Spillover Effects of FDI in China: From the Perspective of Technology Gaps

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Abstract

On January 1, 2008, the Chinese government partly reduced the privileges enjoyed by FDI firms. This policy change again put the effects of FDI into public focus. Using Chinese industry-level panel data, this paper analyzes the spillover effects of FDI from the perspective of technology gaps (GAP). Unlike most previous studies that only analyze two or three levels of GAP, we instead treat it as a continuous explanatory variable. Also, we propose a more accurate measure for GAP. To overcome the difficulty of measuring spillover effects, we transform the spillover regression into the output regression. The method of DEA and a new set of instrumental variables are also employed to solve the problems of misspecification and endogeneity.

We find that the spillover effects are negative and have a U-shaped relationship with GAP. These results are robust to various model specifications and estimation methods. We interpret our seemingly counter-intuitive findings as follows: the overall spillover effect can be divided into three components--the increasing "learning-room effect," the decreasing "learning-ability effect" and the "crowding-out effect," which is uncorrelated with GAP. Mainly because of the strict controls that FDI firms place on their core technologies, the "brain drain" from domestic firms to FDI firms, and the GDP-oriented behaviors of Chinese municipal officials, the negative "crowding-out effect" dominates the other two positive effects, and as GAP decreases from a small initial value, the increasing "learning-ability effect" dominates the decreasing "learning-room effect" (and vice versa). Consequently, a policy of reducing the privileges of FDI firms in industries with middle-sized technology gaps is suggested.

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1. Introduction

Since Reform and Opening in 1978, China has been opening its door wide to foreign investors. By the end of 2006, the accumulated amount of actually-utilized foreign direct investment (FDI) had reached 691.90 billion USD (31.85% of the GDP in 2006), and the ratio of actually-utilized FDI inflow to GDP had increased from less than 1% in 1989 to 3.20% in 2006. However, whether FDI can contribute to the economic growth of host countries has always been a hot debate.

This debate was highlighted by the following policy change of Chinese government: on January 1, 2008, the Chinese government replaced the two separate tax laws for domestic firms and FDI firms with a uniform one, which partly reduced the privileges offered to FDI firms.

Two important questions then have arisen from this policy change: firstly, will FDI have positive or negative spillover effects on host countries? Secondly, which types of FDI will bring the most welfare in terms of domestic growth, the FDI projects with large technology gaps or those with small technology gaps?

Before we get a clear idea about the above two questions, the policies about the privileges for and restrictions on certain kinds of FDI seem subjective and arbitrary. This paper then tries to answer the two questions above. The remaining parts proceed as follows: Section 2 gives a brief review of related literatures. Section 3 provides the theoretical framework of this paper. The empirical framework and the data sources are described in section 4. Section 5 provides the empirical results and analyses. Section 6 concludes and proposes some policy suggestions.

2. Literature review

2.1 Literature on the sign of spillover effects[1]

Using cross-sectional industry-level data, many scholars, such as Blomström and Persson (1983), Blomström (1986), Blomström and Wolff (1994), Kokko (1994), Kokko (1996), Li, Liu and Parker (2001), Driffield (2001), etc., find positive spillover effects of FDI on domestic productivity. Blomström and Sjöholm (1999), Sjöholm (1999a), Sjöholm (1999b) and Chuang and Lin (1999) obtain the same results, although they use cross-sectional plant-level data instead of industry-level data.

However, Görg and Strobl (2001) argue that the cross-sectional data may fail to capture the true development of domestic firms' productivity over a longer time period and thus may lead to biased results. Therefore, they suggest that the results obtained from panel data may be more reliable.

Unfortunately, the researches using panel data have also obtained mixed results. Some researches find significant positive spillover effects, including: Liu et al. (2000) and Haskel et al. (2002) for the UK, Castellani and Zanfei (2002) for Italy, Görg and Strobl (2002) for Ghana, Keller and Yeaple (2003) for the USA,

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[1] Many scholars, such as Saggi (2002), Smarzynska (2002), etc., recognize two major channels for technology transfer: (1) the "horizontal" spillover effects from FDI firms to their local competitors in roughly the same industry; (2) the "vertical" spillover effects from FDI firms to their local suppliers of intermediate goods. Due to data unavailability, this paper will only focus on the horizontal spillover effects, and the term "spillover effect" refers to horizontal spillover effect throughout this paper.

Ruane and Ugur (2002) and Görg and Strobl (2003) for Ireland.

But some other panel-data-based research reports negative spillover effects. One influential study is conducted by Aitken and Harrison (1999), which uses a panel data set of Venezuelan plants between 1976 and 1989. They find that the increases in foreign ownership negatively affect the productivity of wholly domestically owned firms in the same industry. What's more, they point out that many of the previous studies are plagued by a self-selection problem, i.e., FDI may be attracted to more productive industries, resulting in an over-estimation of the positive impact brought by FDI. Other studies which use panel data and report negative spillover effects include: Djankov and Hoekman (2000) for the Czech Republic, Zukowska-Gagelmann (2000) for Poland, Konings (2001) for Bulgaria, Damijan et al. (2003) for seven countries in Central and Eastern Europe, López-Córdova (2002) for Mexico.

Still, some other panel-data-based researches, such as Kathuria (2000) for India, Girma (2002) for the UK, Harris and Robinson (2002) for the UK, find no statistically significant spillover effects.

2.2 Literature on the exact relationship between technology gap and spillover effect

Theoretically, scholars have not achieved a consensus on the exact relationship between spillover effects and technology gaps. For example, Findlay (1978) suggests that a larger technology gap between the home country and the host country will cause a greater backlog of available opportunities to exploit in the host country, a greater pressure for change, and thus a higher speed of the uptake of new technology, i.e., a larger spillover effect. Besides, the theoretical model developed by Wang and Blomström (1992) also suggests that larger technology gaps between foreign and domestic firms lead to larger spillovers. By contrast, Glass and Saggi (1998) argue that the larger the technology gap, the less likely the host country is to have the necessary capital, physical infrastructure, etc., and thus the lower the country's potential for spillovers.

Theoretical studies have not achieved a consensus, nor have empirical studies.

Some scholars find that spillover effects monotonically increase over technology gaps. For example, Sjöholm (1999a) reviews detailed micro-data from the Indonesian manufacturing sector, and finds that the larger the technology gap between domestic and foreign establishments, the larger the spillover effect.

