ATLANTIS PRESS
Advances in Economics, Business and Management Research, volume 49
2nd International Conference on Education, Management Science and Economics (ICEMSE 2017)

The Spillover Effects of Foreign Direct Investments on Innovation in China

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***Abstract*—This study conducts quantitative analysis on the spillover effects of Foreign Direct Investments (FDI) on innovation in China as well as the heterogeneous effects of various innovation types in the eastern, central and western regions. An OLS model employing the panel data from 2005 to 2014 of 30 provinces in China is built. It is found that FDI improves innovation significantly in the nation in general, especially in the eastern and western regions. However, the spillover effects disappear in the central region. Moreover, the promotion effects of FDI on design patents granted by region are much larger than those on utility model patents and invention patents. In the western region, FDI has significant positive effects on all the 3 types of patents. And these effects are all greater than those in the eastern region.**

Keywords—FDI; Innovation; Technological Spillover effects

I. Introduction

In recent years, as constant adjustment of economic development pattern and optimization and upgrading of industrial structure, innovation ability is increasingly becoming the important impetus to maintain high-quality economic growth in China. In the backdrop of the fullest opening-up, Foreign Direct Investments (FDI), among many other factors, plays an indispensable role in innovation ability in China. In 2015, FDI in China reached to RMB 781.35 billion, with year-on-year growth of 6.4%. Compared to 2014, the rate of increase rose by 4.7 percentage points. The amount of FDI in China is growing larger and larger. Thus, a question, which has attracted great attention, is that whether the technological spillover effects of FDI in China are brought into full play. Hence, following the same research thoughts and using new data, this study conducts empirical analysis on the spillover effects of FDI on innovation in China.

In the empirical study on technological spillover effects of FDI, I build an OLS model employing the panel data from 2005 to 2014 of 30 provinces in China. The explained variables include the total amount of patents granted by region and its 3 components: design patents, utility model patents and invention patents granted by region. The core explanatory variable of the model is the amount of FDI. Full-time equivalent of R&D personnel, Intramural expenditure on R&D, Per capita GDP, and Human capital, Loan balance of financial institutions and Law enforcement of patent protection are selected as control variables. I employ the method of econometrics to build a time fixed effects panel data regression model, and make tests and analyses on the results.

The empirical research of this paper is based on different regions and various innovation types. Firstly, with the total amount of patents granted by region as the explained variable, I run a regression on the data of 30 provinces, and run regressions for eastern, central and western regions respectively, from which I observe the effects of FDI on innovation in China and the heterogeneous effects in different regions. Secondly, I select design patents, utility model patents and invention patents granted by region as explained variables to run 3 regressions on data of 30 provinces in order to compare the heterogeneous effects of FDI on various patent types. On this basis, I refine the regression analysis further by running 3 regressions of the eastern, central and western regions for each patent type, and compare the concrete heterogeneous spillover effects of various innovation types in different regions in China.

After the empirical analysis and research above, the study draws 5 conclusions as follows: firstly, FDI improve innovation significantly in the nation in general. When the inflow of FDI increases by 1%, the total amount of patents granted by region increases by 0.2140%. Secondly, the inflow of FDI has significant positive effects on design patents, utility model patents and invention patents granted by region in China. The promotion effects of FDI on design patents granted by region are much larger than those on utility model patents and invention patents. Moreover, in the eastern region, FDI has significant positive effects on both design patents and invention patents granted by region. Thereinto, the effects on design patents are major, and those on invention patents are minor. In the central region, the effects of FDI on the 3 types of patents are either not significant, or significantly negative. In the western region, FDI has significant positive effects on all the 3 types of patents. The promotion effects of FDI on design patents granted by region are the largest. For utility model patents and invention patents granted by region, the promotion effects are minor. Finally, I also come up with the limitations of the empirical research: the measurement of some variables is not accurate enough so that there exists deviation in the model estimation.

This paper is structured as follows. Section 2 reviews the relevant literature. Section 3 builds the model and describes data and empirical strategy, while section 4 gives a descriptive statistical analysis on data and empirical results. The last section presents the conclusions and policy recommendations of the study.

II. Literature Review

MacDougall(1960)[17] firstly put forward "technological spillover effects of FDI". Afterwards, experts and scholars did lots of theoretical and empirical research on the spillover effects of FDI. Blomstrom and Kokko (2001)[9] pointed out that the spillover effects of FDI play a role mainly through competition effect, model and replication effect, human capital flow effect and front and backward linkage effect. From the theoretical perspective, their research, which verified the influencing mechanism of FDI on innovation, constitutes the theoretical basis of my research.

