Does Foreign Direct Investment Hamper Indigenous Technological Creation? Theory and Evidence from China

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Abstract

What impact does foreign direct investment (FDI) have on indigenous technological creation? Despite the answer to this question is both academically interesting and practically important, systematic empirical studies are lacking. This study attempts to help fill this gap by conducting an empirical investigation of the effects of FDI on indigenous technological creation using a firm-level survey data in China. Our empirical analysis yields two findings. First, a firm's expenditure on research and development (R&D) decreases with the amount of FDI it receives. Second, sector-level FDI has a greater positive impact on the R&D effort for the firms with more foreign presence. Combining these two effects together, we find that the net effect of FDI on indigenous R&D effort is negative. Further, we provide a theoretical explanation for our empirical findings through examining the complementary effect and substitution effect of FDI on domestic R&D. Finally, our study has interesting policy implications for China and other developing countries in the utilization of FDI for economic development.

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1. Introduction

It is widely recognized that lack of access to modern technology is one of the main reasons why poor countries remain poor. Developing economies are often advised to narrow their technological gap with developed countries by attracting foreign direct investment (FDI). Such investment often results in technological spillover and technology transfer to their domestic firms, and ultimately improves their productivity. For example, it is argued that a main benefit for China's accession to the World Trade Organization (WTO) is that the implementation of the rules of the WTO in China can result in a more open market and a fairer and more competitive business environment, which will attract more foreign capital that embody superior technology (e.g. Lardy (2002)).[1]

In the existing economic literature, important contributions have been made recently in modeling and quantifying the impacts of FDI on domestic productivity, technological transfers, and easing domestic financing constraints based on detailed firm-level data, which has generally documented the positive impacts of foreign investments.[2] However, while it is a consensus that foreign investments overall play an important and positive role in developing countries, some policy-makers and economists have long been concerned about the impacts of FDI on indigenous technological creation in developing countries, since technological transfer through FDI may substitute domestic technologies in production.[3] For example, based on the empirical evidence that a firm's R&D not only

[1] See Wong (2002) for a rigorous analysis on the role of the WTO in facilitating international capital flows.
[2] See, among others, Aitken and Harrison (1999), Eaton and Kortum (1999), and Harrison, Love and McMillan (2004).
[3] For example, see Stewart and James (1982), Fransman (1986), Kim (1991), and Lall (1993, 2001, 2002).

creates new knowledge, but also increases its capacity to absorb existing technology,[4] this literature emphasizes that the latter function of indigenous R&D is particularly important for developing countries, and it cannot be substituted by technological transfers from advanced countries. It has also been suggested that a firm's investment in R&D can not only improve its own technology, but also enhance a country's technological infrastructure and benefit its economy in both the short and longer terms. Moreover, an economy is likely to receive more (free) technological transfers when it is relatively poor. However, when an economy develops, its further technological development has to depend more and more on its own technological creation. In addition, many developing countries are reluctant to depend heavily on foreign technology because of the political leverage such dependence gives to the supplying country.[5] Therefore, a number of studies on public policy and economic development have been concerned about the effects of FDI inflow on indigenous technological effort.

Despite its theoretical interest for economists and practical importance for policymakers, systematic empirical studies on the impact of FDI on indigenous effort in R&D are lacking. The current paper attempts to help fill this gap, by conducting an empirical investigation into the effects of FDI on indigenous R&D effort. Our empirical study is based on a World Bank survey for Chinese firms from 1998 to 2000. This data set consists of the information of firms' R&D efforts, foreign investment and firms' production and cost. Moreover, China has been an important subject for research on

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[4]See, for example, Cohen and Levinthal (1989) and Griffith, Redding and Van Reenen (forthcoming)
[5] In fact, many developing countries have been reluctant to open up their equity market to foreign ownership in "strategic" industries (e.g. Aizenman, forthcoming).

various issues of FDI in the recent economic literature. Before China introduced its economic reform programme in 1978, there was almost no foreign investment in China. Thereafter, attracting FDI has been a major development policy and foreign investments have been granted with preferential treatments (e.g. Wei, 2003). As a result, China has been the largest developing country recipient of FDI since 1993, and the world's largest FDI host country since 2002, when it surpassed the United States.[6] Thus, our study has important policy implications for China and other developing countries in the utilization of foreign capital for economic development.

This empirical study yields two main findings. First, a firm's effort on R&D decreases with the amount of foreign investment in the firm, suggesting that there is a substitution effect between technology transfer (through FDI at firm level) and technological creation. Second, sector-level FDI has a greater positive impact on the R&D effort for the firms with more foreign presence. Combining these two effects together, we find that FDI has a net negative impact on indigenous R&D effort. While we acknowledge that FDI has many positive effects in developing countries as identified in the existing literature, our findings suggest that the overall effects might be more complex and intriguing than what is previously perceived in the literature.