Conversely, some scholars find a monotonically decreasing relationship between spillover effects and technology gaps. For example, after examining cross-sectional industry-level data for Mexico, Kokko (1994) finds that industries with larger gaps and higher foreign presence experience lower spillovers on average than others, although a larger technology gap does not by itself hinder technology spillovers. Additionally, using firm-level panel data, Girma et al. (2001) find that firms with low productivity relative to the sector average (which they consider as a large technology gap) gain less from foreign firms. More recently, by computing technology gap as the difference between the highest initial total factor productivity (TFP) of the domestic firms and the individual firm's initial TFP, Hale and Long (2006) find that the Chinese domestic firms with small technology gaps enjoy positive spillovers while those with large gaps experience negative spillovers.

Unlike the above two monotonic relationships, some other scholars suggest an inverted-U relationship between spillover effects and technology gaps. For example, Kokko et al. (1996) point out that only when the technology gap is not too large can domestic firms absorb the technology from FDI. Mathematically, they suggest an inverted-U relationship between spillover effects and technology gaps. Smarzynska (2002) also finds a similar result, although he focuses on spillover effects through backward linkages (i.e., vertical spillover) instead. Using data from Lithuania, the author finds that vertical spillover only exists in the group of firms which have moderate technology gaps.

However, none of the above studies treat the technology gap as a continuous explanatory variable that can take on many different values. Instead, most of them only split the whole sample into two or three subsamples according to the technology gaps. For example, Sjöholm (1999a) divides the sample of establishments into only two groups, "high-gap group" and "low-gap group" respectively, and then concludes the general relationship by comparing the coefficients of FDI in the two groups. Another example is Smarzynska (2002), who splits the sample into only three subgroups: (i) firms with the technology gap in the bottom third, (ii) middle third and (iii) top third, and estimates his model for each subgroup respectively. From the estimation result that spillover effects are significant only for the second group, the author concludes that the general relationship between spillover effects and technology gaps may be inverted-U shaped.

Figure 1 gives a clearer description. Apparently, Smarzynska (2002) has actually only found three combinations of spillover effects and technology gaps (say, point A, B and C). Based on these three points, the author concludes that the general relationship can be represented by the inverted-U curve in Figure 1. Although this idea certainly has merit, its logic needs further discussion because two or three values of technology gap are insufficient to deduce the general relationship. In fact, the curves passing through point A, B and C can have many other kinds of shape. For example, the dotted curve in Figure 1 is also possible, which is obviously not inverted-U shaped.

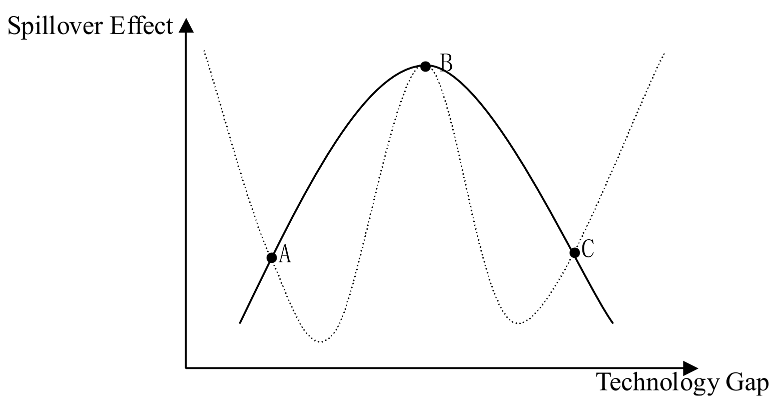

Figure 1 The Implied Inverted-U Relationship and Another Possible Relationship

Our paper will try to overcome this problem by directly treating the technology gap as an independent variable which takes on more than two hundred values.

Even for the few previous studies which have indeed treated the technology gap as a continuous explanatory variable, their measures of the technology gap may still be improved in the following two ways:

Firstly, the studies measure the technology gap as the difference between the sector's average productivity and the individual firm's productivity, as in the case of Girma et al. (2001). However, the sector's average productivity may not be an appropriate benchmark for the technology gap between FDI firms and domestic firms, since this productivity may be lower than that of FDI firms.

Secondly, they use the highest TFP of the domestic firms in the industry as the benchmark to measure technology gap, as in Hale and Long (2006). But this TFP cannot reflect the technology level of FDI firms in the same industry either, because even the most efficient domestic firm may still be less efficient than its foreign counterparts.

Therefore, to accurately measure the true technology gaps between FDI firms and domestic firms, we directly use FDI firms' TFP as the benchmark, and calculate the technology gap as the difference between FDI firms' TFP and domestic firms' TFP for each year.

In addition, unlike Alfaro et al. (2007) who calculate TFP as $\frac{Y}{L^{1/3}K^{2/3}}$, where Y is the output of the domestic firms, L is the amount of labor, K is the amount of capital and $\frac{1}{3}$ is the assumed labor elasticity, we employ the DEA method to avoid the problem of misspecification of functional forms that can be caused by the above parametric method.

2.3 Other related literature

Using firm-level panel data for the Czech Republic, Kinoshita (2001) finds positive spillovers for domestic firms which are R&D intensive and no spillovers for domestic firms in general. Girma (2002) further shows that only when firms have a certain ability to absorb the technology can positive productivity spillovers occur. Some other studies, such as Keller (1996), Borensztein et al. (1998), Xu (2000), also obtain similar results, although they focus on the role of human capital instead.

To capture the effect of human capital (or R&D activities) on spillover effects, we also include the interaction term of human capital and FDI in our regressions.

3. Theoretical framework

To begin with, let's check whether the following story makes sense:

If a pupil only has knowledge of primary mathematics, then he is ill-equipped to learn higher level mathematics. This is not because there is not enough room or scope for him to learn, but because the gap between higher level mathematics and his current knowledge level is too large for him to learn effectively. However, if he has mastered the basics of high school level mathematics, he will be in a much better position to learn. Although in the latter case the actual amount that he can learn is not as much as the former one, he can still learn more effectively with his more sophisticated knowledge basis.

Some scholars, such as Smarzynska (2002), claim that the story of FDI and technology gap is similar to the above one. They argue that when a domestic firm in an industry has a large gap relative to the FDI firm in the same industry, it is possible to learn a lot from the FDI firm, but the resulting spillover effect is small because the width of the large gap prevents effective learning. Therefore, these scholars expect that there will be an inverted-U curve between spillover effects and technology gaps.

At first glace, the logic of the above story is intuitive or even commonsensical. However, we believe that this story needs further analysis. To be clear, we define the effect which is monotonically increasing on technology gap as “learning-room effect”. It is called “learning-room effect” because other things being equal, the larger the technology gap is, the more room there is to learn (and vice versa). This effect is depicted in Figure 2.

Similarly, we define the effect which is monotonically decreasing over the technology gap as the “learning-ability effect”. Other things being equal, the larger the technology gap, the more limited the domestic firm’s ability to learn (and vice versa), as shown in Figure 3.

