Master Thesis of International Studies

How Does Two-way FDI Affect Domestic Technology Development of China?

양방향 외국인직접투자가 중국의 국내 과학기술 발전에 어떤 영향을 미치는가?

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Abstract

The 21st century is the era of knowledge economy. The development of science and technology is playing an increasingly irreplaceable part in the economic growth and the improvement of comprehensive power of a country. From starting the reform and opening up, China has become the developing country with the largest number of foreign capital absorption for many years. In addition, the situation of absorbing foreign capital in central and western regions of China has been improving, and the number of large projects using foreign capital has achieved rapid growth. So far, after the transition from exploration to transformation, China has become one of the main countries of foreign investment, but we can find that the total growth of China's OFDI cannot fully reflect the real situation and the gap with developed countries. However, in view of the requirements of high-quality economic development, the development potential of China's OFDI is still large. For Chinese enterprises, especially private enterprises, there is still a big gap between them and world-class enterprises in terms of development history, technical reserve, high-end technical talent stock and R & D capacity. In order to make up for these shortcomings, enterprises need to take a global view, learn and absorb corresponding technologies, or attract high-end talents through OFDI merger or equity participation in the world's leading similar enterprises.

This paper uses the organic combination model of two-way FDI to supplement the systematic research on the strategy of "bringing in" and "going out" of China, and examines the overall impact of two-way FDI on China's science and technology progress. On this basis, this dissertation takes China’s provincial panel data between

2009 and 2018 for econometric analysis, and combines the IV-2SLS regression method for robustness test, and conducts comparative studies at the national level and among different regions respectively, and makes an objective evaluation on the impact of two-way FDI on the science and technology progress of 30 provinces in China except Tibet. The results are as follows:

1. On the whole, technology spillover caused by FDI has a significant promoting effect on domestic technology progress, while the OFDI inversion spillover can restrain the domestic technological progress. This shows that on the whole, China cannot promote domestic technology progress through the reverse technology spillover of OFDI, but stays in the stage of exporting technology to underdeveloped areas.

2. From the regression results of the three regions, the promotion of technology spillover through FDI to domestic technology progress is weakening from east to west; while the technology spillover formed by OFDI has weakened the promotion of domestic technology progress from west to East.

3. The implication from the results is that when China develops the international strategy of "bringing in" and "going out" at the same time, it should speed up the improvement and optimization of the screening standards of OFDI projects while maintaining the high standard of screening FDI projects, so as to strengthen the strength of reverse technology spillover from OFDI.

Keyword: two-way FDI, panel data analysis, technology spillover, region analysis

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List of Notation and Abbreviation

FDI	Foreign Direct Investment
OFDI	Outward Foreign Direct Investment
OECD	Organization for Economic Co-operation and Development
LDC	Least Developed Country
DC	Developed Country
R&D	Research and Development
MNE	Multinational Enterprise
TFP	Total Factor Productivity
NDRC	National Development and Reform Commission

