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Spillover Effects of FDI on Innovation in China:
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Abstract: We use the provincial data from 1995 to 2000 to test the impact of inward FDI on innovation activity in China. We found a positive effect of FDI on the number of patent applications filed by the domestic firms. This positive relationship persists when we divide the patents by types (invention, utility model and external design) and when we group the provinces into regions (the coastal, central, and the western regions). This positive spillover effect is much stronger for minor innovations such as external design and utility model, highlighting a "demonstration effect" of FDI. However, FDI into the coastal region has a negative effect on invention, which indicates a "crowding-out" effect of imported technology on domestic innovation in that region. The effects of technical development personnel/expenses and the export/output share of FDI firms are also significant and positive.

JEL Classifications: O31, O53
Keywords: FDI, spillover, patent, spatial effect

1. Introduction

One of the primary motivations for developing countries to attract foreign direct investment (FDI) is to obtain advanced technology from developed countries and then base on this to establish domestic innovation capability. Under its “market for technology” policy, China has been the largest recipient of FDI among the developing countries in the 1990s. Are there significant spillover effects from inward FDI on innovation activity by the domestic firms? Or is it that China has been simply importing technologies without developing the ability to innovate on its own? This paper examines the extent to which inward FDI to China has affected the innovation activities by Chinese firms.

As is well recognized in the literature, there are several important channels through which inward FDI can benefit innovation activity of domestic firms in the host country. First, local firms can learn, by the means of reverse engineering for example, about the products and technologies brought in by foreign investors. Second, spillovers can take place in the labor market whereby local firms obtain the technological know-how of foreign-investment-related firms by “stealing” their skilled workers. Third, as we in this paper emphasize, inward FDI has a “*demonstration effect*” on local R&D activity. By their mere presence in the domestic markets, foreign products/technologies can inspire and stimulate local innovators to develop new products and processes. This helps shorten the “trial-and-error” process of local firms in their searching for inventions. Moreover, since the products and technologies that FDI firms bring in have already been “tested” in the foreign markets, the perceived risk of innovating along similar directions is lowered for local firms.

Our analysis is based on the provincial level data in China for the period from 1995 to 2000. We use the number of patent applications as a measure of R&D output. To separate the spillover effect of FDI from the effects of other R&D inputs, we also include in our regression analysis expenditures on science and technical development as well as the number of technical personnel. We found evidence of strong positive spillovers from FDI on the number of patent applications filed domestically. This positive relationship remains even when we divide the patents by types (invention, utility model, and external design) and when we group the provinces into regions (the Coastal area, the Central region, and the West). Moreover, the spillover effect is much stronger for external design patents, relative to inventions and utility models. Since design patents in general are technically less sophisticated relative to other types of innovation, our finding reveals that the positive spillover effect of FDI is largely toward minor innovations. We regard this finding as a reflection of the current innovation capability of Chinese firms, which in general are still technically lagged behind multinational firms from advanced countries.

Our analysis also indicates that a "*crowding out effect*" of FDI may be at work. Specifically, we found that in the Coastal Region, which includes Beijing, Shanghai, Tianjin, and nine provinces, and has received over 85 per cent of the inward FDI that has come to China, FDI has a negative effect on major innovations (invention patent). This negative effect can be understood as a result of imported technologies crowding out domestic innovation in that region. As argued in Lin (2002), since importing technology from abroad is less risky and returns can be realized more quickly relative to innovating on one's own, domestic R&D can be crowded out by inward FDI. The propensity to import technology of a firm thus tends to be very high, especially when foreign technologies are readily available and when competition is intense, which are both true for the Coastal Region. For other regions and other types of patent applications, the "crowding out effect" of FDI is presumably weaker than the spillover effect so that the net effect of FDI on innovation is positive in these cases.

We chose to examine the provincial data, as opposed to industry level data, mainly because spatial proximity is of crucial importance for technology and knowledge spillovers, as documented in the existing literature on R&D spillovers (e.g., Jaffe (1989)). Our choice of the time period covered in our analysis, namely from 1995 to 2000, was based on two reasons. First, the patent law of China, although enacted in 1985, was substantially amended in 1993, with major revisions including extending the patent length from fifteen years to twenty years for invention patents and from eight years to ten years for patents for utility model and external design. In addition, the enforcement of the patent law has been greatly improved since then. Therefore, China's patent protection system in the post-1993 period is significantly different from the one prior to 1993. Second, it is since the 1990s that inward FDI to China has been consistently on a large scale.[1] FDI to China before 1993 was on a relatively small scale and more fluctuated due to political changes in China such as the "Tian-An-Men Square" event in 1989 and the subsequent economic sanctions by major trading partners of China during the years in early 1990s. The political uncertainty of investing in China was greatly reduced after Deng Xiaoping's south tour in 1992.