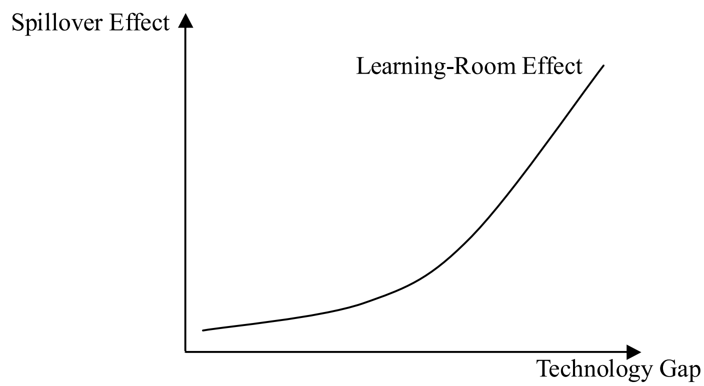

Figure 2 The “Learning-Room Effect”

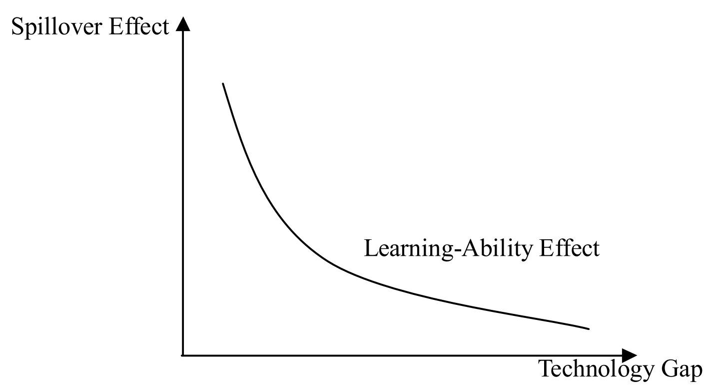

Figure 3 The “Learning-Ability Effect”

We claim that although the trade-off between the above two effects indeed exists, whether one effect will dominate the other is quite uncertain, depending on their relative magnitudes and change rates. For example, a U-shaped relationship depicted in Figure 4 is also possible, so long as the increasing rate (slope) of the “learning-ability effect” curve exceeds the absolute value of the decreasing rate (slope) of the “learning-room effect” curve when technology gap decreases from a small initial value (an initial point to the left of the intersection), and vice versa. Therefore, when combing these two effects into one, it will be U-shaped rather than inverted-U shaped.

In addition, we cannot ignore another important effect. After entering a country, there is no doubt that FDI firms will occupy some share of the domestic market, which will reduce the profit margin of domestic firms. To be clear, we name this effect “crowding-out effect”. Since many FDI firms are internationally renowned, they can quickly occupy a large market share simply by their well-known trademarks, resulting in a large negative "crowding-out effect" on domestic firms.

We assume that this negative "crowding-out effect" is uncorrelated with technology gap (GAP) so that the introduction of this effect will only change the *location* of the Spillover-Gap curve, leaving its *shape* of unaffected. This assumption is by no means far-fetched, because the fame of a certain trademark is determined by many factors, and it is highly possible that the trademark of a small-GAP foreign firm is as famous as that of a large-GAP foreign firm. For example, the food manufacturing industry is a small-GAP industry, since the industry is very labor intensive, and the foreign food-manufacturing technologies

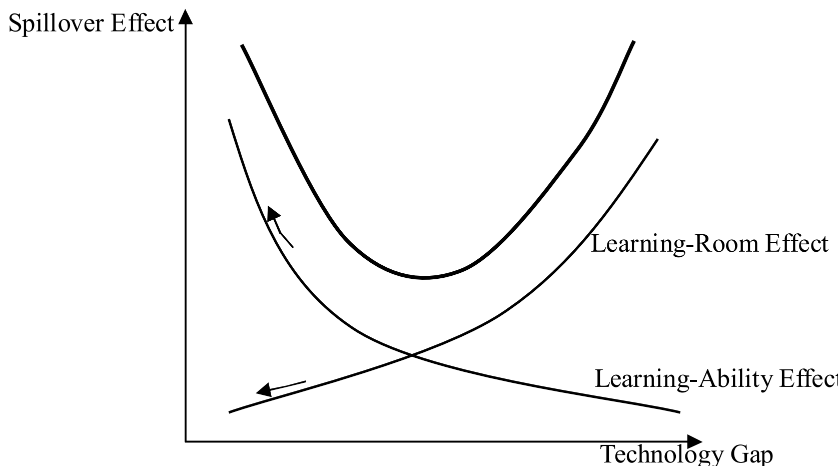

Figure 4 The Possible U Relationship

are not disproportionately more advanced than their Chinese counterparts; by contrast, the computer-manufacturing industry is a large-GAP industry, since it requires much sophisticated knowledge, and the foreign computer-manufacturing technologies may well be much more advanced than their Chinese counterparts. However, we know that there exist famous trademarks in both of the above two industries: in the food manufacturing industry, there are famous trademarks like McDonalds, KFC, and so on; while in the computer manufacturing industry, there are also famous trademarks like Apple, HP, and so on. The "crowding-out effect" is depicted in Figure 5, which is a horizontal line located in the negative half of the vertical axis.

To sum up, the overall spillover effect can be divided into three components: (1) the "learning-room effect", which is increasing over GAP; (2) the "learning-ability effect", which is decreasing over GAP; and (3) the "crowding-out effect", which is negative and assumed to be uncorrelated with GAP (a horizontal line located in the minus half of the vertical axis). After combining the three effects, the overall effect can be monotonically increasing, monotonically decreasing, first decreasing then increasing (U-shaped), or first increasing then decreasing (inverted-U shaped), or it could assume many other relationships over GAP. The overall spillover effect of FDI firms on domestic firms is depicted in Figure 6.