I. Introduction

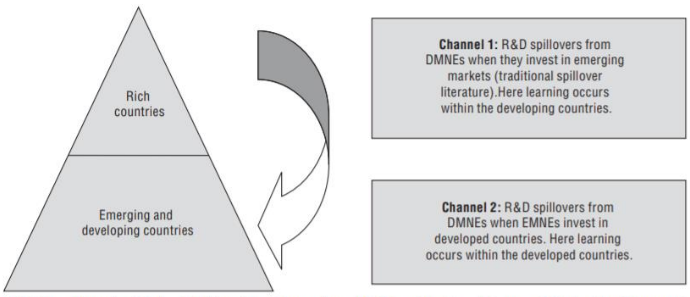
1. Background

In the era of knowledge economy and economic globalization, technological innovation is the key to a country's core competitiveness. As the most active factor in factor endowments, technology plays an important role in the competition between countries and between companies. However, under the conditions of an open economic system, with the continuous flow of international capital, it is difficult for a country to conduct research and development solely on its own to gain absolute advantage, and many developing countries do not have enough power to conduct research and development of new technologies. Therefore, the promotion of technology progress through international technology spillover channels has received more and more attention, and international technology spillover has become an important topic in the field of economics research. Since the 1990s, many countries have taken measures to actively attract the flow of foreign capital, especially some emerging market countries. With regard to China, since the reform and opening up, it has attracted a large number of foreign investors for direct investment with its rich and cheap labor advantages and a series of preferential policies for foreign investment issued by the government. Since 2001, in the 20 years after China's accession to the WTO, China's utilization of FDI presents an accelerated development trend. Nowadays, FDI has become an important indicator of the global economy, and also an important indicator of the business environment of a country or an economy. In the process of implementing reform and opening up for around 40 years, the opening strategy of China has undergone a development process from an export-oriented economy that combines export-oriented and import substitution driven by FDI expansion to an export-oriented economy that brings in and goes out for common development, and the coordinated development of eastern, central and western regions. "Bringing in" and "going out" are important aspects of China's reform and opening up, economic growth and integration into the international division of labor. "Bringing in" here mainly refers to attracting FDI, and "going out" refers to vigorously developing OFDI. Summarizing the development experience of "bringing in" and "going out" has important guiding significance for China's next stage of building a higher level of a new open economic system.

1-1. Technology Spillover Effect

Technology spillover refers to the conscious or unconscious transfer or dissemination of advanced technology in trade or other economic activities. The types of technology spillovers include international technology spillovers, domestic technology spillovers, inter industry technology spillovers and intra industry technology spillovers. Arrow (1962) first used externality to explain technology spillover effect. The paper holds that high-tech enterprises can improve their own productivity through R&D activities, while external enterprises can improve their own productivity through learning as well because of spillover effect. This paper mainly discusses the global technology spillover effect. Figure 1 shows two important channels of global technology spillover.

Figure 1. Two Important Channels of Global Technology Spillover

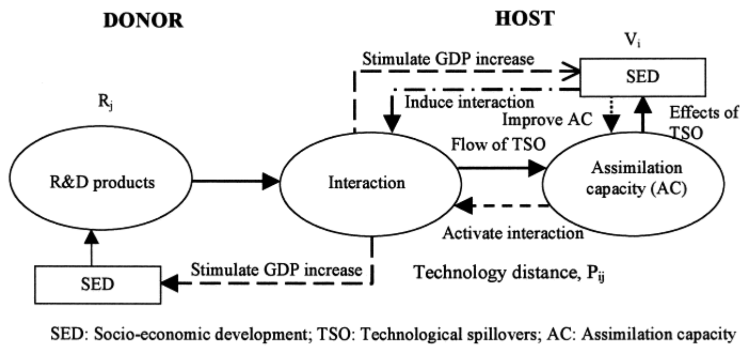


Note: EMNEs = Emerging Market Multinational Enterprises, DMNEs = Developed Country Multinational Enterprises.

Source: adopted from Amann & Virmani (2014)

1-1-1. FDI Technology Spillover

Figure 2. Dynamism of FDI Spillover



Source: adopted from Chihiro Watanabe et al. (2001)

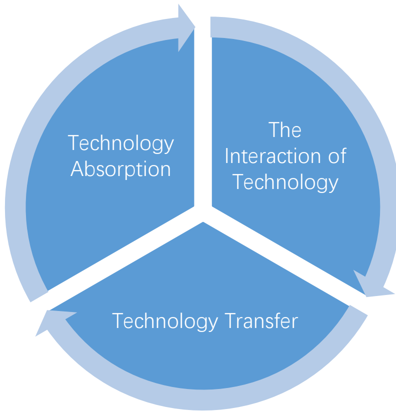
According to the definition of the two most famous scholars Blomström and Kokko in the field of FDI spillover research, FDI Spillover refers to an economic external effect that multinational corporations cannot obtain all of their benefits while causing the progress of local technology or productivity after direct investment in host countries. Figure 2 shows the dynamism of FDI spillover. It can be seen that in this process, multinational companies play a vital role. Multinational corporations are the main inventors and suppliers of advanced technologies in the world. They realize their technology transfer through the internalization of foreign direct investment. A technology spillover is a specific situation of positive externality. It is neither the benefit obtained within the economic activity itself nor the benefit obtained by the user of the product of the activity. The expenditures that developing countries can spend on high-tech research and development are much smaller both in relative and absolute terms. Therefore, it is obvious that technology spillovers from developed countries to developing countries have a great impact on the development of developing countries, and this kind of technology spillover is mainly realized through transnational corporations.