Drawing on insights from existing literature, we then provide further theoretical explanation for our empirical findings with the help of a simple model. It examines both the complementary and substitution effects of FDI on domestic R&D. It shows that an increase in foreign presence will reduce a firm's incentive to engage in R&D if the

[6] Lardy (1992, 1994) and Wei (1996, 2003) provide background information on FDI in China. They also show that FDI has contributed substantially to China's continuous export expansion and economic growth.

increased foreign participation significantly enhances the firm's technology, and that further increases in technology through R&D have relatively small impact on its profit. It also implies that an increase in the aggregate FDI will enhance indigenous effort in R&D through its interaction with a firm's FDI, if an increase in R&D effort enhances the degree of complementarity between firm-level FDI and sector-level FDI in technological spillovers.

This paper is structured as follows. Section 2 describes the data and variables used in the empirical analysis. Section 3 discusses the empirical methodology employed. Section 4 reports and analyzes the main findings. Section 5 provides further theoretical explanations for the empirical findings in a simple model. Section 6 concludes.

2. Data and Variables

The dataset analyzed in this paper is derived from a World Bank firm-level survey from 1998 to 2000. The sample includes 998 Chinese manufacturing firms randomly selected in five major cities over the period 1998-2000. These cities include the capital city (Beijing), the municipalities in the fast-growing eastern coastal belt (Shanghai, Tianjin and Guangzhou) and the western region (Chengdu). They also illustrate the regional differences of China's market reforms: Shanghai and Guangzhou represent the most developed regions in economic liberalization and financial development, while Tianjin and Chengdu typify a relative concentration of state owned enterprises.

The firms are spread among 14 different economic sectors, as defined according to the 3-digit international standard industrial classification (ISIC), and these sectors are listed in Appendix 1. The panel dataset provids us with a broad variety of firm-level characteristics, which enables us to construct measures for firm production and performance, foreign direct investment, and R&D expenditure and personnel. We then complemente the firm-level data with the aggregate foreign direct investment at the sector level in order to examine the macro effect of capital inflow on firms' R&D decisions. Detailed information on the variables and their measurements is presented in Table 1.

Table 1 is about here

Variables for R&D Efforts

As shown in Table 1, our dataset provids us with six measures of R&D efforts, which allows us to test the robustness of the empirical results. The six measures are divided into two categories: R&D expenditure related indicators and R&D staff related indicators. R&D expenditure mainly contains three kinds of costs: investments in R&D related assets, labor compensation, and technology purchase from outside sources. Three variables are created accordingly: R&D expenditure, R&D expenditure per employee, and R&D per sales revenue. The first measurement reflects a firm's absolute amount of R&D investment; and the others evaluate the relative R&D input adjusted by the firm's size proxied by its employees and sales respectively. In our sample, the average R&D spending is around 10.39 million RMB but with a large variation of 158.44 million RMB. Average R&D expenditure per employee and per sales are RMB 6,882 and 0.078 respectively.

We also create three R&D staff related variables: the number of R&D staff, the ratio of R&D staff to total employees, and R&D spending on labor per R&D staff. In our sample, the average number of R&D staff is around 24 persons in each firm, the average ratio of R&D staff to total employees is about 4.5%, and the spending on each R&D staff member averages RMB 240,000.

Variable for Firm-Level FDI

One of the most important independent variables –FDI_Firm – is defined as the stock value of the total foreign investment in the firm. There are various sources of FDI, including foreign individuals, foreign institutional investors, foreign firms, and foreign banks. The surveyed firms on average own FDI of a value of RMB 31.4 million (with large standard deviation).

Variable for Sector-Level FDI

The amount of foreign direct investment at the sector level was hard to establish, since (as far as we are aware) no domestic or international organizations report on China's sectorial FDI. We therefore construct a proxy for sectorial FDI as follows. China's Ministry of Foreign Economic Relations and Trade reports main joint ventures established in China each year in the publication *Almanac of China's Foreign Economic Relations and Trade*, which provides information on the name of each joint venture and wholly foreign owned companies, its location, proposed products, and total capital invested domestically and abroad. The sum of the capital brought into China by foreign investors in different sectors classified by the products can be viewed as a good proxy for sectorial FDI. The *Almanac of China's Foreign Economic Relations and Trade* provided this kind of information from 1991 to 1996, until China's Ministry of Foreign Economic Relations and Trade was absorbed into the Ministry of Commerce in 1997. Fortunately, a similar dataset from 1997 to 2000 is available from figures published in *China's Business* (CB) by the Economist Intelligence Unit, which started reporting detailed information on large joint ventures established in China monthly in 1996.