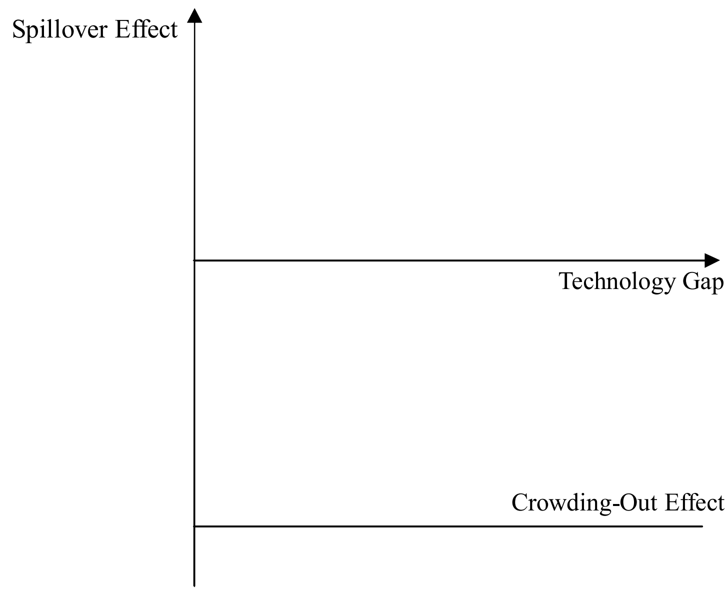

Figure 5 The "Crowding-Out Effect"

We claim that whether the inverted-U relationship or the U relationship (or any other) exists in reality depends on the specific country we are studying. We should adopt a pragmatic approach which considers the specific realities first, and not take a dogmatic approach which assumes there is some kind of relationship.

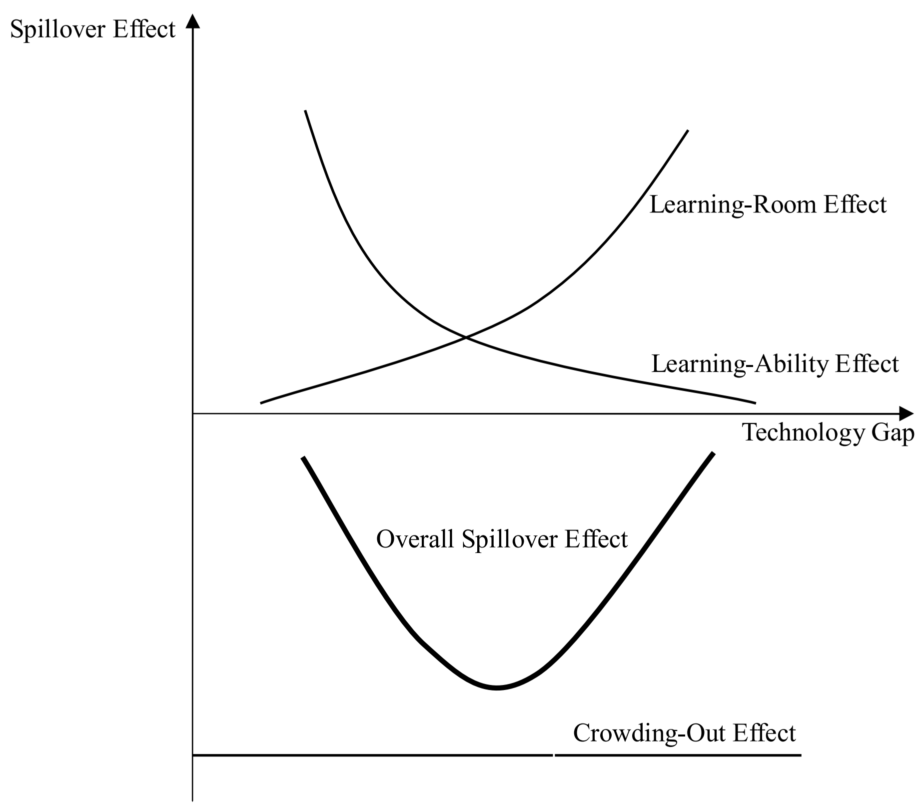

Figure 6 The Overall Spillover Effect and Its Three Components

4. Empirical framework and data sources

4.1 The baseline model

At first glance, our theoretical framework is very simple. That is, we only have to regress spillover effects (SPILLOVER) on the following variables: (1) technology gaps (GAP) between FDI firms and domestic firms; (2) the squared term of GAP (GAP^2); (3) other variables that may affect spillover effects, denoted by a vector X[2]. Mathematically:

$$SPILLOVER = a_1 GAP + a_2 GAP^2 + a_3 X + \varepsilon \qquad ①$$

where a_1, a_2 are the coefficients corresponding to GAP and GAP^2 respectively, a_3 is the vector of coefficient for the control variable vector, and ε is the error term.

If the results show that a_1 is significantly *positive* and a_2 is significantly *negative*, then we will get an *inverted-U* curve for SPILLOVER and GAP. On the other hand, if the results show that a_1 is significantly *negative* and a_2 is significantly *positive*, then we will also get a *U* curve for SPILLOVER and GAP. If, however, the regression results show that a_1 and a_2 are insignificant, then we will follow An and Joen (2006) and regress with the non-parametric method to consider other possible functional forms which can also generate a U or inverted-U relationship because the graph could still adhere to these forms.

4.2 The feasible model

Unfortunately, we cannot regress equation ① directly, since SPILLOVER cannot be observed in reality. To overcome this difficulty, we extend the method used by Aitken and Harrison (1999), who propose an interaction term between DFI_Plant_{ijt} (which denotes the share of foreign equity participation of plant i in sector j at time t) and DFI_Sector_{jt} (which denotes the foreign equity participation averaged over all plants in sector j at time t) to determine whether DFI_Sector_{jt} affects the marginal effect of DFI_Plant_{ijt} on the output of plant i.

Specifically, we will use the following model:

$$\ln VA = b_0 + b_1 \ln L + b_2 \ln K + b_3 FDI * GAP + b_4 FDI * GAP^2 + b_5 FDI * HC + \delta_1 * T_1 + ... + \delta_6 * T_6 + \varepsilon \qquad ②$$

Where:

VA is the total value added of domestic firms of a given industry in a given year, deflated by the "Ex-Factory Price Indices of Industrial Products (by sector)". We will mainly focus on state-owned-enterprises (SOEs), because: firstly, many important industries are controlled by SOEs; secondly, the foreign equity share in SOEs is lower than that in private enterprises, which enables us to focus on the "outside spillover effect" (i.e., spillover effect occurring from foreign firms to domestic firms); thirdly, the industry-level data of Chinese private firms are unavailable except for the most recent two years. As a robustness check, we also regress the total output of private firms and SOEs for the most recent two years and obtain very similar results.

L is the annual average number of employees working in domestic firms of a given industry.

K is the deflated total capital stock of the domestic firms in a given industry

[2] We have used some other control variables, such as financial development, but the results show that the coefficients of these variables except human capital are not significant. In the following analysis, therefore, we will omit all of them except human capital.

in a given year, measured by the deflated value of “annual average balance of net value of fixed assets”(deflated by the “Price Indices of Fixed Assets”).