Generally speaking, FDI technology spillovers can be achieved through the following three channels. First is the competition effect. The competition levels will be great raised due to the entry of international enterprises. When these TNCs invest in industries where there are high barriers, the degree of monopoly distortion will be reduced and, through better resource allocation, the productivity of firms in the host countries will increase. The second is the demonstration effect. Through the contact with advanced enterprises, the relatively backward local enterprises will benefit from imitation and learning, prompting them to make more efforts to catch up. In fact, FDI provides host country enterprises with the opportunity to get in touch with advanced technologies. Host country enterprises can learn while absorbing the experience and lessons of multinational companies' innovation and reduce the cost of trial and error. The third is the effect of personnel mobility. Multinational companies think highly of the training of local staff, and pay more attention to the training of technicians and managers than local enterprises. Multinational companies have advanced management systems and concepts, and their employees naturally surpass those of local enterprises in technical level and management ability. When the local employees who have worked in the subsidiaries of multinational companies flow to the local enterprises of the host country, the know-how learned in the multinational companies will transfer with them, and the spillover will occur.

1-1-2. OFDI Reverse Technology Spillover

OFDI reverse technology spillover generally refers to that enterprises from less developed countries participate in the high-end industrial chain through greenfield investment or cross-border mergers and acquisitions, so as to be able to access the advanced R&D resources, intelligence factors and management experience of developed countries, so as to realize the technology spillover from the host country to the home country. Figure 3 shows the triangle circulation transmission mechanism model of OFDI reverse technology spillover effect: through laying out to the host country, the home country enterprise interacts with the enterprises and scientific research institutions of the country received investment, and then realizes the technology transfer from the overseas funded company to the parent company through income feedback and personnel flow, and finally the parent company absorbs and digests the new technology and makes self-innovation. Finally, technology progress will be achieved. The improvement of the overall technology level of the enterprise creates conditions for the next round of technology interaction of overseas subsidiaries. Therefore, acquiring international technology spillover through the channel of OFDI can eliminate the barriers to technology introduction to a certain extent, improve the speed of technology acquisition, reduce the cost of technological innovation, and is more conducive to acquiring the advanced technology of the host country.

Figure 3. The Mechanism Model of OFDI Reverse Technology Spillover Effect



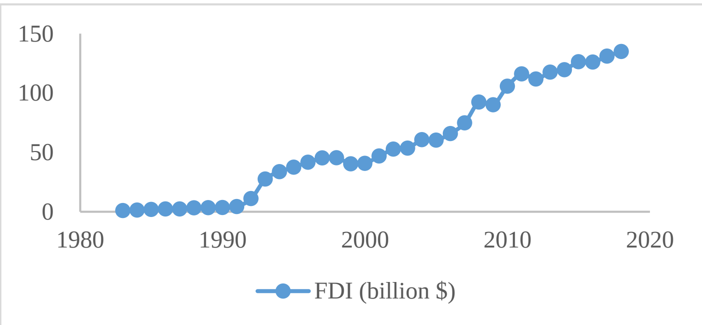
Source: adopted from Guo &Huang(2012)

