ( $= 0.065 \times (3.47 - 2.97)$ ) during the four-year period.

## 5.3 Spillovers through employment of educated workers

Now, what are reasons for the substantial difference in spillover effects between Japanese and non-Japanese MNEs? In Tables 7 and 8, we found that Japanese MNEs utilize educated labor substantially less than US MNEs. This may be a reason for no spillovers from Japanese MNEs. To test this hypothesis, we employ the MNE industry aggregate of educated workers as an additional proxy for the size of MNEs and estimate equation (1).

Table 10 shows GMM results based on three alternative definitions of educated workers; workers with a master's or higher degree, those with a bachelor's or higher degree, and those with overseas education. In column (1), we find that MNEs' workers with graduate education have a positive and significant impact on the productivity of domestic firms in the same industry, while the effect of total MNE labor force is insignificant as before. However, column (2) indicates that MNE workers with only an undergraduate education do not contribute to productivity improvement of domestic firms. The comparison between the two findings suggest that MNE knowledge spills over through highly educated workers, i.e., holders of master's and doctorates, but not through holders of bachelor's degrees.

**Table 10: Spillover Effects Through Educated MNE workers**

Regressor	Description	(1)	(2)	(3)
		GMM	GMM	GMM
InK	Capital stock	0.265*** (0.0928)	0.250*** (0.0934)	0.297*** (0.0968)
InL	Labor	0.822*** (0.186)	0.922*** (0.205)	0.762*** (0.198)
InR	R&D stock	0.229*** (0.0744)	0.217*** (0.0773)	0.231*** (0.0773)
SHARE	Market share	4.706 (2.928)	5.479 (4.168)	4.819 (3.280)
InFL	Industry aggregate of MNE employees with master's or higher degree	0.00681 (0.0522)	-0.0519 (0.107)	0.0262 (0.0535)
InFE1	Industry aggregate of MNE employees with master's or higher degree	0.137** (0.0649)		
InFE2	Industry aggregate of MNE employees with bachelor's or higher degree		0.0753 (0.113)	
InFE3	Industry aggregate of MNE employees with overseas education			0.181*** (0.0673)
Number of observations		1,504	1,504	1,504
Hansen J statistic		0.218	0.105	0.039

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

Source: Author's calculations based on the firm-level data for Zhongguancun Science Park.

In column (3) of Table 10, we find that MNE employment of workers with overseas education also promotes spillovers from FDI. Since the definition of overseas education in our data set includes both graduate and undergraduate education, this result suggests that bachelor's degree holders of foreign universities contribute to spillovers, although bachelor's degree holders from PRC universities do not. This difference is probably due to the multicultural background and linguistic strength of returnees from overseas, which promotes interaction between foreign and domestic workers and thus knowledge spillovers.

## 5.4 Robustness checks

To check the robustness of the results, we further experiment with three alternative specifications. First, when we constructed firms own R&D stock, we imposed several assumptions as indicated in the Appendix. Since these assumptions may be too strong, we exclude firms' own R&D stock from the set of regressors in the production function equation. Second, following studies such as Javorcik (2004), we first estimate productivity at the firm level using the method developed by Olley and Pakes (1996) and then estimate the impact

of FDI variables on the productivity level. The estimated elasticity of capital and labor are 0.232 and 0.743, respectively, which is not very different from the elasticity from the previous system GMM estimations. Third, we use a trans-log production function, rather than a Cobb-Douglas function indicated by equation (1), incorporating the squared log of capital and labor and the interaction between the log of capital and labor in the estimation equation. The results from the three alternative specifications, not shown here for simple presentation but available upon request, are very similar to the results from the benchmark specification presented in Table 10, suggesting the robustness of the benchmark results. In the third alternative specification, the coefficient on the squared terms and the interaction term is always insignificant, and in some cases the coefficient on the log of capital and labor also becomes insignificant, probably due to multicollinearity. Therefore, we do not use the trans-log function for our benchmark regression.