There have been a number of recent studies of FDI spillovers to host countries. For example, Baldwin et al. (1999) studied R&D spillovers through FDI for some OECD countries, while Aitken and Harrison (1999) examined the effect of FDI on productivity in Venezuela. Blomstrom and Kokko (1999) provided a review of the empirical evidence on spillovers from inward FDI. Although it has been the major objective of the Chinese government that inward FDI will simulate innovation activity in China, empirical studies of FDI spillover effects in China are rare. The only work on China that we are aware of is the recent study by Hu and Jefferson (2001). The authors used data for large and medium size enterprises in China to examine the spillover effect of FDI for each industry.[2] Our study is complementary to Hu and Jefferson's in that we analyze the provincial data and emphasize the geographical aspect of FDI spillovers. Similar to us, Hu and Jefferson also found positive spillover effects of FDI on Chinese firms. One other difference between the two studies is that Hu and Jefferson used new product sales as a measure of R&D output, whereas we in this paper use the number of patents. They also looked at the effect of FDI on productivity of Chinese firms. Taken together, our findings and that of Hu and Jefferson indicate that FDI to China has not only benefited the productivity and economic growth in China, it has also promoted R&D activity by Chinese firms via various spillover channels, making them more capable of innovating on their own.

[1] Our analysis does not include the year 1994 because the provincial data for patent applications for that year are not complete.

[2] Their data set, drawn from a private survey, spans a period of five years from 1995 to 1999 and 29 manufacturing industries and 511 firms.

The rest of the paper is organized as follows. A theoretical framework of spillover effect of FDI on innovation is presented in Section 2. Section 3 contains an overview of inward FDI to China during the second half of the 1990s and its distribution over the provinces. Section 4 contains a brief description of the patent protection system in China, as well as of the distribution of patent applications across types and regions. The regression model and results are presented in Section 5 and Section 6, respectively. Section 7 concludes.

2. Spillover Effects of FDI on R&D

The R&D process is essentially a knowledge producing process; one utilizes resources (scientists, engineers, technicians, research equipment, and so on) to create new knowledge. In general, the R&D production function can be represented by

$$I = f(L, K; I_0), \qquad (1)$$

where L and K represent labor input and the capital input, respectively, whereas I represents the R&D output, which are largely embedded in the new products or new processes generated by the R&D process. The component I_0 stands for the initial level of knowledge available at the beginning of the R&D project concerned.

One of the important channels that contribute to the initial knowledge level is inward FDI. By bringing in new technologies and products into the host country, inward FDI can benefit local firms' innovation in several ways. First, local firms can learn about the designs of the new products or new technology, through reverse engineering for example, and then improve upon them to come up with new inventions and innovations. The Japanese experiences in the 1960s-1970s are good example of this form of learning foreign technology. Second, inward FDI can spillover to local firms through labor market whereby local firms can "steal" skilled workers, legally or otherwise, from FDI firms. Quite a number of lawsuits against unfair method of competition in China in recent years are related to this type of labor mobility.[3]

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[3] See Chu (2001).

Third, FDI can have a "*demonstration effect*" to local firms. The mere presence of foreign products in the market can stimulate local firms' creative thinking and help generate blue prints for new products and processes. Moreover, the products or technologies that FDI firms bring in have already been "tested" by consumers in the foreign markets. Thus, modifications of those products and technologies will likely work for the host country as well.[4] Such a *demonstration effect* is likely to be strong for small innovations (such as utility model and external design) and may be significant in the early stage of a country's opening up process.

The *demonstration effect* is related to the usual R&D spillover in the literature of innovation, whereby information about a firm's *on-going* R&D activity leaks to its competitors. Such information can benefit the competitors by improving their efficiency in the searching process for innovation. The FDI spillover effect, on the other hand, originates from the FDI firms' *finished* R&D projects (their products and technologies) and spillovers to the local firms. By observing and analyzing the *output* of the FDI firm's past R&D projects, local firms become more effective in conducting their own innovation activity.[5]

To focus on the effect of FDI on innovation by the local firms, so we can rewrite (1) as

$$I = h\ (L, K, FDI). \qquad (2)$$

In our analysis, we use the FDI and patent data from the provinces in China. As the existing studies in the literature on R&D spillovers (e.g., Jaffe, 1989) shows, geographic proximity facilitates flow of knowledge. The probability that knowledge is transmitted from one agent to another, through channels such as personal contacts, labor turnover and contracts with upstream and downstream producers – decreases as geographic distance increases.

[4] If one considers innovation process as one in which desirable new products and processes are selected from an unknown set of alternatives, then the presence of foreign products tells local innovators that such specific candidates are in the feasibility set.

It may be argued that the FDI in general tends to benefit local firms in the same industry that FDI flows into. This is so because spillovers generated by a given FDI project are technically relevant to the industry only, and may not be useful to other unrelated industries. However, spatial factors are also important. The spillover effects of a FDI project diminish as one moves away from where it is located. The closer a local firm is located to the FDI firm, the more likely that these two firms and their employees interact with one another face to face, the stronger will be the demonstration effect, and more frequent labor moves between these two firms. This is simply one major aspect of the so-called "clustering effect" of innovation. Moreover, FDI projects also have spillover effects to vertically related industries (suppliers or customers), which often are located close to one another.

Furthermore, an important aspect of FDI to China is that investment by a foreign company often creates a number of smaller competitors (or imitators) in the sounding neighborhood of the FDI project. These new firms may be collectives or private owned enterprises. They may be either new or have been in other businesses prior to the entry of the FDI firm but losing money. The entry of the FDI firm creates profit opportunity for these new firms as they can mimic the products of the FDI firm. Through the various spillover channels, these new firms can improve on their innovation capability, and generate certain R&D output over time.

Before presenting our empirical analysis in section 5, we first provide a brief picture of inward FDI in terms of geographic distributions and the patent system in China.