FDI is the proxy for foreign direct investment. Following Yao et al. (2006), we measure FDI by the ratio of foreign capital to the sum of foreign and domestic capital, which represents the extent to which an industry absorbs foreign capital. Here we will not deflate the data of capitals because FDI is a ratio rather than a level, and if we divide the denominator and the numerator by the same index, the value of FDI will remain unchanged.

GAP is the technology gaps between FDI firms and domestic firms. We will use the method of DEA to calculate the TFP for domestic firms and FDI firms in the same industry respectively, and then obtain the technology gap by subtracting domestic TFP from foreign TFP.

HC stands for the stock of human capital of domestic enterprises, measured by the ratio of the number of technicians to the total number of employees.

T_1, …, T_6 are year dummies for 1999, 2000, 2001, 2002, 2003, 2005 respectively. Note that we’ve discarded the year 2004 since the data of capital is not available in that year.

ε is the error term.

We do not include FDI as an independent variable in equation ② because the effect of FDI on lnVA occurs via FDI*GAP, FDI*GAP^2 and FDI*HC. If we also include FDI, we will be subject to the problems of over-control and multicollinearity.

Take the partial derivative with respect to FDI on both sides of ② to get:

$$\frac{\partial \ln VA}{\partial FDI} = b_3 * GAP + b_4 * GAP^2 + b_5 * HC \qquad ③$$

The left-hand side of equation ③ is the partial effect of FDI on the log of value added of domestic firms. By definition, this is exactly the partial effect of FDI on the growth rate of domestic output. In other words, $\frac{\partial \ln VA}{\partial FDI}$ is just the variable of SPILLOVER in equation ①.

Similar with the baseline model, if b_3 is significantly positive and b_4 is significantly negative, then we will get an inverted-U curve for SPILLOVER and GAP; alternatively, if b_3 is significantly negative and b_4 is significantly positive, then we will get a U curve for SPILLOVER and GAP.

4.3 Data sources

Our Chinese data of non-deflated VA, L, K, the capital of FDI firms, ex-factory price indices of industrial products (by sector), and the price indices of fixed assets in all years come from *Chinese Statistics Yearbook* (2000, 2001, 2002, 2003, 2004, 2006, 2007), except for the capital data in 2002, which come from the *China Industry Economy Statistical Yearbook* (2003). In addition, the data of the number of technicians working in domestic firms come from the *China Statistical Yearbook on Science and Technology* (2000, 2001, 2002, 2003, 2004, 2006, 2007).

Note that all of the above price indices are given in year-by-year growth, so we need to convert them into base-year growth. We set the year 1999 as the base year, and calculate the base-year indices by ourselves.

We discard the year 2004 because the capital data in this year are unavailable. In addition, we discard the following four industries because their data are also unavailable in 2002: Extraction of Petroleum and Natural Gas; Mining of Other Ores; Manufacture of Artwork and Other Manufacturing; Recycling and Disposal of Waste and oil mining.

In a word, we'll use a balanced panel data set for seven years across 35 industries, with 245 observations altogether.

In Section 5.2, we will use the nominal exchange rates of RMB to US dollar, and the industry-level Producer Price Indices (PPI) of USA. The data of nominal exchange rates from 1999 to 2005 come from the *International Financial Statistics* (Feb. 2007, Page 270), and those of 2006 come from *International Financial Statistics* (Dec. 2007, Page 292). To be more accurate, we choose the rates of "Period Average" rather than "End of Period" as the proxies of nominal exchange rates. The industry-level data of Producer Price Indices (PPI) of USA come from the U.S. Bureau of Labor Statistics, which are given monthly. We average the monthly PPI to get annual data, and then convert them into base-year growth form, just as we did with the Chinese data.

5. Empirical results and analysis

5.1 Estimates without outliers and without instrumental variables (IV's)

In this subsection, we will in turn use pooled OLS, fixed-effect estimation (FE), and random effect estimation (RE) to regress equation ② without considering endogeneity.

Preliminary regression with all data shows that there are five obvious outliers (the regression results with outliers are omitted due to space constraint). In order to eliminate the effect of these outliers on our regression, we drop these outliers and redo our estimations with pooled OLS, FE, and RE. The results of these estimations without outliers are listed in Table 1.

All the results are highly consistent with those obtained with outliers: the coefficient of FDI*GAP (b_3) is negative, and that of FDI*GAP^2 (b_4) is positive, although the estimated b_3 and b_4 in pooled OLS are not statistically significant. All of these results suggest a U relationship between technology gaps and spillover effects of FDI on domestic firms, no matter whether we include outliers or not.

Additionally, all three estimations show that the coefficient of FDI*HC (b_5) is statistically significant at 5% level. This is consistent with Keller (1996) and Xu (2000), who point out that if the human capital of one country is too low, it may not capture the advanced knowledge from FDI.

Of course, as far as RE is concerned, the coefficient of FDI*GAP without outliers is not very significant, and the coefficient of FDI*GAP^2 is even insignificant at 10% level. However, the p-value of the Hausman test is as low as 0.010, which is a strong evidence for FE and against RE. The p-value of F test is as low as 0.000, again supportive of FE over pooled OLS.

Table 1 Regression without IV's and without outliers

lnVA	Pooled OLS	FE	RE
lnL	0.414***	0.280**	0.392***
	(0.000)	(0.035)	(0.000)
lnK	0.618***	0.468***	0.548***
	(0.000)	(0.000)	(0.000)
FDI*GAP	-0.495	-2.956***	-1.536*
	(0.653)	(0.004)	(0.099)

FDI*GAP^2	2.355	2.666**	1.462
	(0.167)	(0.026)	(0.206)
FDI*HC	3.733**	2.552**	2.727**
	(0.009)	(0.024)	(0.018)
Time dummies	Y	Y	Y
Overall R^2	0.907	0.875	0.896
F test for H_0: all u_i=0	p=0.000		
LM test for H_0: Var(u) = 0			p=0.000
Hausman test for FE and RE		p = 0.010	

Notes:

In all tables, p-values are in parenthesis. ***, **, and * denote 1%, 5% and 10% significance respectively. We include year dummies in all regressions.

Therefore, based on the results of FE, we evaluate spillover effects at the mean value of human capital without outliers (as the mean is the most representative and economically meaningful level of human capital), and then draw a graph between spillover effects and technology gaps.

As can be seen in Figure 7, SPILLOVER is decreasing over GAP until 0.576 and increasing afterward. This U relationship is reliable, since outliers have already been discarded and thus all the points are located near to each other.

However, as pointed out before, it is possible that FDI is endogenous, causing the three variables— $FDI*GAP, FDI*GAP^2$ and $FDI*HC$ —to be endogenous as well. Consequently, the above results need further analysis. We address these concerns in the following subsections.