Some scholars believe that the inflow of FDI could bring advanced foreign technology. Host countries can benefit from the spillover effects and improve their own technological ability. Using data of 23 Australian manufacturing industries in 1962 and in 1966, Caves(1974)[10] built an empirical model on the spillover effects of FDI, and the findings presented that there was a positive correlation between productivity of Australian enterprises and the proportion of foreign investment in the industry. It is concluded that FDI have significant positive spillover effects in Australian manufacturing industries.

Some other researches manifested that the effects of FDI on technological progress of host countries are not significant. Haddad and Harrison (1993) [14]employed panel data of 15 Moroccan manufacturing industries and some enterprises from 1985 to 1989 to analyze the relation between FDI and technological improvement of the enterprises in host countries. The finding showed that the spillover effects of FDI were not apparent in industries. Although to some extent, their researches denied the promotion of FDI on technological progress in these countries, they inspire us to think through the conditions and opportunities when the spillover effects of FDI are significant.

Referring to literature in China and abroad, this paper uses panel data for 30 Chinese provinces, municipalities directly under the Central Government and autonomous regions from 2005 to 2014. In the model, explained variables include the total amount of patents granted by region and its 3 components: design patents, utility model patents and invention patents granted by region. The core explanatory variable of the model is the amount of FDI. In addition, we introduce 6 variables that could influence the amount of patents granted by region as control variables from different aspects. Finally, we give explanation for technological spillover effects of FDI and the difference according to different regions and patent types, and come up with conclusions and policy recommendations.

III. Theoretical Basis, Model and Data

A. Theoretical basis

Firstly, policies to support local technological capability and labor skills may facilitate spillovers of technology from foreign MNCs. The reason is that a more skilled local labor force reduces the costs of intra-firm technology transfer within the MNC, which is likely to encourage affiliates to import technology from their parents. Secondly, policies to ensure that the foreign affiliates operate in a competitive environment appear to be essential. Foreign MNCs facing national or international competition must continuously adjust their operations and technologies, which create a greater potential for spillovers to local industry.

B. Model and data

The paper builds a regression model as follows to estimate effects of FDI on innovation in China:

$$\begin{aligned} \ln Innov_{i,t} &= a_0 + a_1 \ln FDI_{i,t} + a_2 \ln Pers_{i,t} \\ &+ a_3 \ln Expen_{i,t} + a_4 \ln GDP_{i,t} + a_5 \ln Humcapi_{i,t} \\ &+ a_6 \ln Loan_{i,t} + a_7 \ln Case_{i,t} + \gamma_t + u_{i,t} \end{aligned} \quad (1)$$

There into, γ_t represents the dummy variable for 2006 to 2014. Time period fixed effects are added in the model so that we could control factors which vary as time goes by but remain constant as units change.

In the regression model, explained variable Innov, which is used to measure innovation ability, represents the amount of patents granted by region. As a measurement of scientific research and development level, the amount of patents granted by region, to some extent, could reflect innovation ability.

The paper employs panel data from 2005 to 2014 for 30 Chinese provinces, municipalities directly under the Central Government and autonomous regions to estimate the effects of FDI on innovation ability in China (The inflow of FDI in Tibet is few. In order to avoid the data resulting in large deviation in the regression results, we remove the data of Tibet). The sources of the data we use are State Statistics Bureau, CEINET[i] Statistical Data Base, the State Intellectual Property Office of China and "Yearbook of Science and Technology of China" and "Yearbook of Finance of China" for related years. All the data in the model are adjusted to the form of natural logarithm.

IV. Empirical Results

The data processing in this paper is done with the application software Excel. The data operation, graph plotting and econometrics regression are finished with the econometrics software Stata12.0.

A. Regression results from the aspect of the total amount of patents

1) Regression for 30 Chinese provinces

a) Scatter diagrams and fitted lines of the total amount of patents and FDI

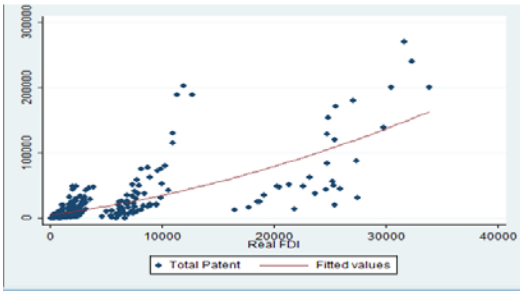

Fig. 1. Scatter diagram and fitted line of the total amount of patents and FDI

According to figure I, it could be found intuitively that at national scale, there exists apparent positive correlation between total amounts of patents granted by region and FDI. As a result, this paper forecasts that FDI has positive effects on total amounts of patents granted by region.

b) Empirical results

Table I presents the regression results of the effects of FDI on total amount of patents granted by region in 30 provinces.