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[5] Of course, ongoing R&D by the FDI firm can also spillover to local innovators. But most multinational companies that have entered the China market did not set up their own R&D centers in China until recently.

3. FDI to China: 1995-2000

In early stage of China's opening up, FDI inflow increased at a modest rate until early 1990s. The realized value of inward FDI to China was $3.49 billion in 1990, but soared to $27.5 billion in 1993. The figure reached $37.5 billion in 1995, peaked at $45.3 billion in 1997 before declining to $40.3 billion in 1999, largely due to the negative effects of East Asia Financial crisis. The number for 2000 was $40.7 billion. The surge in FDI since 1993 was driven by several factors. Following Deng Xiaoping's support of further economic liberalization in 1993, the Chinese government resumed a policy of far reaching economic reforms, and launched a new round of measures to attract FDI. The major driving force for persistent FDI inflow is, of course, the big "China market" factor for foreign investors.

Table 1: Shares of Inward FDI by Provinces (%)

	1995	**1999**		**1995**	**1999**		**1995**	**1999**
Coastal area			**Central region**			**West**		
Beijing	2.90	4.77	Shanxi	0.17	0.94	Chongqing	-	0.58
Tianjin	4.09	4.26	Inner Mongolia	0.16	0.16	Sichuan	1.46	0.82
Hebei	1.47	2.51	Jilin	1.10	0.73	Guizhou	0.15	0.10
Liaoning	3.83	2.56	Heilongjiang	1.39	0.77	Yunnan	0.26	0.37
Shanghai	7.77	6.84	Anhui	1.30	0.63	Tibet	0.00	0.00
Jiangsu	13.95	14.66	Jiangxi	0.78	0.77	Shaanxi	0.87	0.58
Zhejiang	3.38	2.97	Henan	1.29	1.26	Gansu	0.17	0.10
Fujian	10.87	9.71	Hubei	1.68	2.39	Qinghai	0.00	0.01
Shangdong	7.23	5.95	Hunan	1.36	1.58	Ningxia	0.01	0.12
Guangdong	27.57	31.10				Xinjiang	0.15	0.06
Guangxi	1.81	1.53						
Hainan	2.85	1.17						
Sub-total	*87.71*	*88.03*		*9.21*	*9.22*		*3.08*	*2.75*

Source: China's Statistical Yearbook, various years.

FDI in China is characterized by a very uneven geographic distribution. Regional breakdown of FDI shows a dividing line between coastal provinces and inland provinces in attracting foreign capital (Table 1). In 1995, nearly 90% of FDI (in realized value, as opposed to contract value) was concentrated in coastal provinces and more precisely in five of them; Guandong, Jiangsu, Fujian, Shanghai municipality and Shandong received more than 65% of total FDI. The central regional received only 9% of total FDI, and the West region, only 3% of the total in that year. The geographic distribution of inward FDI in 1999 (and through the send half of the 1990s) was almost the same as it was in 1995. This uneven distribution is primarily due to the fact that the coastal region is the most developed area in China and was the first region to allow FDI when China opened up its door in the 1980s.

4. Patent Protection in China

In less than 20 years, China has made tremendous progress in establishing a legal system for the protection of innovations. China's first patent law and its implementing regulations were enacted in 1984 and came into effect in 1985. Since then, the patent law has been amended twice. The first revision, undertaken in 1992, extended the patent length from 15 years to 20 years for invention patents and from 5 to 10 years for patents for utility model and external design. The second revision, which was completed in September 2000, eliminated the provisions under the old law that prevented state-owned enterprises from trading their patents in technology markets. The second revision also introduced new provisions designed to make it more rewarding for enterprise employees to innovate. Since the passage of the 1984 patent law, the central government has issued over twenty regulations and guidelines so as to promote innovation activity in China. Today's patent law in China is pretty much in line with the international standard. Up till now, China has acceded to all the international patent treaties and its laws on intellectual property rights meet the requirements of the WTO's Agreement on Trade Related Intellectual Properties (TRIPs). Enforcement of the patent law has been greatly improved in China since the 1994 due to both the internal interests of China and external pressures from its major trading partners, such as the United States.[6]

[6] See Lin (2001) for a detailed description and analysis of the patent system in China.

4.1 Types of Patents

The patent law of China divides patents into three categories: invention, utility model, and external design. The term of protection is 20 years for invention patents and 10 years for utility model and external design. Invention patents are regarded as major innovations. To obtain a patent for invention, an application must meet the requirements of "novelty, inventiveness, and practical applicability." Usually, it takes about one year to one year and half for the State Patent Office to process an invention patent application.

The applications for patents for utility models or designs, on the other hand, need only to pass an "initial examination" wherein the patent office simply checks for the completeness of the files and makes sure the same object has not been patented before. The processing time for patent applications for utility model is about six months, and it is even shorter for design patent.[7]

4.2 Patent Applications by Domestic Innovators

Since 1995, the total number of patent applications filed from domestic inventors has increased significantly (see Table 2), rising 68,880 in 1995 to 109,958 in 1999.[8]

In terms of patent type, the share of invention applications has been very low, maintaining at around just 14 per cent during the period. The share of utility model applications, though declining, has been maintained for over 50 percent. The share of external design patent, however, has been growing in both absolute and relative terms, from about 22 per cent in 1995 to 34 percent in 1999. The picture for overseas application is quite different, with over 80 per cent of the applications being for major innovations (invention).