1-2. The Development of FDI in China

We can divide China's FDI development into three main stages. The first is the exploration stage between 1979 and 1991. In 1979, the Chinese government began to establish special economic zones in coastal areas. However, China lacked experience and sufficient understanding in attracting FDI, whether from the central government to the local government to the academic community. Foreign investment has only made some exploratory investment in the uncertain situation of China's politics and economy. Therefore, the inflow of FDI in the initial stage was quite little. The second stage is the leap forward development among 1992 and 2001. During his period, China has rapidly established open and development zones, and governments have given foreign-invested enterprises various preferences. China enjoyed the first round of prosperity brought about by foreign direct investment. We can see from Figure 4 that during the year from 1992 to 1993, there was an obvious leap in the amount of FDI flowing into China, and in the following years, FDI also increased steadily year by year. The third is the stage of innovation and development since 2002. With China's entry into WTO in 2001 and China's opening to the outside world in an all-round way, FDI continues to grow. Even in the context of the global financial crisis and the European debt crisis, FDI into China has remained stable and growing. In addition, with the promulgation and implementation of Foreign Investment Law of the People's Republic of China which has been formally implemented since January 1, 2020, in the process of opening to the outside world, China will gradually shift the policy of attracting FDI from low-level factor preference and policy preference to high-quality institutional supply. This marks that China has entered a new stage of institutional opening-up, which is a milestone in promoting foreign investment.

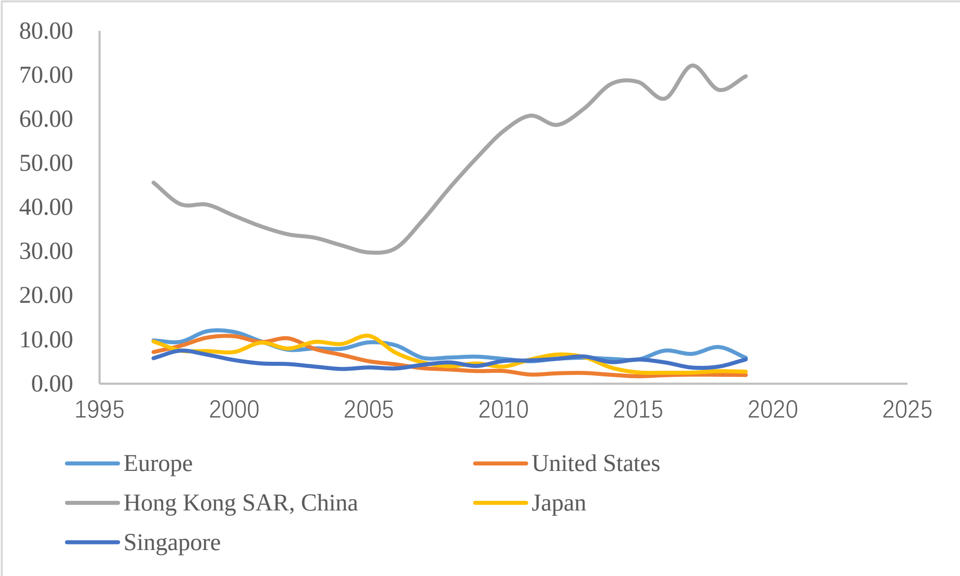
It can be found from Figure 5 that the vast majority of FDI entering China comes from economically developed countries or regions. The proportion of funds from Hong Kong SAR has been very high, which is related to the natural affinity between Hong Kong SAR and the mainland in terms of blood relationship, language and culture.