Our sample of firms is distributed in 14 sectors (defined according to the 3-digit ISIC classification). Based on the information of product composition of these sectors in the ISIC manual, we are able to construct variables for annual foreign direct investment for each of the 14 sample sectors. Once we estimate the annual FDI flow data from 1991 to 2000, we are able to obtain the stock value of FDI for each of the years from 1998 to 2000 as the accumulation of annual FDI flow from 1991 to the sample year for each of the 14 sectors. It should be noted that FDI in China grew significantly in the 1990s (and not before). These procedures therefore yield a reasonable proxy for FDI stock in China.

Variables for Other Firm Characteristics

Three variables are constructed to reflect firms' other characteristics. The first variable is capital, which was used to control the size of the firm. It averages 94.7 million with large variation among firms in the sample. The second is the firm's age, which averages 14.3 years in our sample. The third is a dummy variable, which equals 1 if a firmis a state-owned enterprise (SOE) and 0 if not. We use this SOE dummy to control for the potential influence of ownership on a firm's R&D efforts.

3. Econometric Methodology

3.1. Model Specification

We empirically examine the following three questions in this section. (1) What is the impact of a firm's foreign presence on its R&D effort? (2) What is the impact of an increase in foreign direct investment in an industry on firms' spending on R&D? (3) Does the interaction between firm-level FDI and sector-level FDI affect indigenous technological effort? These questions can be incorporated in the following general specification:[7]

$$\begin{aligned} Y_{ijt} = \alpha_0 + \alpha_1 FDI\_Firm_{it} + \alpha_2 FDI\_Sector_{jt} + \alpha_3 FDI\_Firm_{it} * FDI\_Sector_{jt} \\ + \alpha_4 X_{it} + \alpha_5 CityD + \alpha_6 YearD + \alpha_7 SectorD + \varepsilon_{ijt} \end{aligned} \quad (1)$$

where *Y* is the logistic value of R&D effort of firm *i* that invests in sector *j* in city *m* at time *t*; *ε* is the error term. *FDI_Firm* and *FDI_Sector* are the logistic values of foreign direct investment in firm *i* and in sector *j* respectively. (*FDI_Firm*FDI_Sector*) is the interactive term permitting us to examine whether the effect of sectorial FDI differs across the firms with different levels of foreign involvement. *X* is a vector of variables for firm characteristics such as capital, wage, and age. *CityD*, *YearD* and *SectorD* are the city, year

[7] Our model specification is similar to that by Aitken and Harrison (1999) except that our dependent variable is firm R&D efforts while theirs is firm productivity.

and sector dummies respectively, and are used to control for variation across cities, over years and across sectors.

We estimate Equation (1) by robust OLS,[8] which down-weights the sample outliers to make the estimation less sensitive to the measurement errors. We also use White-corrected standard errors to deal with potential heterskedasticity in all models. The robust OLS regression results serve as our benchmark estimators.

3.2. Estimation Issues

An estimation issue we may face is the potential endogeneity of the variable for firm FDI. Since the selection of foreign participation might not be random, it could be the case that foreign involved firms systematically invest less (or more) in R&D than non-foreign involved firms for reasons that are not related to foreign capital, and instead could be unobservable economic and political factors as well as unobservable firm characteristics. The bias could be upward, if more productive firms with better R&D structure receive more foreign investment; the bias could also be downward, if, for example, weak intellectual property protection in China discourages foreign investment in R&D.

We deal with this issue by two methods. First, we apply the method of ownership-type fixed effect, through which we try to tackle the unobservable group characteristics inherent in different ownership types. For example, privately owned firms might be more willing to invest in R&D as they are more concerned about firms' long-run perspectives

[8] See, for example, Huber (1964) for the reference.

(e.g. Qian, 1996). Specifically we categorize the sample firms into four groups: SOEs, collectives, joint venture and private firms. Then, we run group-fixed effect regressions, which captures the differences in R&D efforts among the four groups of firms due to unobservable group-specific characteristics.

Second, although the method of group-fixed effect helps capture the selection bias between groups, there might still exist unobserved characteristics associated with R&D effort for the firms within groups. Therefore, we also apply the method of firm-specific fixed effect to control firm heterogeneity.

The endogeneity problem will be further alleviated if we can find instrument variables correlated to the independent variable but uncorrelated to the dependent variable. But given the limitation of the dataset used in this paper as well as China's macro statistics, it is hard to find such good instruments. Thus, we try the firm-specific effect regressions with the one-year lagged firm FDI and its interactive term with sector FDI. It provides a further robustness checking for the benchmark results, since the pre-determined firm FDI is highly correlated to its current value but is unaffected by the current R&D efforts.

4. Empirical Results

Table 2 provides the robust OLS regression results on the relationship between FDI and indigenous technological effort using the six measures of R&D described in Section 2.[9]

[9] For the sake of brevity, the coefficients of city, sector and year dummies are not reported in the result tables.