In addition, since the elasticity of capital and labor may differ across industries, we divided firms into four broadly-defined industry categories,<sup>12</sup> and estimated the elasticity of capital and labor using the method of Olley and Pakes (1996) for each category. For one category, the estimated elasticity of capital exceeded one, whereas for another, the estimated elasticity of labor exceeded one. These values are not acceptable for elasticity of capital or labor. A possible reason for the seemingly biased estimates is that the influence of outliers is exaggerated in smaller subsamples of firms. However, as an experiment, we ignored the possible estimation biases and used the industry-specific elasticity to construct the TFP level for each firm to estimate the spillover effects using the two-step approach of Javorcik (2004). Then, we found that the OLS results are similar to the OLS results in the benchmark estimation assuming the same elasticity of capital and labor across industries. However, in all GMM estimations, the orthogonality between the instruments and the error term was rejected according to the Hansen *J* test, and hence the instruments were invalid. Therefore, we do not assume discrepancies in the capital and labor elasticity across industries but stick with the benchmark assumption of the same elasticity. One justification of this assumption is that entries to the Z-Park are restricted to high-tech firms so that discrepancies across firms and industries may not be as large as in the case when the sample covers any type of firm in the economy. In addition, we experimented with a trans-log production function, in which we do not assume constant elasticity, and found that the coefficient on the squared terms and the interaction term is insignificant, as we mentioned above. This result also justifies the benchmark assumption.

## 5.5 Differences in the spillover effect across industries

So far, we have assumed that the spillover effect is the same in size across industries, but the effect may vary depending on industry characteristics. To check this possibility, we incorporated the interaction term between the industry aggregate of educated MNE workers and industry characteristics. In particular, we hypothesize that the size of FDI spillovers through educated labor depends on the importance of R&D activities represented by the ratio of R&D expenditures to sales, or the R&D intensity.

The results are shown in columns (1)–(3) of Table 11, indicating that for all three different definitions of educated labor, the effect of the interaction term is positive and statistically significant, while the industry aggregate of educated MNE workers alone has no significant effect. This evidence suggests that the size of FDI spillovers through educated MNE workers is larger in more R&D-intensive industries.

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<sup>12</sup> These are (1) the petroleum, chemical, and pharmaceuticals industries, (2) the non-metal, metal, machinery, and transportation equipment industries, (3) the electric equipment, communication equipment, computer, and precision machinery industries, and (4) other industries.

**Table 11: Differences in Spillover Effects Across Industries**

Regressor	Description	(1) GMM	(2) GMM	(3) GMM	(4) GMM
<i>lnK</i>	Capital stock	0.262*** (0.097)	0.297*** (0.098)	0.255*** (0.092)	0.292*** (0.090)
<i>lnL</i>	Labor	0.770*** (0.203)	0.813*** (0.205)	0.698*** (0.203)	0.782*** (0.192)
<i>lnR</i>	R&D stock	0.219*** (0.082)	0.233*** (0.077)	0.273*** (0.083)	0.241*** (0.076)
<i>SHARE</i>	Market share	4.806 (3.317)	3.355 (3.016)	5.454 (3.935)	3.986 (3.182)
<i>lnFE1</i>	Industry aggregate of MNEs' employees with master's or higher degree	0.062 (0.045)			
<i>lnFE1*RI</i>	Interaction between <i>lnFE1</i> and industry-level R&D intensity	1.396** (0.669)			
<i>lnFE2</i>	Industry aggregate of MNEs' employees with bachelor's or higher degree		0.012 (0.039)		
<i>lnFE2*RI</i>	Interaction between <i>lnFE2</i> and industry-level R&D intensity		0.678* (0.393)		
<i>lnFE3</i>	Industry aggregate of MNEs' employees with overseas education			0.025 (0.066)	
<i>lnFE3*RI</i>	Interaction between <i>lnFE3</i> and industry-level R&D intensity			2.966** (1.301)	
<i>lnFL</i>	Industry aggregate of MNEs' capital stocks				0.033 (0.038)
<i>lnFL*RI</i>	Interaction between <i>lnK</i> and industry-level R&D intensity				0.465 (0.302)
Number of observations		1,504	1,504	1,504	1,504
Hansen <i>J</i> statistic		0.281	0.144	0.069	0.263

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

Source: Author's calculations based on the firm-level data for Zhongguancun Science Park.

In addition, we estimate the effect of the interaction term between the industry aggregate of MNE labor force and the industry R&D intensity, in order to check whether we can find knowledge spillovers through MNE production activities under the new assumption. However, as column (4) of Table 11 shows, we find no significant impact for either the

interaction term or the industry aggregate labor alone. This evidence suggests that, even if we assume variations in the size of spillover effects across industries, our main conclusion remains unchanged: MNE knowledge spills over through their employment of educated labor, but not through their production alone.