Figure 4. FDI into China



Source: author’s derivation using China Statistical Yearbook

Figure 5. The Proportion of the Main Sources of FDI into China



Source: author's derivation using China Statistical Yearbook

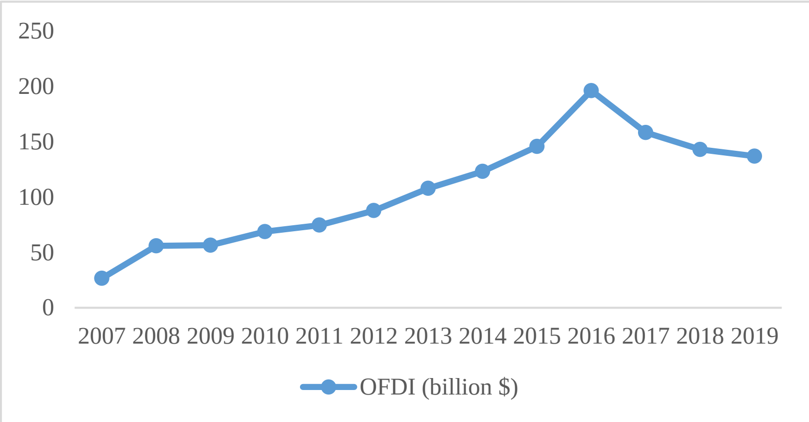
1-3. The Development of OFDI in China

Compared with FDI, China's OFDI started relatively late. In recent years, with the "Belt and Road" initiative, China has accelerated its strategic deployment of OFDI. From 1991 to 1993, the number of new non-trade overseas enterprises approved by the Chinese government exceeded the sum of 1979 to 1990, with investments in 139 countries and regions, mainly in Australia, Canada and the United States. Since 2003, China's OFDI has achieved continuous and steady growth. In 2005, the net amount of China's OFDI exceeded 10 billion US dollars for the first time. Since then, the forms and fields of investment have gradually diversified, which indicates that China's OFDI and economic situation have entered a new stage.

Figure 6 shows China's OFDI data from 2007 to 2019. In 2016, China's OFDI reached 14 times that in 2006. Since 2012, China has been among the top three foreign investors in the world, and in 2017 it became the world's second largest foreign investor for the first time. However, in 2017, the scale of China's OFDI showed a downward trend for the first time since 2003, and during 2017-2019, it even fell 19%, 10% and 18% year-on-year respectively for three consecutive years. The reason for this phenomenon is not only the unstable change of international investment environment, but also the Chinese government's regulation of enterprise investment behavior. In fact, China has started to summarize the experience and lessons learned from the explosion of OFDI in the previous years since the end of 2016, strengthened the review of authenticity, compliance and economic rationality of the OFDI project, tried to guide enterprises to make prudent decisions, rationally carry out OFDI and combat the outflow of funds caused by false investment. And this also marks that China's foreign investment in the future will enter a stage of high-quality development.

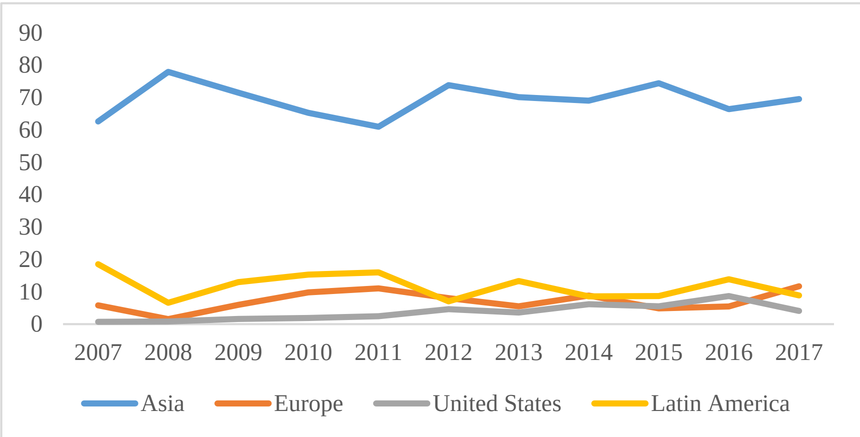
It can be seen from Figure 7 that China's OFDI mainly flows to developing countries, but with the development of the economic level, China's OFDI development strategy is constantly optimized and adjusted. Taking 2014 as an example, China's OFDI investment in Asia and Latin America grew by -2% and -37%, respectively. On the contrary, OFDI investment in Europe and the United States increased by 60% and 72% respectively during the same period, which accounted for 3.8% of the total amount of foreign investment used by the EU in that year.

Figure 6. OFDI from China



Source: author's derivation using China Statistical Yearbook

Figure 7. The Proportion of the Main Sources of OFDI from China



Source: author's derivation using China Statistical Yearbook

1-4. The Development of Science and Technology in China

In 1962, China initially established emerging technology fields and industrial sectors such as semiconductor, computer, electronic technology, automation technology, atomic energy technology and jet technology. By 1970, China's scientific and technological talents had rapidly expanded to more than 290000. During the "Cultural

Revolution", the development of science and technology in China has been greatly impacted and even stagnated to a certain extent. However, the arrival of reform and opening up has brought new vitality to the development of science and technology in China. As the reform and opening up has brought new opportunities to China's higher education, the number of scientific and technological talents in China has increased rapidly. In the meantime, a lot of overseas scientific research talents have returned home and contributed to China's scientific research. As of 2000, the number of scientific research talents in China has exceeded 3 million. Since the beginning of the 21st century, the contribution of tech innovation to the sustainable growth of social economy and the optimization and adjustment of industrial structure has become more and more obvious. Therefore, the Chinese government has formally put forward the development strategy of an innovative country. In 2015, State Council of PRC officially issued "made in China 2025". Since then, China's science and technology development route has further leaped from a big country in science and technology to a powerful country in science and technology in the world. As of 2017, the number of scientific research talents in China has exceeded 6.21 million.