Table 2 is about here

Two important findings are illustrated in Table 2. First, foreign direct investment at firm level has a significantly negative effect on a firm's R&D input in all of the six models. In other words, firms with more foreign participation tend to devote less resource to research and development. This is probably because foreign investors in China generally possess better technology than domestic firms. The greater the foreign presence in a firm, the more technological transfer it is likely to receive from its foreign partners, thus reducing the need for its own technological creation. Furthermore, as the technologies suitable for use with China's relatively unskilled labor force are usually relatively simple, firms may decide that it is not worth investing in R&D after receiving significant technological transfers from their foreign partners. Although the foreign presence in a firm might complement the effectiveness of R&D in the firm, our empirical findings show that the substitution effect resulting from direct technological transfer clearly dominated, and hence an increase in foreign presence reduce a firm's incentive to engage in R&D.[10]

Second, we find that the coefficient of the interactive term of FDI_Firm and FDI_Sector is positive and statistically significant, while the (direct) effect of the aggregate FDI at sector level on a firm's decision to invest in R&D is not statistically significant. In other words, sector-level FDI has a greater positive impact on the R&D effort of firms with more foreign presence/participation. We may interpret this result as follows. The presence of a large number of foreign involved firms provides a potential source of learning through

[10] There may be other reasons for this effect. For example, R&D is a long-term investment and requires large capital input. Some firms with foreign investment may be deterred from investing in R&D because their foreign partners believe investment on such a scale is politically too risky.

technological spillover for every firm of the home country. However, the effectiveness of learning from firm to firm may differ greatly. If a firm receives a large amount of FDI, its foreign partners might be able to facilitate technological spillovers from other firms. This is because foreign partners possess more general skills for learning foreign knowledge and they are more efficient in interacting with other foreign firms due to their cultural and language proximity. By contrast, if a domestic firm receives little or no help from its foreign partner due to the lack of foreign presence in the firm, the firm may benefit little from the presence of foreign firms in its R&D due to its difficulty of communicating with foreign firms and/or its lack of ability to digest foreign technology.

To examine the net effect of FDI at firm and sector levels on R&D, we take the first derivative of the equation of estimation in (1), which yielded

$$\frac{d(Y_{ijt})}{d(FDI\_Firm_{it})} = \alpha_1 + \alpha_3 FDI\_Sector_{jt} \tag{2}$$

From (2), noting that our regression results showed that $\alpha_1 < 0, \alpha_3 > 0$, it is clear that the negative impact of firm-level FDI on a firm's R&D was counterbalanced by sectorial FDI. Hence, the net effect of foreign presence need to be estimated by substituting α_1, α_3 and FDI_Sector into (2). Based on our results in Table 2, we find that equation (2) remained negative for all models. In other words, foreign participation in a firm discourages its R&D activities overall, although the negative effect might be smaller in an industry with high foreign concentration.

In terms of the control variables, the regression analysis show that a firm's investment in R&D increases with its size. This result is consistent with the findings of the existing literature (For example, see the survey by Cohen and Levin (1989)). We also observe that R&D expenditure decreases with a firm's age.

Next we check the robustness of estimation results in Table 2 based on the discussion in Section 3.2. We first run regressions for the ownership group-specific fixed effect and presented the results in Table 3.

Table 3 is about here

As shown in Tables 3, we also find significantly negative impact of firm-level FDI as well as significantly positive impact of the interactive term of FDI at firm and sector levels on R&D efforts.

The group-fixed effect regression controls the variations among firms of different ownership, but the heterogeneous firm characteristics within ownership groups might remain uncovered. We therefore further run firm-specific fixed effect regressions and reported the results in Table 4 and 5.

Table 4 is about here

Table 5 is about here

Table 4 uses the current value of firm-level FDI and its interactive term with sector-level FDI as the independent variables, while Table 5 applies the one-period lagged firm-level FDI and its interactive term with sector FDI as the independent variables. In Table 4 and 5, we again find that firm FDI is significantly and positively associated with R&D efforts and the coefficient of the interactive term is significantly negative.

In sum, we observe that the main findings of FDI on indigenous technological effort are fairly robust in all model specifications. Specifically, in Tables 2-5, foreign participation at firm level consistently has a significantly negative impact on R&D and the interactive terms of FDI at firm and at sector levels are all significantly and positively associated with R&D effort. Moreover, by applying equation (2) into the results in Tables 2-5, we find that the net effects of FDI on R&D efforts were consistently negative.

5. Further Theoretical Explanations

The purpose of this section is to further explain our empirical findings with the help of a simple model. In particular, it attempts to demonstrate that under some reasonable conditions, we can derive the following results: (1) a firm reduces its R&D effort as it receives more FDI. (2) Sector-level FDI, through its interaction with a firm's FDI, has a positive impact on the firms' R&D effort.