[7] The information is obtained from a personal conversation with staff at the State Patent Office. Over the 1990s, patent application processing time has been declining, especially for invention patent, due to improved efficiency and increased manpower at the State Patent Office. In 1990, the processing time for the three types of patent applications was, respectively, twenty-six, six, and three months.

[8] Domestic applications include those applications filed by foreign invested enterprises (wholly foreign owned and joint venture) located in China, as well as those by Chinese firms. Typically, a foreign invested enterprise files protection for its intellectual property *before* it sets up a subsidiary or a joint venture in China, in which case the application is classified as overseas, rather than domestic. Moreover, once established, FDI firms in China typically do not conduct much R&D within the PRC board, at least not on a

There are several reasons that the proportion of domestic applications for invention patent has been low. First, relative to utility models and external designs, successful discovery of inventions requires higher R&D costs and a longer period of time. Second, in today's Chinese economy, the majority of firms are of small scale. Because of this and fast-changing market conditions, these small enterprises are more likely to focus their innovative effort on short-term R&D projects, leading to a disproportionately large number of patents for utility model and design. Lastly, once invented, patents for utility model and design are easier to obtain, as they do not need to pass the test of "novelty, inventiveness, and practical applicability" set for invention patent. As a result, certain inventors may have chosen to file their applications as for utility model or external decision patents, rather than for invention patent, in order to have their new products enter the market quickly and at the same time obtaining legal protection as early as possible.

Table 2: Types of patent applications

	1995	1997	1999
Domestic applications	68880	90071	109958
Invention	14.54 %	14.11%	14.18%
Utility model	63.05%	55.40%	52.03%
External design	22.41%	30.48%	33.78%
Overseas applications	16165	24133	24282
Invention	82.02%	86.81%	86.89%
Utility Model	2.20%	0.94%	1.14%
External Design	15.78%	12.25%	11.96%

Source: China's Statistical Yearbooks for Science and Technology, various years.

4.3 Patent Applications by Provinces/Regions

From Table 3, we also see that patent applications in China are characterized by a very uneven geographic distribution. Regional breakdown of patent applications shows a large discrepancy between coastal provinces and inland provinces. In 1995, nearly 65% of

large scale, for fear of leaking their R&D information to local competitors. For this see China's Science & Technology Development Report 2000.

patent applications were filed by inventors from the coastal provinces and concentrated mainly in six of them: Guandong, Beijing, Shandong, Liaoning, Jiangsu, and Zhejiang. These six provinces filed about 50% of total domestic patent applications in that year. The central region filed around 23% and the west region, only 12% of the total. This geographic distribution was about the same in 1999.

The distribution of patent applications across regions was even more uneven if we look at the type of applications. In 1995, nearly 82% of design applications were filed from the coastal provinces. The four provinces, Guandong, Zhejiang, Shandong and Fujian, made up of more than 57% of total design applications. The central region filed only about 10% of total patent applications, and the west region made up of the rest. The high concentration in the geographic distribution (in the coastal region) has not changed much over the study period and is highly correlated with the inward FDI inflows, as can be seen by comparison with Table 1.

Table 3: Shares of Domestic Patent Applications by Provinces (%)

1995	All Types	Invention	Utility	Designs	1999	All Types	Invention	Utility	Design
Coastal area									
Beijing	9.95	13.10	10.97	5.09		7.69	14.32	7.90	4.63
Tianjin	2.58	2.50	2.89	1.78		2.01	1.67	2.35	1.64
Hebei	4.23	4.46	5.02	1.91		3.31	3.49	4.15	2.02
Liaoning	6.96	7.87	8.20	2.93		6.04	5.89	8.62	2.31
Shanghai	3.84	3.66	3.81	4.06		4.58	7.27	3.81	4.61
Jiangsu	6.38	5.63	6.79	5.73		7.06	5.74	8.24	5.86
Zhejiang	6.32	3.74	5.82	9.40		8.14	4.08	6.77	11.83
Fujian	3.10	2.09	2.05	6.64		3.37	1.67	2.15	5.86
Shangdong	7.23	6.72	7.31	7.36		8.55	6.87	9.47	7.89
Guangdong	12.09	4.85	5.94	33.80		16.72	7.82	8.91	31.87
Guangxi	1.93	2.27	1.85	1.90		1.60	1.61	1.68	1.46
Hainan	0.29	0.34	0.17	0.57		0.37	0.47	0.27	0.48
Sub-total	**64.90**	**57.24**	**60.82**	**81.18**		**69.43**	**60.90**	**64.32**	**80.47**
Central									
Shanxi	1.43	1.82	1.71	0.43		1.13	1.91	1.37	0.47