However, the current development of China's science and technology has not yet been able to meet the needs of innovation-driven development and the acceleration of the strategy of building an innovative country. China's science and technology development is still facing several huge challenges: the lack of world-class science and technology experts, the lack of innovative products with international leadership, and the lack of a perfect market-oriented environment to effectively support innovation-driven development. To solve these problems, China still needs to strengthen original innovation, establish a market-based system of combining science and technology with economy, and make up for these deficiencies through continuous learning and development. (Xu Guanhua, 2015)

2. Overview of the Study

In fact, scholars have studied the technology spillover effect of FDI and OFDI. Especially there are a lot of in-depth research results on the FDI spillover effect from different angles and aspects. But even so, the current research is mostly limited to partial analysis in one field. Even the few studies that conducted the two at the same time did not integrate the two organically into an overall system, and the conclusions of the literature are quite different.

Therefore, unifying the FDI technology spillover effect and the OFDI reverse technology spillover effect within a same systematic analysis framework can more accurately, comprehensively and in-depth analyze the FDI technology spillover impact and the OFDI reverse technology spillover impact and its dynamic influence mechanism. It is also possible to have a more comprehensive understanding of the connotation of China's internationalization strategy combining "bringing in" and "going out". According to what mentioned above, this dissertation selects the latest data from the 30 effective provinces in China for the past 10 years after excluding the missing data (Tibet), and conducts an in-depth exploration of the impact of two-way FDI on the development of China's technology in an overall and sub-regional manner. With that in mind, the following will elaborate the research methods and data information, so as to draw empirical results and research conclusions.

II. literature Review

The theoretical research on international technology spillover started from Grossman and Helpman (1991) and Coe and Helpman (1995), but they only focused on the technology spillover effect of international trade on importing countries. The research found that R&D spillover from international trade channels can improve the technology level of importing countries. Then, Lichtenberg and Pottelsberghe (1996) revised the equation on the basis of Coe and Helpman (1995), and further expanded the outflow path of international technology, including FDI and OFDI. The study found that both outward foreign direct investment and international trade have technology spillover effect.

1. FDI and technology spillover

Most of the existing studies have come to the conclusion that FDI has a positive effect on technology spillover. Blomström (1986) took Mexico as an example to demonstrate the positive relationship between foreign investment and productivity efficiency. Kokko et al. (1996) took the manufacturing sector of Uruguay as the research object and concluded that FDI would produce technology and productivity spillover effects. Liu et al. (2000) studied the data of UK industries and concluded that FDI has positive spillover effect. Basing on the provincial panel data of China, Shangguan (2016) confirmed that FDI has a significant positive effect on China's provincial technology progress. Xia and Cheng (2010) used the data of China's industrial enterprises and found that for industrial enterprises, FDI from other regions except Hong Kong, Macao and Taiwan has technology spillover effect in China, and the technology spillover effect is the best when the market share of foreign-funded enterprises is about 55%. Using data from 20 developed OECD countries and 27 LDCs from 1988 to 2001, Alejandro and Wang (2005) found that both FDI and trade served as important channels of international technology diffusion. However, there exist heterogeneous effects of FDI in DCs and LDCs: FDI from DCs to LDCs does not promote technology improvement in host LDCs unless the human capital passes a certain threshold level in LDCs. However, some research results do not support the conclusion that FDI has a positive effect on technology spillover. Simeon and Bernard (2000) studied Czech enterprises and questioned the positive spillover effect of FDI on developing countries. The findings of Damijan and Knell (2005) on two Eastern European transition economies (Estonia and Slovenia) also do not support the positive overflow impact of FDI.