The model examines a firm's behavior in profit maximization through choosing the optimal level of R&D efforts. A firm's profit is affected by its technology, which comes from two possible sources: its own technological creation through R&D and technology transfer from its foreign partner. We assume that technology transfer from its foreign partner (t) increases with the FDI in the firm (f) (e.g. Teece, 1977), so we define

$$t = T(f), T'(f) > 0 \qquad (3)$$

A firm's own technology creation (*r*) is determined by the following factors: (1) the firm's R&D expenditure, *R;* (2) the effect of the foreign presence in the firm, *f*; (3) the technological spillover from FDI in the industry as a whole, which we denote by *S*. It should be noted that the last two factors may be important for a firm's R&D, because, for example, the foreign partner's experience in advanced countries can reduce the firm's cost of trial and error, and the demonstration effect of the foreign investment in other firms can stimulate the creative thinking of the firm's R&D personnel (e.g. Aitken and Harrison, 1999). Thus, we define

$$r = H(R, f, S) \tag{4}$$

We assume that *H(R, f, S)* is an increasing function of its variables, that is, $H_1 > 0, H_2 > 0, H_3 > 0$. Meanwhile, the law of diminishing returns implies that $H_{11} < 0$. H_{13} represents the effect of the aggregate FDI on the firm's effectiveness on R&D. A positive H_{13} implies that the firm will be more efficient at its own technological creation through R&D with an increase in aggregate FDI. Similarly, H_{12} is the effect of FDI presence at firm level on the firm's effectiveness at R&D.

Combining (3) with (4), we know that a firm's total technology, which comes from its own technology creation and technology transfer from its foreign partner is

$$\Omega \equiv T(f) + H(R, f, S) \tag{5}$$

Then, we can express the firm's profit as

$$V(\Omega) - R = V(T(f) + H(R, f, S)) - R \tag{6}$$

$$V' > 0, V'' < 0$$

where $V(\Omega)$ denotes the firm's revenue function of technology. V'' (<0) reflects the law of diminishing returns for the improvement in technology in increasing a firm's profit. We assume that the optimal solution is interior. Then, the first order condition is

$$V' H_1 - 1 = 0 \tag{7}$$

Now, totally differentiating (7) with *R* and *f*, we get

$$\frac{dR}{df} = \frac{V' H_{12} + H_1 V'' T' + H_1 V'' H_2}{1 - V' H_{11} - V'' H_1^2} \tag{8}$$

Recall that $H_{11} < 0$ and $V'' < 0$, which implies $1 - V' H_{11} - V'' H_1^2 > 0$. Thus, from (8), we can get that $\frac{dR}{df} < 0$ if and only if

$$V' H_{12} + H_1 V'' T' + H_1 V'' H_2 < 0 \tag{9}$$

Clearly, $H_1 V'' T' < 0, H_1 V'' H_2 < 0$. Thus, we will have that $\frac{dR}{df} < 0$ if H_{12} (and hence $V' H_{12}$) is relatively small and the absolute values of $V'' T'$ is relatively large.

To explain the intuition here, we first note the following: (a) T' represents the impacts of technology transfer from a firm's foreign partner. A greater T' implies a greater technology transfer from an increase in the foreign presence in the firm. (b) V'' (<0) reflects the law of diminishing returns of further increases in technology in enhancing a firm's profit. The greater the absolute value of V'' is, the greater the diminishing returns exhibits. (c) H_{12} is the complementary effect of firm-level FDI on a firm's R&D. A greater H_{12} means a greater complementary effect of foreign participation on the effectiveness of a firm's R&D.

An increase in the foreign presence in a firm therefore has two opposite effects on the firm's incentive to engage in R&D. On one hand, it enhances the firm's technological level through technology transfer, which reduces its need to create new technology itself. Moreover, this disincentive effect is stronger when the absolute value of $H_1 V'' T'$ is greater, namely when the value of technology to the firm exhibits stronger diminishing returns and when the technological transfer from an increase in the foreign presence is greater. On the other hand, an increase in the foreign presence in a firm may result in a greater complementarity effect on R&D, which will tend to give the firm more incentive to engage in R&D. Thus, an increase in firm-level FDI will reduce a firm's incentive to engage in R&D if and only if the substitution effect dominates the complementary effect, which means (1) an increase in the foreign presence in a firm leads to a large increase in technology transfer to the firm, (2) the effect of technology on the firm's profit exhibits strong diminishing returns, and (3) the effect of the increased foreign presence on the firm's efficiency in R&D is relatively weak. When these conditions are satisfied in reality, we will observe that foreign direct investment at firm level had a significantly negative effect on a firm's R&D input.