Inner Mongolia	1.01	1.23	1.13	0.56		0.97	1.37	1.09	0.62
Jilin	2.17	2.65	2.56	0.81		2.10	3.05	2.50	1.12
Heilongjiang	4.02	4.81	4.75	1.50		2.97	3.94	3.81	1.35
Anhui	1.61	1.59	1.84	0.97		1.71	1.98	1.80	1.48
Jiangxi	1.58	1.93	1.78	0.79		1.38	1.53	1.49	1.16
Henan	3.73	4.35	4.33	1.68		3.44	4.17	4.52	1.54
Hubei	3.13	4.02	3.59	1.31		2.95	3.51	3.69	1.63
Hunan	4.11	4.83	4.74	1.91		3.39	4.36	4.09	1.95
Sub-total	**22.80**	**27.21**	**26.41**	**9.96**		**20.04**	**25.84**	**24.36**	**11.32**
West									
Chongqing	-	-	-	-		1.27	1.33	1.48	0.93
Sichuan	4.98	5.76	5.13	4.07		3.66	4.23	3.52	3.63
Guizhou	0.88	1.39	0.83	0.66		0.79	1.07	0.78	0.68
Yunnan	1.50	2.04	1.19	1.99		1.24	1.32	1.19	1.28
Tibet	0.02	0.04	0.01	0.03		0.01	0.01	0.01	0.01
Shaanxi	2.69	3.33	3.08	1.21		1.68	2.59	2.06	0.74
Gansu	0.85	1.51	0.87	0.38		0.58	1.03	0.73	0.17
Qinghai	0.16	0.24	0.17	0.06		0.17	0.27	0.15	0.16
Ningxia	0.26	0.23	0.33	0.10		0.26	0.41	0.33	0.10
Xinjiang	0.95	1.01	1.16	0.36		0.87	0.99	1.08	0.52
Sub-total	**12.30**	**15.55**	**12.77**	**8.86**		**10.52**	**13.25**	**11.33**	**8.22**

Source: China's Statistical Yearbook for Science and Technology.

5. The Empirical Model and Data Description

Based on the theoretical model presented in Section 2, we use the following model to estimate the spillover effect of FDI on innovation in China.

$$Patent_{it} = \beta_0 + \beta_1 Fdi_{it-1} + \beta_2 STperson_{it} + \beta_3 STexp_{it} + \beta_4 Feexpt_{it} + \varepsilon_t \quad \ldots (3)$$

where

$Patent_{it}$ --- share of domestic patent applications in province *i* to the total number of applications in year t, i = 1, 2, …, 30;

$Fdi_{i\,t-1}$ --- share of realized value of FDI in province *i* to the total realized value of FDI in year *t-1*.

$STperson_{it}$ --- share of science and technical development personnel in province *i* to the total number of science and technical development personnel in year *t*.

$STexp_{it}$ --- share of science and technical development expenditures in province *i* (of region *j*) to the total expenditures on science and technical development in year t.

$FEexpt_{it}$ --- foreign enterprises' export in province *i* as a percentage of their total output in year t.

ε_t --- random error term

We use the number of patent applications as a measure of innovation output, as embodied in new product or new process, by the domestic firms in each province. FDI with lag one was chosen to analyze the spillover effect of FDI on innovation activity.[9] As measures of input in to innovation activity, we include as independent variables personnel of science and technical (S&T) development and expenditures on science and technical development, which are reported to and published by the State Bureau of Statistic every year.[10] We also include the share of foreign funded enterprises' export to its gross output, so as to test how FDI firms' exposure to international market might affect innovation activity of domestic firms in China.

Equation (3) was estimated using the Ordinary Least Squares (OLS). The data were taken from the China Statistical Yearbook, various issues, covering four administrative cities and twenty-six provinces for the period from 1995 to 2000. Tibet was excluded, as most of the relevant data for it were zero during the period. Thus, the sample consists of a total of 177 data points. (The Administrative City of Chongqing was established in 1997). All variables are transformed into logarithmic form.

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[9] In our regression analysis, we also used FDI with lag two, but the residual sum of squares was larger than that for FDI with lag one.

[10] Data on R&D expenditures, which are a part of S&T expenditures, are not collected on a systematic basis under the current statistic system in China.

6. Empirical Findings

We first estimated equation (3) for the entire country for the total number of domestic patent applications, as well for each type of patent — invention, utility model, and design. We observed high correlation (0.95) between the share of science and technical development personnel (SHSTPER) and the share of science and technical development expenditure (SHRDEXP) of each province over the entire sample period. This is largely due to the fact that S&T expenses include expenses on S&T personnel as a major component.[11] To reduce colinearity, we estimated equation (3) by using only one of these two variables at a time. The estimated equation with smaller residual sum of squares was chosen as the more "fit" outcome and is boldfaced in the tables to be presented below.

6.1 Spillover Effect of FDI

Table 4 reports the results of regression results for the entire country. The results show that the spillover effects of FDI on innovation in China (coefficients of SHFDI) are positive and significant. In particular, a one per cent increase in the foreign investment ratio will increase the ratio of domestic patent applications (of all types) by about 0.27 per cent. When estimated for each type of patent application, the coefficients are 0.15, 0.18 and 0.43 per cent for invention, utility model and design patents, respectively. These results inform us that the FDI does have a positive spillover effect for innovation by domestic firms in China, with a very large effect on design patent applications. The relative large effect on design innovation is consistent with the "demonstration effect" of FDI mentioned earlier, as it is easier for domestic innovators to follow the examples of the external characteristics of foreign products or processes, relative to invention or utility model innovations.

Estimated coefficients for the share of S&T personnel are positive and significant in all cases. Specifically, an one per cent increase in the S&T personnel ratio will increase the ratio of patent applications (of all types) in a province by 0.60 per cent. The coefficients for invention patents, utility models and designs are 0.71, 0.79, and 0.27 per cent,

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[11] Other categories of S&T expenditures include expenses on raw materials, fixed assets, etc.

respectively. Note that the shares of S&T personnel are bigger for invention and utility model than for design patents. This is perhaps due to that invention or utility model innovations are technically more sophisticated than design innovations and thus an increase in S&T personnel input tend to have a greater effect on these two types of innovations than on design innovations.