TABLE I. REGRESSION RESULTS OF THE EFFECTS OF FDI ON TOTAL AMOUNT OF PATENTS IN 30 PROVINCES

Explanatory Variables	Regression(1.1)	Regression(1.2)	Regression(1.3)	Regression(1.4)
FDI	0.8665*** (0.0296)	0.2440*** (0.0254)	0.2912*** (0.0381)	0.2140*** (0.0352)
Pers		1.0248*** (0.0344)	0.9661*** (0.0459)	1.0402*** (0.0624)
Expen		-0.1812*** (0.0518)	0.0443 (0.0907)	-0.0665 (0.0956)
GDP			0.0077 (0.1057)	-0.0394 (0.0899)
Humcapi			-0.5277*** (0.0927)	-0.4077*** (0.0851)
Loan				0.3020*** (0.0633)
Case				0.0907*** (0.0178)
Constant a_0	1.4174*** (0.2634)	-5.3811*** (0.4780)	-6.4668*** (1.4818)	-6.5352*** (1.3755)
Adjusted R^2	0.7627	0.9388	0.9442	0.9551
F-Statistic	119.72	386.57	312.42	403.71
No. of Obs.	300	300	300	300
Fixed Effects	Year	Year	Year	Year

Explained variable: total amount of patents granted by region adjusted to the form of natural logarithm.
The numbers in the table are regression coefficients, and robust standard errors clustered on province-year combinations are presented in parentheses.
*, **, *** indicate statistical significance at the 10, 5 and 1% level, respectively. Each variable has 300 data.
All models include year fixed effects.

Regression equation (1.1) indicates that FDI has significant positive effects on the total amount of patents granted by region. When the inflow of FDI increases by 1%, the total amount of patents granted by region increases by 0.8665%.

Regression equation (1.2) indicates that FDI still has significant positive effects on the total amount of patents granted by region. However, the regression coefficient of FDI decreases sharply as a result of the adding of control variables. When the inflow of FDI increases by 1%, the total amount of patents granted by region increases by 0.2440%. Meanwhile, Full-time equivalent of R&D personnel has large positive effects on the total amount of patents granted by region. The coefficient of Pers is positive and statistically significant at the 1%level. When Full-time equivalent of R&D personnel increases by 1%, the total amount of patents granted by region increases by 1.0248%. The regression result manifests that in recent years, work efficiency and scientific research ability of R&D personnel in China has improved. On the contrary, Intramural expenditure on R&D has significant negative effects on the total amounts of patents granted by region. When Intramural expenditure on R&D increases by 1%, the total amount of patents granted by region decreases by 0.1812%. This regression result manifests that our scientific expenditure has not brought improvement of innovation ability as expected. That is because that the usage efficiency of R&D expenditure in China is low, and there exist some problem about fund embezzlement.

Regression equation (1.3) and (1.4) indicates that FDI has significant positive effects on the total amount of patents granted by region, and the effect is similar to that in regression equation (1.2). Full-time equivalent of R&D personnel still has significant positive effects on the total amount of patents granted by region, and the effect is similar to that in regression equation (1.2). The regression coefficient of Expen in regression equation (1.3) is positive while that in regression equation (1.4) is negative, and the coefficient of Expen does not appear to be statistically significant in either model. This finding further proves that Intramural expenditure on R&D does not have significant effects to improve innovation ability in China. Per capita GDP can hardly influence the total amount of patents granted by region (the coefficient of GDP is not statistically significant in either model). That means that at present economic development level, we cannot expect that a simple increase of Per capita GDP could facilitate improvement of innovation ability. Human capital has significant negative effects on the total amount of patents granted by region. When Human capital increases by 1%, the total amount of patents granted by region decreases by 0.4077% to 0.5277%. This is because that with the sharp increase of Chinese college enrollment in recent years, the quality of recruited students has declined, and high-quality talents tend to disperse. This may cause negative effects on innovation in China. Finally, Loan balance of financial institutions and Law enforcement of patent protection both have significant positive effects on the total amount of patents granted by region. This proves that the effects of financial development and law enforcement of patent protection on innovation ability in China should not be ignored.

2) Respective regression for eastern, central and western regions

The objective conditions of eastern, central and western regions in China are quite different. Since the reform and opening-up, the rate of economic growth of coastal areas outdistances inland areas, and coastal areas have great advantages in infrastructure, human capital, degree of opening-up, policy measures, etc. These factors, to some extent, can influence spillover effects of FDI in different regions. Meanwhile, the eastern region is also a main receiving region of FDI.