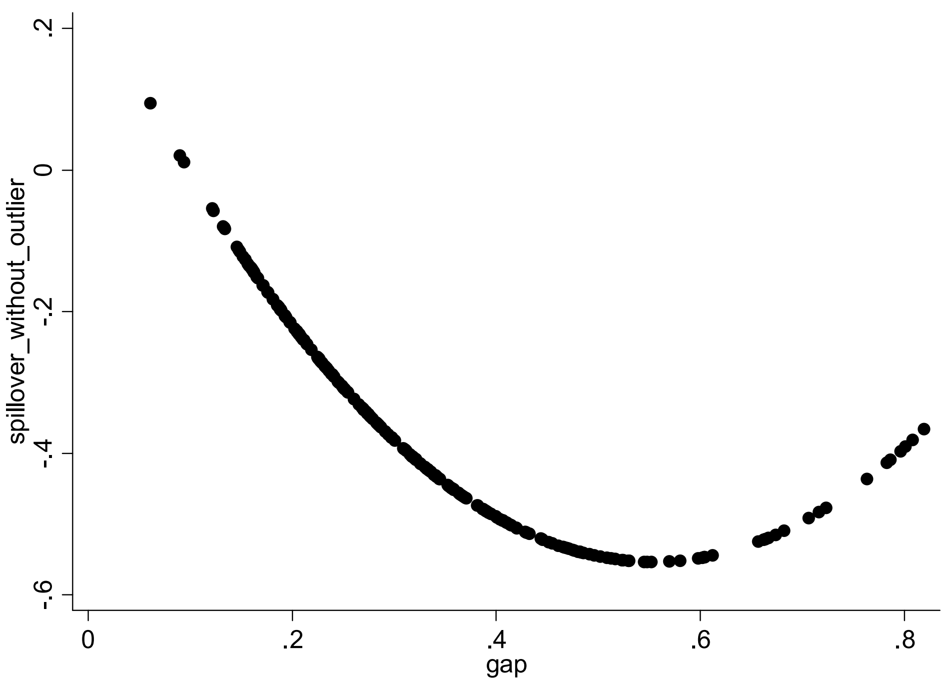

Figure 7 The Relationship Between Spillover and Gap (without Outliers or IV's)

5.2 Instrumental variables

Due to endogeneity concerns, we need to look for some instrumental variables (IV's) in order to determine the effect of GAP on SPILLOVER, that is, the effect of FDI*GAP and FDI*GAP^2 on lnVA.

As pointed out by Borensztein et al. (1998), Alfaro et al. (2004) and Luo (2006), lagged-one-period FDI (hence LagFDI) is a good IV for FDI. Another IV we are going to use is the real exchange rate at the industry level (RER[3]), which equals the product of the nominal exchange rate and the ratio of industry-level foreign price to industry-level domestic price. Although Luo (2006) has tested the validity of the nominal exchange rate and concluded that it is not a valid IV for FDI, we claim that there exist two problems with the result: (1) we need to use the real rather than the nominal exchange rate, since it is the real exchange rate that significantly affects the choice of foreign investors; (2) we need to use the industry-level exchange rate rather than the national-level rate, since we are considering the industry-level output and FDI. As far as we know, no research has yet used the industry-level real exchange rate as an IV for FDI. Alfaro et al. (2007) have come close, but then they conclude that the unavailability of data for industry-level real exchange rates prevents further analysis.

We know that a valid IV has to satisfy the following two conditions: (1) it should be highly correlated with the endogenous variables (in this case FDI*GAP, FDI*GAP^2 and FDI*HC); (2) it should not be directly correlated with the dependent variable (lnVA). Regressions using the methods of Acemoglu et al. (2001) and others show that LagFDI*GAP, LagFDI*GAP^2, LagFDI*HC, RER*GAP, RER*GAP^2 and RER*HC have satisfied these two conditions, and thus they are indeed qualified IV's. Due to space constraint, we do not report the results here, but they are available upon request.

5.3 Estimates with IV's

As in section 5.2, we conduct our regressions both with and without the outliers. As before, the results of the two are almost identical. In order to emphasize the economic analysis rather than the econometric process, we only report the result without outliers. See Table 2.

Table 2 Two-stage least squares (TSLS) without outliers

lnVA	FE	RE
lnL	0.359***	0.456***
	(0.018)	(0.000)
lnK	0.305***	0.444***
	(0.006)	(0.000)
FDI*GAP	-3.567***	-2.123**
	(0.002)	(0.025)
FDI*GAP^2	3.234***	2.003**
	(0.006)	(0.045)
FDI*HC	1.390	1.654
	(0.227)	(0.137)
Year dummies	Y	Y
Overall R^2	0.860	0.880
F test that all u_i=0	0.0000	

[3] It follows that we are going to use RER*GAP, RER*GAP^2 and RER*HC as the IV for FDI*GAP, FDI*GAP^2 and FDI*HC respectively.

Hausman test	0.759

We can see that both the fixed-effect TSLS results and the random-effect TSLS results show a significantly negative coefficient of FDI*GAP and a significantly positive coefficient of FDI*GAP^2, just as before. In other words, the U relationship between technology gaps and spillover effects still holds even after considering endogeneity and dropping the five outliers. Also, both estimation methods indicate that FDI*HC has no significant effect on the log value of output. Furthermore, the result of the Hausman test shows that RE is preferred to FE, so we rely on the RE result and write the formula of spillover effects as:

$$SPILLOVER = \frac{\partial \ln VA}{\partial FDI} = -2.123 * GAP + 2.003 * GAP^2 \quad ④$$

We also plot a graph of SPILLOVER and GAP. The maximum spillover effect in Figure 8 is -0.123, occurring at a GAP of 0.061, and the minimum spillover effect is -0.563, occurring at a GAP of 0.530.