Table 4. Spillover Effects of FDI on Domestic Innovation (N=177)

	Constant	SHFDI(-1)	SHSTPER	SHSTEXP	SHFEEX		
Aggregate	β_0	β_1	β_2	β_3	β_4	$\bar{R}^2$	**SSR**
Patent Applications	-0.135 (-0.847)	0.245 (9.702)**	0.356 (3.608)**	0.238 (2.680)**	0.137 (2.790)**	0.884	21.789
	0.152 (1.013)	0.227 (8.536)**	---	0.541 (12.951)**	0.083 (1.662)	0.877	23.015
	-0.251 (-1.543)	***0.274 (10.672)*****	***0.599 (14.071)*****	***---***	***0.155 (3.017)*****	***0.880***	***22.673***
Invention	0.158 (1.010)	0.114 (5.043)**	0.409 (3.938)**	0.291 (2.809)**	0.039 (0.827)	0.858	21.053
	0.422 (2.986)*	0.091 (4.253) **	---	0.639 (20.734)**	-0.001 (-0.028)**	0.844	23.231
	0.016 (0.111)	***0.149 (7.250)*****	***0.706 (21.121)*****	***---***	***0.060 (1.290)***	***0.850***	***22.373***
Utility model	-0.257 (-1.339)	0.163 (5.332)**	0.676 (6.571)**	0.108 (1.149)	0.124 (2.081)**	0.878	22.896
	0.179 (0.991)	0.126 (3.742) **	---	0.680 (12.538) **	0.058 (0.994)	0.847	28.819
	-0.309 (-1.617)**	***0.176 (5.945)*****	***0.785 (17.245)*****	***---***	***0.132 (2.184)****	***0.877***	***23.076***
Design	-0.136 (-0.765)	0.414 (11.835)**	-0.270 (-1.604)	0.526 (3.720) **	0.147 (2.522)*	0.813	49.944
	-0.278 (-1.616)	***0.437 (12.297)*****	***---***	***0.294 (6.692) *****	***0.162 (2.669)*****	***0.811***	***50.762***
	-0.371 (-1.910)+	0.490 (14.108)**	0.267 (4.604)**	---	0.176 (2.742)**	0.801	53.582

** stands for significant at the 1% level, * at the 5% level, and + at the 10% level.

Similar to the results for S&T personnel, the estimated coefficients for the share of S&T development expenses are positive and statistically significant in all cases. In general, the increase in the S&T expenses increases the innovation output ratio more for invention and utility patent than for design patents.

Lastly, the effect of foreign funded enterprises' export as the share of their annual output (SHFEX) is also positive and significant for utility model and design patents, but insignificant for invention patent. An explanation for this is as follows. A higher share of exports to gross output may imply that a higher proportion of FDI concerned is cheap-labor/export driven. This type of FDI therefore tends to be more labor intensive and thus less sophisticated technologically. As a result, their products (toys, shoes, clothes and other light-industry products, for example) are easier to imitate by the local producers, leading to a stronger spillover effect on minor innovations (utility model and external design).

In sum, the regression results support the hypothesis that a beneficial spillover effect from FDI on innovation activity by domestic firms exists. Moreover, we find that the share of S&T expenses, the share of S&T personnel and the share of foreign exports to gross output all contribute to innovation output in China.

6.2 Spillover Effects of FDI by Regions

To examine whether there are regional differences in terms of the effect of FDI on innovation, we also estimated equation (3) for each of the three regions. The results for different types of patent are shown in Table 5. We find that the estimated coefficients for FDI are positive and significant for all three regions. In particular, a 1% increase in FDI share of a province in the Coastal region will lead to a 0.19 percent increase its share of patent application. The corresponding figures for the Central region and the West region are 0.08 and 0.36 per cent, respectively.

Table 5. Estimated Results for the Share of Total Patent Applications by Region.

	Constant	SHFDI(-1)	SHSTPER	SHSTEXP	SHFEEX			
Number of patent application	β_0	β_1	β_2	β_3	β_4	$\overline{R}^2$	SSR	
Coastal region	-0.204 (-0.497)	0.209 (2.385)*	0.258 (1.346)	0.339 (1.985)+	0.171 (1.285)	0.763	12.508	N=72
	-0.229 (-0.555)	***0.185 (2.147)****	**---**	***0.558 (10.70) *****	***0.199 (1.502)***	***0.761***	***12.851***	
	-0.132 (-0.317)	0.269 (3.207)**	0.620 (10.43) **	---	0.120 (0.897)	0.753	13.254	
Central region	-0. 121 (-0.404)	0.094 (1.868)+	0.375 (1.821)+	0.359 (2.255)*	0.109 (1.404)	0.809	1.961	N=54
	0.322 (1.798+	***0.084 (1.640)+***	**---**	***0.618 (8.608)*****	***0.032 (0.484)***	***0.800***	***2.100***	
	-0.531 (-2.001)+	0.147 (3.019)**	0.789 (7.847)**	---	0.183 (2.322)*	0.795	2.156	
West region	0.088 0.331)	0.359 (5.490)**	0.050 (0.295)	0.330 (2.294)*	0.181 (2.091)*	0.895	4.190	N=51
	0.101 (0.415)	***0.359 (5.472)*****	**---**	***0.374 (3.656) *****	***0.185 (2.181)****	***0.898***	***4.196***	
	0.098 (0.359)	0.399 (6.186)**	0.342 (3.062)**	---	0.157 (1.756)	0.891	4.487	