Next, totally differentiating (7) with *R* and *S*, we obtain

$$\frac{dR}{dS} = \frac{V' H_{13} + H_1 V'' H_3}{1 - V' H_{11} - V'' H_1^2} \tag{10}$$

As discussed earlier, the denominator of (10) is positive. Thus, we can assert that $\frac{dR}{dS} \geq 0$ if and only if

$$V' H_{13} + H_1 V'' H_3 \geq 0 \tag{11}$$

H_{13} represents the spillover effect of aggregate FDI on a firm's efficiency in R&D. The greater H_{13}, the greater the spillover effect. Meanwhile, as discussed earlier, V'' (<0) reflects the law of diminishing returns of further increases in technology in enhancing a firm's profit. As in the previous analysis, an increase in aggregate FDI also has two opposite effects on domestic R&D. On one hand, a domestic firm tends to spend more on R&D if it becomes more efficient in its own technology creation through R&D resulting from an increase in aggregate FDI. On the other hand, the enhanced technology reduces the marginal return from further technological improvement, which reduces a firm's incentive to spend on R&D. If these two effects cancel out each other, the net effect will be zero. Thus, this result explains our empirical finding that the (direct) effect of the aggregate FDI at sector level on a firm's decision to invest in R&D is not statistically significant.

Finally, we study the joint impact of firm-level FDI and sector-level FDI on R&D by examining the cross derivative, $\frac{d^2 R}{df dS}$. From (10), we obtain

$$\frac{d^2R}{dfdS} = \frac{H_{123}(1 - V'H_{11} - V''H_1^2) + \Sigma}{(1 - V'H_{11} - V''H_1^2)^2} \tag{12}$$

where

$$\begin{aligned}\Sigma \equiv\ & (1 - V'H_{11} - V''H_1^2)[(V'H_{13} + V'''H_1H_3)(T' + H_2) + V''H_{12}H_3 + V''H_1H_{23}] \\ & + (V'H_{13} + H_1V''H_3)[(V'H_{11} - V''H_2^2)(T' + H_2) + V'H_{112} - 2V''H_2H_{23}]\end{aligned}$$

It is easy to see that the sign of Σ is ambiguous. Recall that

$$(1 - V'H_{11} - V''H_1^2) > 0$$

Then, from (12), we can see that if H_{123} is sufficiently large, we will have $\frac{d^2R}{dfdS} > 0$.

The intuition of H_{123} can be explained as follows. Note that we can rewrite H_{123} as $\frac{d(H_{23})}{dR}$. H_{23} represents the degree of complementarity between firm-level FDI and sector-level FDI in technological spillovers from foreign firms, and hence a greater H_{23} enhances the efficiency of creation of indigenous technology. Then, if $H_{123} > 0$, an increase in R&D effort will enhance the degree of complementarity between firm-level FDI and sector-level FDI. Moreover, the greater H_{123} is, the greater it enhances the degree of complementarity, and hence the more incentive the firm has in investing in R&D. Therefore, if H_{123} is sufficiently large, we will empirically observe that sector-level FDI, through its interaction with a firm's FDI, has a positive impact on the firm's R&D effort.

6. Conclusion

It is often argued that FDI has become an important driving force for economic globalization. In particular, China's decision to join the World Trade Organization is motivated by the perspective that a fairer and more competitive business environment in line the rules of the WTO can attract more foreign capital. In the economic literature, with increasing accessibility to firm-level data, there has been increasing empirical research in the last decade that examined various aspects of FDI on developing countries, which include productivity, technological transfers, and domestic firms' financing constraints. Moreover, this literature generally reveals positive and significant effects of FDI in all of these aspects examined. These empirical contributions enhance our understanding of both the qualitative and quantitative impacts of FDI on developing economies.

The current paper conducts an empirical investigation of FDI and R&D efforts based on a World Bank survey for Chinese firms.[11] It complements the existing literature by examining an additional aspect of the effects of FDI. Moreover, this paper addresses an issue that is not only academically interesting but also has important policy implications for developing economies. In particular, recently Chinese government highlights the importance of innovation in China's further economic development.

This empirical study yields two main findings. First, a firm's expenditure on R&D decreases with the amount of foreign investment in the firm, suggesting that there is a substitution effect between technological transfers (through FDI at firm level) and

[11] As far as we are aware, it is the systematic empirical study that examines with firm-level data the issue of R&D and FDI in China. Jefferson et al (forthcoming) also analyze the determinants of R&D intensity for Chinese firms, but they do not consider foreign investments.

technological creation. Second, sector-level FDI has a greater positive impact on the R&D effort for the firms with more foreign presence. Considering their combined effects, we find that FDI has an overall negative impact on indigenous technological creation.

Further, we provide a theoretical explanation for our empirical findings with the help of a simple model. It examines the complementary effect and substitution effect of FDI on domestic R&D. The model shows that an increase in foreign presence will reduce a firm's incentive to engage in R&D if it significantly enhances the firm's technology, and that further advances in technology through R&D have a relatively small impact on its profit. Moreover, an increase in aggregate FDI will enhance indigenous effort in R&D through its interaction with a firm's FDI, if an increase in R&D effort significantly enhances the degree of complementarity between firm-level FDI and sector-level FDI in technological spillovers.