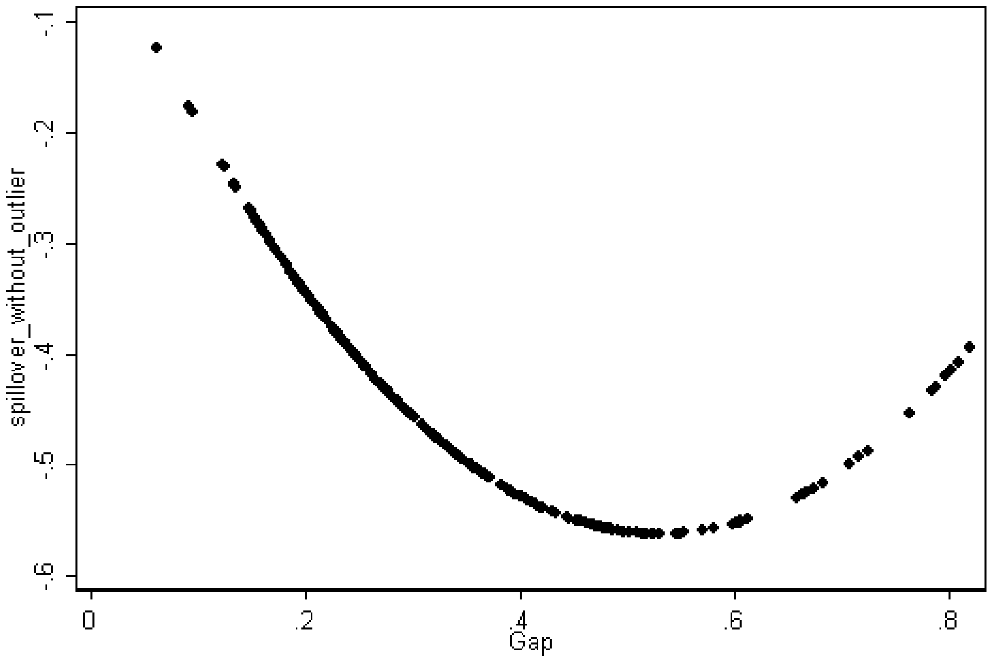

Figure 8 The Relationship Between Spillover and Gap (without Outliers but with IV's)

5.4 Explanation of Results

5.4.1 Why are the spillover effects negative?

An obvious characteristic of Figure 8 is that all the spillover effects of FDI on the output of domestic firms are negative. Although this result is inconsistent with Blomström and Hakan (1983) and Blomström (1986), it does coincide with the opinions of many other researchers like Aitken and Harrion (1999), who point out that the previous scholars did not consider the endogeneity of FDI, and thus overestimated the positive impact by FDI.

Our own theory developed in former sections can also give a reasonable explanation for this result. Notice that we have split the overall spillover effect into the following three components: (1) the "learning-room effect", which is increasing over GAP; (2) the "learning-ability effect", which is decreasing over GAP; and (3) the "crowding-out effect", which is negative and assumed to be uncorrelated with GAP (i.e., a horizontal line located in the minus half of the vertical axis). After combining the three effects, the overall effect can be monotonically increasing, monotonically decreasing, first decreasing then increasing (U-shaped), or first increasing then decreasing (inverted-U shaped), or it could assume many other relationships over GAP.

The location of the overall spillover effect depends on the relative magnitudes and change rates of its three component effects. However, past experiences show that all the above three effects are adverse to the domestic firms. Specifically:

(1) The positive "learning-room effect" is small because FDI firms have put strict controls on their core technologies. Many FDI firms do not conduct R&D activities in China in order to avoid the spillover of their core technologies. Even for those FDI firms which indeed conduct some R&D activities in China, they tend to develop only *auxiliary* technologies in China, while developing almost all *core* technologies in their parent countries in order to limit spillovers.

As a result, the Chinese domestic firms do not have much room to learn and gradually degenerate into simple processing factories, creating little value-added. The statistical data also confirms this conclusion. For example, in the year 2005, the processing trade accounted for 54.7% of total Chinese export trade[4].

(2) The positive "learning-ability effect" is small because the "brain drain" from domestic firms to FDI firms is prevalent. Obviously, the "learning-ability" of domestic firms is highly correlated with the number of skilled employees. However, a large proportion of proficient Chinese employees have been "stolen" by FDI firms because of the higher wages they offered. The data shows that 40% of top Chinese workers are employed by FDI firms.

But why can FDI firms offer higher wages? Of course, one explanation is that the profitability of FDI firms is much higher than that of domestic firms, but there is another important fact that we cannot ignore: the FDI firms have been enjoying many preferential policies offered by Chinese government, including tax deduction and subsidized land use. Since 1993, China has been enforcing two separate tax laws[5]. One applies to domestic firms, and the other to FDI firms. As a result, the average tax rate of FDI firms is about 10% lower than that of domestic firms.

In addition, the output of FDI firms is an important component of GDP, while the current evaluation system adopted by Chinese government is largely GDP-oriented. Therefore, many Chinese municipal officials spare no efforts in attracting FDI firms, sometimes granting them more preferential policies than afforded by law.

(3) The negative "crowding-out effect" is large due to the large "brand effect". A famous trademark can allow a foreign firm to easily defeat the less prestigious domestic competitors and quickly occupy the market.

In China, this story has been repeated again and again after so many internationally-renowned firms have entered. Even in the event of a joint venture between a famous Chinese firm and a famous foreign one, its products are often marketed under the foreign trademark, while the Chinese trademark gradually fades from people's memories.

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4 Data source: http://cys.mofcom.gov.cn/aarticle/h/200601/20060101345149.html.

5 As will be mentioned later, the two separate laws for domestic firms and FDI firms was replaced by a uniform law on January 1, 2008, in which both of domestic firms and FDI firms are taxed at the same rate. Since the duration of our sample extends only to 2006, we do not need to consider the effect of this policy change while explaining the regression results.

Consequently, when we combine the above three effects, the negative "crowding-out effect" will dominate the positive "learning-room effect" and "learning-ability effect", thus making the overall spillover effect negative.

5.4.2 Why is the relationship between spillover effects and technology gaps U-shaped?

As stated before, the shape of the overall spillover effect depends on the relative magnitudes and change rates of the three components: the "learning-room effect", the "learning-ability effect" and the "crowding-out effect". As seen in section 3, if, as GAP decreases from a small initial value, (1) the "learning-room effect" decreases more and more slowly, and (2) the "learning-ability effect" increases faster and faster (and vice versa[6]), then the relationship between the overall spillover effect and GAP will be U-shaped[7].

According to the analysis in subsection 5.4.1, FDI firms have put strict controls on their core technologies in order to limit the "learning-room effect". It is highly possible that as a small GAP[8] decreases further (that is, the FDI firms become less advanced in their technologies), the FDI firms will find that the marginal revenue of controls will become smaller while the marginal cost of controls remains largely unchanged. Therefore, they may put less strict controls on their technologies, making the "learning-room effect" decreasing more and more slowly (vice versa). Thus the above condition (1) is satisfied.

On the other hand, although the labor quality of domestic firms cannot rival that of FDI firms, as the GAP becomes smaller, it will still be easier for the domestic firms to imitate the technologies of FDI firms, since doing so now requires less knowledge. As a result, the "learning-ability effect" will increase faster and faster (and vice versa). Thus the above condition (2) is satisfied.

Combining the above two effects with the horizontal "crowding-out effect", we obtain the U curve, as shown in the empirical results.