Among the regions, the west region has the strongest FDI spillover effect, followed by the Coastal region and the Central region. This pattern may be understood as follows. Although inward FDI to China has been concentrated in the Coastal region (over 85% of the total FDI inflow), FDI into the West region is more concentrated within the region, relative to the Coastal and the Central regions. This can been seen from Table 1 which shows that during the second half of the 1990s over 60% of the total FDI inflow to the West region went to the Sichuan (Chongqing City included) and Shaanxi, whereas the foreign investments to the East and Central Region were more evenly distributed among the provinces within the regions. Since location proximity is of crucial importance to technology/knowledge spillovers, higher degree of spatial concentration of FDI tends to yield a stronger effect on local innovation.

As for other independent variables, both S&T personnel and S&T expenditures contribute positively to innovation output of domestic firms in all three regions, as expected. However, the export/output share of foreign enterprises has a significant effect at 5 % level only in the West provinces. We do not have a good explanation for this last finding.

Table 6. Estimation Results for Invention by Region.

	Constant	SHFDI(-1)	SHSTPER	SHSTEXP	SHFEEX			
Invention Applications	$\hat{\beta}_0$	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_3$	$\hat{\beta}_4$	$\bar{R}^2$	SSR	
Coastal region	0.504 (2.132)*	-0.157 (-2.734)**	0.183 (1.336)	0.570 (4.313)**	0.047 (0.585)	0.843	8.022	N=72
	0.481 ***(1.444)***	***-0.173*** ***(-2.515)****	---	***0.725*** ***(17.985)*****	***0.069*** ***(0.635)***	***0.842***	***8.194***	
	0. 638 (2.169)**	-0.056 (-0.932)	0.796 (21.376)**	---	-0.045 (-0.482)	0.804	10.138	
Central region	0.305 (0.661)	0.108 (1.292)	0.426 (1.377)	0.190 (0.789)	0.042 (0.325)	0.599	4.149	N=54
	0.766 (2.596)**	0.107 (1.245)	---	0.465 (4.256)**	-0.025 (-0.214)	0.594	4.283	
	0. 068 ***(0.191)***	***0.132*** ***(1.652)***+	***0.661*** ***(4.412) *****	---	***0.082*** ***(0.720)***	***0.602***	***4.200***	
West region	0.083 (0.336)	0.257 (5.043)**	0.170 (1.069)	0.316 (1.867)+	0.180 (2.269)*	0.902	3.658	N=51
	0.122 ***(0.516)***	***0.258*** ***(4.819)*****	---	***0.467*** ***(6.237)*****	***0.195*** ***(2.440)****	***0.902***	***3.738***	
	0.101 (0.403)	0.294 (6.454)**	0.449 (6.281) **	---	0.152 (1.996)+	0.897	3.933	

Tables 6 to 8 contain the regression results by region for invention patent, utility model and external design, respectively. As Table 6 shows, the estimated coefficients for FDI on invention patent are significant but mixed for all three regions. While a 1 per cent increase in FDI share will increase the share of invention applications in the Central and West regions by 0.13 and 0.26 percent, respectively, such a change will lead to a 0.17 percent decrease in the Coastal region. Similar results, though not significant, are observed for utility patent applications by region (Table 7). These imply that FDI into the Coastal region has tended to depress the innovation activities in this region that would have generated invention (and perhaps utility model patents).

Table 7. Estimation Results for Utility Models by Region

	Constant	SHFDI(-1)	SHSTPER	SHSTEXP	SHFEEX			
Utility Model Applications	$\hat{\beta}_0$	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_3$	$\hat{\beta}_4$	$\bar{R}^2$	SSR	
Coastal region	-0.369 (-1.207)	-0.074 (-1.018)	0.802 (4.566)**	0.082 (0.535)	0.238 (2.048)*	0.853	9.316	N=72
	-0.467 (-1.065)	-0.153 (-1.941)+	---	0.763 (14.813)**	0.333 (2.083)*	0.804	12.616	
	-0.349 (-1.184)	***-0.059 (-0.9337)***	***0.890 (22.275)*****	***---***	***0.224 (2.121)****	***0.855***	***9.360***	
Central region	-0.112 (-0.354)	0.098 (1.834)+	0.372 (1.704)+	0.429 (2.522)*	0.159 (1.935)+	0.819	2.228	N=54
	0.328 (1.729)+	***0.088 (1.625)***	***---***	***0.686 (8.979) *****	***0.082 (1.179)***	***0.812***	***2.366***	
	-0.610 (-2.118)*	0.161 (3.067)**	0.870 (8.030)**	---	0.249 (2.912)**	0.800	2.512	
West region	0.414 (1.320)	0.428 (7.163)**	-0.211 (-1.512)	0.427 (3.292)**	0.201 (2.024)*	0.920	2.757	N=51
	0.345 (1.145)	***0.428 (7.596)*****	***---***	***0.240 (2.944)*****	***0.190 (1.854)+***	***0.919***	***2.864***	
	0.458 (1.432)	0.492 (9.241)**	0.140 (1.497)	---	0.171 (1.724)+	0.910	3.164	