2. OFDI and reverse technology spillover

Kogut & Chang (1991) were the first to study the OFDI inversion overflow impact on the home country. They believed that OFDI by Japanese companies in the United States was mainly concentrated in R&D expenditure-intensive industries, and its main purpose was to absorb and share American technological capabilities. Driffield and Love (2003) confirmed the existence of OFDI's reverse technology spillover effect using panel data from the British manufacturing industry. Zhao et al. (2006) concluded that China's OFDI has a reverse technology spillover effect through national-level data research. By using the Chinese multinational enterprises' data from 2003 to 2013 of provincial level, Li et al. (2016) tested OFDI reverse spillover effect. They found that the OFDI reverse spillover effect on certain province is related to how big the disparity of technology development level between that place and host country.

3.Two-way FDI and technology spillover

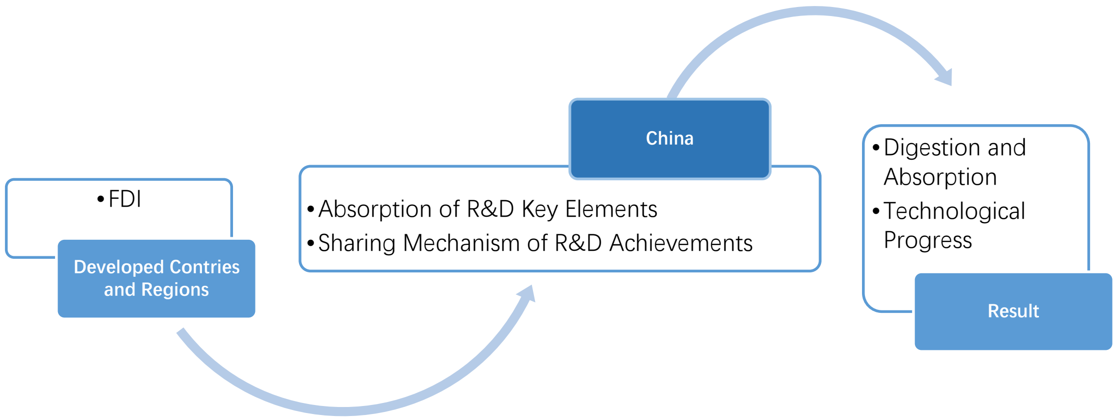
By using a sample of 13 OECD states within the period 1983-1990, Xu and Wang (2000) found evidence that OFDI transmitted foreign technology back to the home country but no evidence that FDI was associated with technology spillover. Applying the data for 21 OECD countries plus Israel during the period from 1981 to 1998, Zhu and Bang (2007) found that although bilateral FDI was positively related to international R&D spillovers, their impact was relatively smaller than bilateral trade. Braconier et al. (2001) used the micro data of Swedish multinational companies to test the technology spillover effects of OFDI and FDI channels, and the results showed that OFDI and technology spillover effects have a significant positive correlation. Further research has found that the more developed the country where foreign direct investment flows, the more intensive the R&D resources, and the more obvious the reverse technology spillover effect. Lin and Liu (2011) used China's overall level data from 1994 to 2008 and found that FDI promotes China's TFP, but the effect is less important than that of domestic research capital; while OFDI have a few negative effects on China's TFP. The reasons for OFDI's research results include the imperfection of OFDI data at that time, the limited scale of China's outbound investment at that time, and the small proportion of outbound investment in technology acquisition. As the research time interval is relatively close, Li (2012) also reached a similar conclusion. However, in follow-up research, Li (2016) used the updated OFDI data combined with rigorous research methods, and reached a more convincing conclusion about OFDI's contribution to China's technological progress. By using the China’s provincial panel data and the approach of IVFE, Chen and Wu (2016) found that it is possible for China to acquire the reverse spillovers from advanced states through OFDI, but not the transition and developing countries. In contrast, China produces positive technology output to them. However, the FDI spillover not only has a feeble effect on the development of China's technology, but also made a hindering effect. Shao (2017) uses panel data at the overall level and finds that developed countries’ FDI to China and China’s OFDI to developed countries hinder China’s technological progress, while FDI and OFDI in other countries or regions during the same period have promoted China’s technological progress.