Table 1. Summary Statistics

Variables	Unit	Obs.	Mean	Stdev.
Dependent Variables				
R&D Expenditure	1000RMB	2994	10388.32	158441.4
R&D Expenditure / Employees	1000RMB/Worker	2854	6.882	34.44
R&D Expenditure / Sales	Ratio	2832	0.078	1.256
R&D Personnel	Worker	2898	24.969	112.874
R&D Personnel / Employees	Ratio	2760	0.045	0.111
R&D Spending on Labor / R&D Personnel	1000 RMB	2898	230.482	7142.848
Independent Variables				
FDI_Firm	1000RMB	2987	31432.69	178511.8
Sales Revenue	1000RMB	2832	201465.9	1295585
Capital	1000RMB	2987	94734.28	418911.3
Age	Year	2991	14.29	15.89

Table 2. Robust OLS Regression on the relationship between R&D Efforts and FDI

Dependent Variables:	Ln (R&D Expenditure)	Ln (R&D Expenditure /Employee)	Ln (R&D Expenditure /Sales)	Ln (R&D Staff)	Ln (R&D Staff /Employee)	Ln (R&D Spending on Labor /R&D Staff)
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Ln (FDI_Firm)	-0.638***	-0.663***	-0.776***	-0.236***	-0.242***	-0.213**
	(0.128)	(0.137)	(0.134)	(0.061)	(0.067)	(0.100)
Ln (FDI_Sector)	-0.087	-0.182	-0.126	-0.035	-0.097	0.033
	(0.194)	(0.208)	(0.200)	(0.106)	(0.106)	(0.153)
Ln (FDI_Firm*FDI_Sector)	0.034***	0.037***	0.041***	0.012***	0.014***	0.011*
	(0.008)	(0.009)	(0.008)	(0.004)	(0.004)	(0.006)
Ln (Firm Size)	0.700***	0.202***	0.058*	0.333***	-0.160***	0.146***
	(0.034)	(0.033)	(0.032)	(0.016)	(0.017)	(0.024)
Ln (Age)	-0.264***	-0.348***	-0.148**	-0.113***	-0.181***	-0.067
	(0.072)	(0.072)	(0.073)	(0.034)	(0.035)	(0.052)
SOE Dummy	-0.160	-0.439**	0.350**	0.236**	-0.072	-0.45***
	(0.175)	(0.175)	(0.167)	(0.093)	(0.095)	(0.126)
Sector Dummies	Yes					
City Dummies	Yes					
Year Dummies	Yes					
Constant	-3.057	-2.617	-6.402**	-1.697	-1.858	-1.187
	(2.970)	(3.176)	(3.054)	(1.625)	(1.622)	(2.336)
Observations	2811	2799	2792	2723	2712	2723
Adjusted R-squared	0.33	0.22	0.18	0.32	0.26	0.06

Note: 1) ***, ** and * denote 1%, 5% and 10% significant level respectively.
2) The numbers in the brackets are standard white-corrected errors.

Table 3. Ownership Group-Specific Fixed Effect Regression on R&D Efforts and FDI

Dependent Variables:	Ln (R&D Expenditure)	Ln (R&D Expenditure /Employee)	Ln (R&D Expenditure /Sales)	Ln (R&D Staff)	Ln (R&D Staff /Employee)	Ln (R&D Spending on Labor /R&D Staff)
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Ln (FDI_Firm)	-0.642***	-0.671***	-0.753***	-0.246***	-0.256***	-0.212***
	(0.115)	(0.118)	(0.114)	(0.055)	(0.058)	(0.082)
Ln (FDI_Sector)	-0.097	-0.193	-0.128	-0.041	-0.103	0.029
	(0.174)	(0.178)	(0.173)	(0.083)	(0.088)	(0.123)
Ln (FDI_Firm*FDI_Sector)	0.037***	0.039***	0.043***	0.013***	0.015***	0.012**
	(0.007)	(0.007)	(0.007)	(0.003)	(0.004)	(0.005)
Ln (Firm Size)	0.669***	0.176***	0.036	0.320***	-0.170***	0.135***
	(0.032)	(0.033)	(0.032)	(0.016)	(0.017)	(0.023)
Ln (Age)	-0.173**	-0.268***	-0.108	-0.062*	-0.138***	-0.035
	(0.073)	(0.075)	(0.074)	(0.036)	(0.037)	(0.053)
Constant	-2.866	-2.478	-6.266**	-1.529	-1.754	-1.210
	(2.670)	(2.730)	(2.657)	(1.276)	(1.348)	(1.886)
Observations	2811	2799	2792	2723	2712	2723
Adjusted R-squared	0.32	0.21	0.15	0.30	0.25	0.06

Note: 1) ***, ** and * denote 1%, 5% and 10% significant level respectively.