It can be found that the inflow of FDI can lead to an increase of the total amount of patents granted by region in eastern and western regions. The regression coefficients of FDI are both positive and the coefficient of FDI appears to be statistically significant at the 1%level in both models. The contribution of FDI on innovation in western region is greater than the one in eastern region. In western region, when the inflow of FDI increases by 1%, the total amount of patents granted by region increases by 0.3481%. In eastern region, when the inflow of FDI increases by 1%, the total amount of patents granted by region only increases by 0.1549%. The reason of the results is that in recent years, the pace of introducing FDI into western region is quickened, and western region has made good use of the demonstration effect and copycat effect of FDI on innovation.

B. Regression results from the aspect of different innovation types

In the previous section, the paper employs the total amount of patents granted by region to measure innovation level in China. In fact, the patents granted by region are composed of 3 types of patents: design patents, utility model patents and invention patents granted by region. Compared with design patents and utility model patents, invention patents contain high technical content. But also, the amount of invention patents account for a small proportion in the total amount of patents in China.

1) Regression for 30 Chinese provinces

It can be concluded that an increase of FDI has significant positive effects on all the 3 types of patents, however, the degrees of the effects are different: FDI has the largest effects on the amount of design patents granted by region, for which the technology level is low, while the effects on amounts of utility model patents and invention patents granted by region are small. That is because that design patents are mainly related to the packaging, patterns and colors of products, and this kind of patents only needs low technology in the R&D process.

2) Respective regression for eastern, central and western regions

In the analysis above, the paper builds an empirical model of the effects of FDI on different types of patents at the national level. We are also intended to further analyze the difference of the effects in different Chinese regions. In this section, we divide our country into eastern, central and western regions again so as to refine the effects of FDI on technological innovation.

Table II lists what effects FDI has in eastern, central and western regions and on the amounts of 3 types of patents granted by region respectively.

TABLE II. REGRESSION RESULTS OF THE EFFECTS OF FDI ON THE AMOUNTS OF 3 TYPES OF PATENTS IN EASTERN, CENTRAL AND WESTERN REGIONS

Explanatory Variables	Eastern region			Central region			Western region		
	Design (2.1)	Utility model(2.2)	Invention (2.3)	Design (2.4)	Utility model(2.5)	Invention(2.6)	Design (2.7)	Utility model (2.8)	Invention (2.9)
FDI	0.3128*** (0.0786)	0.0737 (0.0482)	0.0963** (0.0432)	0.1250 (0.2531)	0.0834 (0.1341)	-0.2076** (0.0944)	0.6120*** (0.1584)	0.2502** (0.0970)	0.2980*** (0.0650)
Pers	1.9429*** (0.1555)	0.8755*** (0.1054)	0.6756*** (0.0783)	0.7664*** (0.1819)	1.0845*** (0.1100)	0.7493*** (0.1025)	0.8541*** (0.2916)	1.0259*** (0.1354)	0.9169*** (0.1104)
Expen	-2.8010*** (0.2862)	-0.0929 (0.1886)	0.6165*** (0.1443)	0.5369* (0.3123)	0.6588*** (0.2093)	0.9230*** (0.1557)	-0.2358 (0.3685)	-0.8711*** (0.1656)	-0.2317 (0.1452)
GDP	2.9841*** (0.2985)	0.9034*** (0.2049)	0.2221 (0.1890)	-1.2935*** (0.3894)	-0.2963 (0.2814)	1.0396*** (0.2862)	-0.3299 (0.3212)	-0.9767*** (0.1701)	-0.9454*** (0.1227)
Humcapi	-0.6261 (0.3943)	-0.9568*** (0.1511)	-0.5247*** (0.1947)	-0.7774** (0.3284)	-0.4939* (0.2549)	-0.4063 (0.2529)	-0.5604 (0.4109)	1.1873*** (0.2256)	0.4664** (0.1920)
Loan	0.8683*** (0.1407)	-0.2340** (0.0988)	0.5050*** (0.0840)	-0.2292 (0.4301)	-0.5037** (0.2490)	-0.3593* (0.1871)	0.6635*** (0.1877)	0.4207*** (0.0966)	0.4082*** (0.0809)
Case	0.0108 (0.0582)	0.0081 (0.0320)	0.0648** (0.0284)	0.1763*** (0.0441)	0.0105 (0.0266)	0.0507* (0.0265)	0.0842 (0.0599)	0.0896*** (0.0316)	0.0347 (0.0235)
Constant a_0	-61.3267*** (4.3559)	-15.6714*** (3.3215)	-3.5923 (2.4001)	7.9999 (5.2885)	-1.0555 (3.1963)	-7.7799** (3.1296)	-7.3539 (5.7700)	4.7794 (2.9242)	3.9949* (2.2947)
Adjusted R^2	0.9457	0.9760	0.9719	0.8325	0.9367	0.9426	0.8016	0.9361	0.9563
F-Statistic	124.88	309.59	321.74	45.17	68.80	112.56	34.99	269.15	69.75
No. of Obs.	110	110	110	80	80	80	110	110	110
Fixed Effects	Year	Year	Year	Year	Year	Year	Year	Year	Year