## 6. DISCUSSION AND CONCLUDING REMARKS

This paper examines whether or not advanced knowledge of MNEs spills over to domestic firms and if so, under what conditions such spillovers take place, using a firm-level panel data set for a high-tech cluster in China. We are particularly interested in the role of MNE employment of educated workers and possible differences in spillover effects between Japanese and US MNEs.

The results from the estimations of this paper lead to the following conclusions. First, MNE knowledge in the Z-Park does not unconditionally spill over to domestic firms in the same industry. However, when MNEs employ highly educated workers, such spillovers in fact take place. A possible reason for this finding is that MNE's advanced knowledge remains in a black box for local workers when MNEs engage only in production activities that require unskilled labor. However, when MNEs engage in advanced activities, such as R&D, using local skilled labor, the black box opens and those educated workers can learn the advanced knowledge of MNEs. Then, the advanced knowledge spills over to domestic firms through labor turnovers, startups of new firms, and technological collaboration between MNEs and domestic firms, as suggested in Section 2. In addition, the size of such FDI spillovers is larger in more R&D-intensive industries.

Second, we find that Japanese MNEs in the Z-Park contribute less to spillovers to domestic firms than non-Japanese MNEs, which include US MNEs. This is most likely due to the fact that Japanese MNEs employ educated labor much less than non-Japanese MNEs.

Finally, we should emphasize a number of limitations of this paper. First, the analysis of this paper focuses on intra-industry knowledge spillovers. Although FDI may also benefit upstream industries through inter-industry spillovers, or vertical spillovers, as Javorcik (2004), Kugler (2006), Blalock and Gertler (2008), and Liu (2008) find, we generally disregarded such vertical spillovers. Therefore, our findings do not rule out the possibility of vertical spillovers from FDI through production activities. Second, our data set allows for only a short panel data which may underestimate the dynamic effect of FDI spillovers. Third, while the Z-Park provides us with a desirable context for examining technology diffusion via interpersonal interactions and labor mobility within a geographically concentrated unit, a study based on one park also limits the generality of our research results. We expect future research to be conducted which will address these limitations.

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## APPENDIX: 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 values of industrial output and input are reported in the annual reports filed by firms in the Z-Park and are then deflated by industry-specific price deflators for output and input taken from the National Bureau of Statistics of China (2005).

The capital stock  $K$  is constructed using the following procedure. 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 the depreciation. Second, nominal investment is deflated by the price deflator for investment to create the value of real investment. The investment price deflator is again taken from the 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 engaged in R&D activities. We subtract labor engaged in R&D to avoid double counting, since our value-added equation includes the R&D stock as another input.

Firm market share  $SHARE$  represents the ratio of a firm’s sales to the total sales of the industry into which the firm is classified.

We construct a firm’s own R&D stock using the following procedure.<sup>13</sup> First, we obtain real R&D expenditure by dividing nominal R&D expenditure by the investment price deflator taken from the National Bureau of Statistics of China (2005). Second, we estimate the growth rate of firm  $i$ ’s real R&D expenditure  $g_i^r$  by running an OLS regression of the log of real R&D expenditure,  $r_i$ , on years. Third, if firm  $i$  was established before 2000, we estimate the firm’s R&D stock in 2000,  $R_{i,2000}$ , by

$$R_{i,2000} = \sum_{t=0}^{2000-T_i} r_{i,2000} e^{-(0.15+g_i^r)t}$$

where 0.15 denotes the depreciation rate of the R&D stock and  $T_i$  is firm  $i$ ’s year of establishment or 1995 when firm  $i$  was established before 1995. That is, we assume that R&D activities before 1995 do not affect the R&D stock in 2000 or later. This assumption can be justified, since 65% of all firms in the data set for the year 2000 were established in or after 1995.<sup>14</sup> If firm  $i$  was established in 2000 or later, the R&D stock in the year of establishment is equal to the real value of 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%.

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.

<sup>13</sup> A similar procedure is employed in other studies, e.g., Basant and Fikkert (1996).

<sup>14</sup> Moreover, modifying this assumption does not materially change the benchmark results.