2) The numbers in the brackets are standard errors.

Table 4. Firm-Specific Fixed Effect Regression on R&D Efforts and FDI

Dependent Variables:	Ln (R&D Expenditure)	Ln (R&D Expenditure /Employee)	Ln (R&D Expenditure /Sales)	Ln (R&D Staff)	Ln (R&D Staff /Employee)	Ln (R&D Spending on Labor /R&D Staff)
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Ln (FDI_Firm)	0.243	0.069	-0.628**	-0.425***	-0.520***	0.097
	(0.230)	(0.229)	(0.263)	(0.076)	(0.082)	(0.181)
Ln (FDI_Sector)	0.163*	0.067	0.135	-0.045	-0.062**	0.037
	(0.088)	(0.089)	(0.095)	(0.029)	(0.031)	(0.069)
Ln (FDI_Firm*FDI_Sector)	0.023**	0.030***	0.021*	0.023***	0.024***	0.019**
	(0.011)	(0.011)	(0.011)	(0.004)	(0.004)	(0.008)
Ln (Firm Size)	0.124	0.008	-0.139	0.126***	0.009	0.135
	(0.105)	(0.104)	(0.113)	(0.035)	(0.037)	(0.083)
Ln (Age)	0.923***	0.338*	-0.156	0.422***	-0.000	0.039
	(0.196)	(0.198)	(0.219)	(0.066)	(0.071)	(0.156)
Constant	-5.151***	-6.578***	-6.733***	0.159	-2.792***	-2.866**
	(1.603)	(1.609)	(1.755)	(0.532)	(0.572)	(1.262)
Observations	2811	2799	2792	2723	2712	2723
Adjusted R-squared	0.09	0.05	0.02	0.11	0.05	0.05

Note: 1) ***, ** and * denote 1%, 5% and 10% significant level respectively.
2) The numbers in the brackets are standard errors.

Table 5. Firm-Specific Fixed Effect Regression on R&D Efforts and FDI (Cont.)

Dependent Variables:	Ln (R&D Expenditure)	Ln (R&D Expenditure /Employee)	Ln (R&D Expenditure /Sales)	Ln (R&D Staff)	Ln (R&D Staff /Employee)	Ln (R&D Spending on Labor /R&D Staff)
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Ln (Lag FDI_Firm)	-0.583***	-0.628***	-0.557***	-0.297***	-0.341***	-0.322**
	(0.190)	(0.199)	(0.208)	(0.065)	(0.075)	(0.146)
Ln (FDI_Sector)	0.062	0.033	0.063	-0.046	-0.074*	-0.046
	(0.098)	(0.101)	(0.106)	(0.033)	(0.037)	(0.074)
Ln (Lag FDI_Firm*FDI_Sector)	0.037***	0.039***	0.032***	0.020***	0.022***	0.025***
	(0.011)	(0.012)	(0.012)	(0.004)	(0.004)	(0.009)
Ln (Firm Size)	0.283**	0.173	0.066	0.147***	0.037	-0.016
	(0.140)	(0.143)	(0.151)	(0.047)	(0.053)	(0.106)
Ln (Age)	1.379***	1.192***	0.412	0.394***	0.208	0.226
	(0.371)	(0.377)	(0.404)	(0.124)	(0.139)	(0.281)
Constant	-3.880*	-7.424***	-9.506***	-0.232	-3.821***	0.818
	(2.063)	(2.104)	(2.237)	(0.697)	(0.778)	(1.576)
Observations	1927	1923	1918	1867	1863	1867
Adjusted R-squared	0.08	0.07	0.03	0.10	0.05	0.04

Note: 1) ***, ** and * denote 1%, 5% and 10% significant level respectively.
2) The numbers in the brackets are standard errors.

Appendix 1. Sector Distribution based on 3-Digit ISIC Classification

Sectors	Average Stock Value of FDI (1000RMB)
Cut and Sew Apparel Manufacturing	4.47E+06
Leather and Hide Tanning and Finishing	4.54E+05
Leather and Allied Product Manufacturing	5.13E+05
Apparel Knitting Mills	9.55E+05
Computer and Peripheral Equipment Manufacturing	1.97E+07
Communications Equipment Manufacturing	1.38E+07
Audio and Video Equipment Manufacturing	1.60E+07
Electron Tube Manufacturing	1.51E+05
Bare Printed Circuit Board Manufacturing and Assembly Manufacturing	3.50E+06
Semiconductor and Related Device Manufacturing	1.58E+07
Electronic Capacitor, Resistor, Coil, Transformer, Connector Manufacturing	4.88E+06
Household Electronic Products	1.54E+07
Motor Vehicle, and Parts Manufacturing	4.31E+07
Motorcycle, Bicycle, and Parts Manufacturing	4.42E+06

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