Explained variables: amounts of design patents, utility model patents and invention patents granted by region in eastern, central and western regions adjusted to the form of natural logarithm respectively.

Other figures and symbols have the same meaning as those in Table II.

Regression equation (2.1), (2.2) and (2.3) reflects the effects of FDI on various types of patents in eastern region. It could be found that in eastern region, the inflow of FDI is beneficial to the increase of the amount of design patents granted by region significantly. When the inflow of FDI increases by 1%, the amount of design patents granted by region increases by 0.3128%. The inflow of FDI can also facilitate the increase of the amount of invention patents granted by region significantly, however, the impact is less. When the inflow of FDI increases by 1%, the amount of invention patents granted by region only increases by 0.0963%. Although the regression coefficient of FDI on the amount of utility model patents granted by region is positive, it does not appear to be statistically significant. In the last decade, eastern region has been at the forefront of the optimization and upgrading of industrial structure, emphasizing the development of technology-intensive industries and international trade. Therefore, this region makes great efforts in R&D of invention patents, while the R&D demand for utility model patents has decreased. In addition, in order to adapt to the industrial structure, the FDI in eastern region tends to be capital intensive and technology intensive. In regressions (2.4), (2.5) and (2.6), it is worth noting that the effects of FDI on the 3 types of patents in central region are either not significant or significantly negative, which means that in the last decade, innovation capability at different levels in central region and the amount of FDI this region received are uncorrelated. It can be found in regression equations (2.7), (2.8) and (2.9) that in western region, FDI has positive effects on the amounts of all the 3 types of patents granted by region, and coefficients of FDI appear to be statistically significant. Here, we could see the significance of our macro-control and policy support for economic development and improvement of innovation ability in a region.

V. CONCLUSIONS AND POLICY RECOMMENDATIONS

Using panel data from 2005 to 2014 for 30 Chinese provinces, municipalities directly under the Central Government and autonomous regions and taking the amount of patents granted by region as a measurement of innovation capability , the study builds an empirical model to do quantitative analysis about the effects of FDI on innovation in China, and the conclusions are as follows:

- At first, employing the data of 30 provinces, we use the total amount of patents granted by region as explained variable to run regressions, and it is found that FDI can improve innovation in China significantly. When the inflow of FDI increases by 1%, the total amount of patents granted by region increases by 0.2140%.
- The effects of FDI on innovation in China are apparently different for various types of innovation. The inflow of FDI has significant positive effects on design patents, utility model patents and invention patents granted by region in China. The promotion of FDI on design patents granted by region is far more than the one on utility model patents and invention patents, which means that the spillover effects of FDI mainly remain on innovation projects with inferior technological levels.

Based on the conclusion, the paper comes up with several policy recommendations. First of all, we should take full advantage of the spillover effects of FDI on design patents and make efforts to learn this type of innovation of foreign enterprises. Moreover, while maintaining the advantage in design patents, we should also lay emphasis on spillover effects of FDI on utility model patents and invention patents. For these 2 types of patents with more technology content, the government is advised to improve our absorptive capacity for technological spillover of FDI through increasing the input of R&D personnel and expenditure.

- In the further analysis on different regions and various types of patents, the study find that in eastern region, FDI has significant positive effects on both design patents and invention patents granted by region. Thereinto, the effect on design patents is major, and the one on invention patents is minor. As for utility model patents granted by region, the effect of FDI is positive but not significant; in central region, the effects of FDI on the 3 types of patents are either not significant, or significantly negative; in western region, FDI has significant positive effects on all the 3 types of patents. Here, we could see the significance of our macro-control and policy support for economic development and improvement of innovation ability in a region.
- The paper also comes up with the limitation of the empirical research: with limited data sources, although we have added comprehensive control variables in the regression model, the measurement of some variables, such as Human capital and Law enforcement of patent protection, is not accurate enough so that there exists deviation in model estimation; this paper only builds a multivariable linear regression model. In future researches, we could use more complex model forms such as a model with instrumental variables; in the model estimation for each region, the small amount of data would result that the accuracy of regression coefficient estimation reduces.

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