One plausible reason for the negative effect of FDI on invention in the Coastal region may be due to a "crowding out" effect of FDI. Since importing technology and innovating on one's own are substitutes, firms under certain circumstances may choose to purchase technologies from abroad (by setting up joint ventures with foreign investors, for example), rather than to innovate on their own. This is especially more likely when the technology concerned is of high standard (such as invention) or when competitors are all purchasing technologies. When such a "crowding out" effect is stronger than the spillover effect, FDI inflow may be accompanied by a decline in local innovation activity in a given region.[12]

Table 8. Estimation Results for Design Patent Applications by Region

	Constant	SHFDI(-1)	SHSTPER	SHSTEXP	SHFEEX			
Extern design	$\hat{\beta}_0$	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_3$	$\hat{\beta}_4$	$\bar{R}^2$	SSR	
Coastal region	-0.134 (-0.262)	0.740 (6.192)**	-0.293 (-1.144)	0.486 (2.164)*	0.019 (0.103)	0.626	24.491	N=72
	-0.098 ***(-0.202)***	***0.769*** ***(6.925)******	***---***	***0.237*** ***(4.835)******	***-0.016*** ***(-0.098)***	***0.625***	***24.934***	
	-0.020 (-0.039)	0.826 (7.696)**	0.230 (3.833)**	---	-0.060 (-0.364)	0.608	26.029	
Central region	0.292 (0.813)	0.379 (6.157)**	0.153 (0.617)	-0.025 (-1.232)	-0.114 (-1.232)	0.714	2.536	N=54
	0.469 (2.250)*	0.379 (6.204) **	---	0.076 (0.940)	-0.143 (-1.818) +	0.717	2.560	
	0.323 ***(1.195)***	***0.376*** ***(6.596)******	***0.123*** ***(1.118)***	***---***	***-0.120*** ***(-1.460)***	***0.719***	***2.537***	
West region	-0.165 (-0.454)	0.575 (5.848)**	0.202 (0.672)	0.012 (0.043)	0.229 (1.992)+	0.763	16.197	N=51
	-0.118 (-0.365)	0.577 (5.739)**	---	0.192 (1.157)	0.248 (2.225)*	0.766	16.311	
	-0.164 ***(-0.453)***	***0.576*** ***(6.056)******	***0.213*** ***(1.241)***	***---***	***0.228*** ***(1.983)+***	***0.768***	***16.197***	

[12] When all three regions are lumped together, one may still get positive spillover effect of FDI for a given type of innovation, as was the case in Table 4.

Unlike the cases for invention and utility model, the estimated coefficients for FDI are all positive and significant for design patent applications (Table 8). In particular, for the East, Central, and the West regions, a 1 per cent increase in FDI share will increase the share of design patent application share by 0.77, 0.38 and 0.58 per cent, respectively. Put differently, the spillover effects are more likely toward minor innovations.

In sum, when we break down patent applications by type in three regions, we found positive spillover effect of FDI for all, but one, cases. The negative effect of FDI on invention patent applications in the coastal region can be explained by the "crowding-out effect" of FDI on local R&D.

Finally, in order to test whether the differences in the FDI effect between the three regions are significant, we also conducted regression analysis by adding regional dummy variables to equation (3). The results are consistent with the patterns reported in Table 6 to Table 8.

7. Conclusions

It is well recognized that inward FDI can have beneficial effects to innovation activity in the host country though various spillover channels such as reverse engineering, labor mobility, demonstration effects, and so on. However, attempts to find empirical evidence of spillover effects of FDI in China are rare. This is surprising given that China has been the largest recipient of FDI among the developing countries in the 1990s and that it has been China's primary objective in the past two decades to develop its domestic innovative capacity by bringing in foreign investment and technology. Our work is among the first attempts to test empirically the spillover effect of FDI on innovation in China.

Realizing the importance of location proximity for knowledge spillovers, we use the provincial data for FDI and patent applications to test the impact of inward FDI on innovation activity in China. Using the data of the 31 provinces over the period 1995-

2000, our regression results reveal a positive effect of FDI on the number of patent applications filed by domestic firms. This positive relationship persists when we divide the patents by types (invention, utility model, and external design) or when we group the provinces into regions (the Coastal area, Central region, and the West), with the exception of invention patent in the Coastal region. This positive spillover effect is much stronger for minor innovations (design patent and utility model), relative to major innovation (invention). This finding is consistent with the current R&D capability of typical Chinese enterprises. We also found a negative effect of FDI for invention patent in the coastal region, which suggests the existence of a strong “crowding out effect” of FDI on domestic innovation in that region. The effects of science and technical development expenditures and personnel, as well as the share of export by the FDI firms, also have significant impact on domestic innovation in China.

One limitation of our approach is that we used provincial data only. However, as we mentioned in the Introduction, our findings complement and are consistent with those reported by Hu and Jefferson (2001) who also found positive spillover effect of FDI on innovation activity at each industry in China. We believe that our findings will remain valid if one further breaks down the provincial data by industry. We did not extend our analysis along this direction due to absence of relevant data (on FDI as well as on patent).

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