5.5 Robustness check

We perform the following robustness checks in turn:

(1)We redo our regression without the log forms in order to test the robustness of functional forms. See the second column of Table 3.

(2)As pointed out by Ljungwall (2005), some of the variables in our regressions may be non-stationary, which may make the estimation results biased. To account for this possibility, we apply the dynamic panel method suggested by Arellano and Bond (1998) to our regression[9]. See the third column of Table 3.

(3)In the fourth column of Table 3 we use the level of foreign capital as the proxy for FDI.

(4)In the fifth column we use the price of industry 1 in 1999 as the base price, and thus change the definition of real exchange rate (RER).

(5)In the sixth column we use the Consumer Price Index (CPI) of the USA in 1999 as the base price, and thus use another definition of real exchange rate (RER).

To make full use of the property of our panel data, we conduct both fixed-effect regression and random-effect regression for all the regressions except

[6] That is, if the "learning-ability effect" decreases slower and slower and the "learning-room effect" increases faster and faster as GAP increases from a large initial value.

[7] Notice that the "crowding-out effect" is uncorrelated with the technology gap.

[8] Graphically, this means that the initial value of GAP is to the left of the axis of symmetry.

[9] Yao et al. (2006) also employ this method to solve the problem of non-stationary variables.

for the “dynamic panel method.” We then report only one of them according to the result of the Hausman test. To make our results more reliable, we also perform the regressions with outliers (but get very similar results which we do not report here).

As can be seen in Table 3, for our interested variables all of the regressions produce results similar to before: the coefficient of FDI*GAP is negative, while that of FDI*GAP^2 is positive, and both coefficients are significant at around the 5% level. In the second column they are even significant at the 0.5% level. All the above results provide strong evidence in support of a U-shaped relationship between spillover effects and technology gaps.

We also calculate the location of the axis of symmetry for each U curve. We can see that most of these axes are very close to each other, and three of them are actually equivalent. This is strong evidence for the reliability of our analysis.

Table 3 Robustness Checks

lnVA(or VA)	Without log form	Dynamic panel method	FDI=foreign capital’s level	RER is based on industry 1 of 1999	RER is based on CPI of 1999
Lag(lnVA)		-0.721***			
		(0.006)			
lnL(or L)	-3.639***	0.257	0.456***	0.454***	0.457***
	(0.000)	(0.238)	(0.000)	(0.000)	(0.000)
lnK(or K)	0.259***	0.995***	0.444***	0.443***	0.446***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
FDI*GAP	-4443.30***	-2.956*	-2.123**	-2.191**	-2.065**
	(0.000)	(0.076)	(0.025)	(0.021)	(0.028)
FDI*GAP^2	3670.137***	3.317*	2.003**	2.071**	1.949**
	(0.000)	(0.087)	(0.045)	(0.038)	(0.049)
FDI*HC	575.3388	0.173	1.654	1.587	1.670
	(0.614)	(0.908)	(0.137)	(0.154)	(0.132)
Year dummies	Y	Y	Y	Y	Y
Arellano-Bond test		p=0.333			
Overall R^2	0.620		0.880	0.879	0.880
Hausman test	p=0.067		p=0.759	P=0.730	p=0.728
Axis of symmetry	0.605	0.446	0.530	0.550	0.530

6. Conclusion

This paper exploits an industry-level panel data set of 35 industries for the period of 1999-2006 to examine the sign of spillover effects of FDI on domestic firms, as well as the exact relationship between spillover effects and technology gaps.

Specifically, our paper contributes to the existing literatures in the following aspects:

(1) We divide the overall spillover effect into three components, and use a real-life story as well as mathematical graphs to demonstrate that the relationship between spillover effects and technology gaps is not necessarily inverted-U

shaped, but instead depends on the relative magnitudes and change rates of these sub-effects.

(2) For the few previous studies which have indeed treated the technology gap as a continuous explanatory variable, we improve the measures of technology gap by using FDI firms' TFP (instead of the sector's average productivity or the highest TFP of the domestic firms) as the benchmark.

(3) Instead of assuming a certain structure and a certain value of the elasticity of labor or capital in advance, we use the DEA method to obtain TFP and thus GAP.

(4) We transform the spillover regression equation into the output regression equation to overcome the difficulty of measuring spillover effects (i.e., we regress lnVA on FDI, and then take the derivative of lnVA with respect to FDI).

(5) We propose a new set of IV's to address the endogeneity of FDI.

(6) We find a U relationship between spillover effects and technology gaps (instead of an inverted-U one).

We interpret our results by analyzing the relative magnitudes and change rates of the three components of the spillover effect. Mainly because of the strict controls that FDI firms place on their core technologies, the "brain drain" from domestic firms to FDI firms, and the GDP-oriented behaviors of Chinese municipal officials, the negative "crowding-out effect" dominates the positive "learning-room effect" and "learning-ability effect", and as the technology gap decreases from a small initial value, the increasing "learning-ability effect" dominates the decreasing "learning-room effect" (and vice versa).

The negative sign of the spillover effect could be interpreted as reason for restricting all FDI firms in China. However, we will not go to that extreme, because we have not considered some other positive effects of FDI. For example, FDI firms can alleviate some of the current pressure in the Chinese domestic labor market.

Bearing this in mind, we propose our policy suggestions as follows: at the present stage, the Chinese government should consider differentiating among FDI projects according to the relative technology gaps between foreign and domestic firms. For those industries with middle-sized technology gaps, it is time to cut down or even abolish the preferential policies offered to FDI firms, since the magnitudes of the negative spillover effects are the largest in such industries. For those industries with either very small or very large technology gaps, we can maintain the existing policies to accommodate the domestic labor market and to avoid a steep reduction in China's GDP.

In fact, the Chinese government has realized the negative spillover effects of FDI, and has partly implemented the above suggested policy. It has replaced the two separate tax laws for domestic firms and FDI firms with a uniform law that partly reduces the privileges offered to FDI firms. There is, however, an important difference between the policy already adopted by the Chinese government and the recommendation of this paper, that is: the current policy cuts down the preferential policies for *all* FDI firms, whereas this paper suggests reducing the preferential policies *only* for those FDI firms in industries with middle-sized technology gaps.

We acknowledge that our analyses are preliminary and can be improved from at least two aspects: (1) other positive effects of FDI firms need to be quantified and taken into consideration; (2) we are limited to industry-level data due to the unavailability of Chinese firm-level data. Compared with firm-level data, industry-level data have some additional merit because policy suggestions based on such data are industry-oriented rather than firm-oriented, which may be more appropriate for governmental macro-controls. However, firm-level data may be able to capture more variations than industry-level data and thus more accurately pin down the exact relationship between spillover effects and technology gaps.

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