III. Mechanism Analysis

A country's technology progress mainly benefits from its own independent innovation and technology spillover from abroad. Technology spillovers from abroad are generally obtained through three ways: first, technology spillovers caused by foreign direct investment from other countries; second, reverse technology spillovers caused by OFDI invested into other countries; third, technology spillovers caused by import trade.

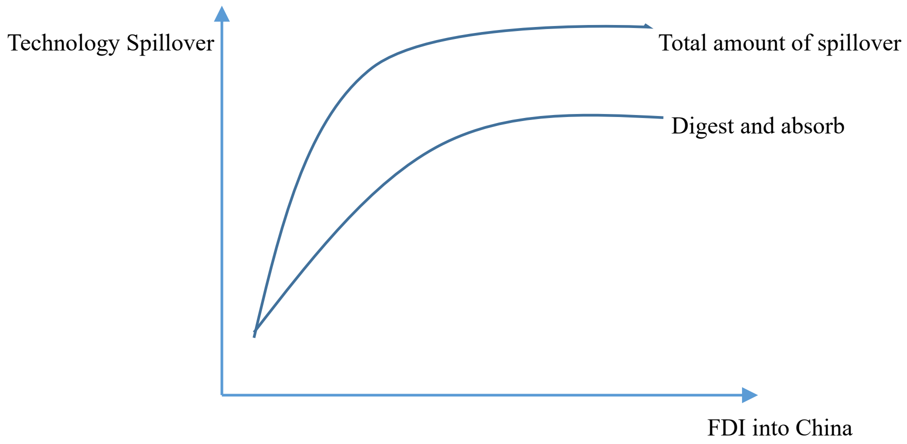
For FDI, most of the FDI received by China comes from developed countries or regions. Therefore, China's ability to absorb advanced science and technology from developed regions is crucial to how much advanced technology China can get from FDI and ultimately promote its own progress. Investment from developed countries mainly causes technology spillover through two ways: the first is the absorption of R&D elements, that is, after the investment and establishment of factories in China by developed countries, local employees continuously absorb R&D elements from developed countries through long-term follow-up and imitation, in-depth learning, resource sharing and personnel exchange, so as to obtain technology progress. The second is the sharing mechanism of R&D achievements, that is, developed countries obtain some R&D achievements through investment in branches in China, which will enhance China's technology progress through demonstration effect in China. Therefore, only with enough digestion and absorption ability, can China fully learn and utilize developed technology, so as to achieve scientific and technological progress (see Figure 8). China obtains the total amount of technology spillovers from developed countries through the above two channels, and then after digesting and absorbing, what it ultimately obtains is the part of effective technology progress (see Figure 9).

Figure 8. The Theoretical Mechanism of FDI to Promote China's Technology



Source: arranged by author

Figure 9. The Effect of Absorptive Capacity on FDI Technology Spillover



Source: arranged by author

Based on the regression method used by Coe & Helpman (1995) and Lichtenberg & Pottelsberghe (1996) to analyze international technology spillovers, assuming that China's total factor productivity not only depends on own research input, but also on external technology spillovers and China's absorptive capacity, the following basic model is derived:

$$TFP = F(S^D, S^F) \quad (1)$$

where TFP is total factor productivity, S^D is domestic R&D capital, S^F is R&D spillover from abroad. As mentioned above, R&D spillovers from foreign countries are generally divided into three parts, so based on the basic model (1), it can be expanded to:

$$S^F = H(S^{FDI}, S^{OFDI}, S^{IM}) \quad (2)$$

where, S^{FDI}, S^{OFDI}, S^{IM} are the foreign R&D capital stocks embodied in the inward FDI, OFDI and import, respectively. From the above theoretical mechanism, we can know that the technology spillover obtained through FDI shall be depended on how much China is able to absorb and digest, that is absorptive capacity. This paper takes human capital stock (H) as a proxy variable for the capacity of China's absorption. Therefore, S^{FDI} in function (2) can be defined as a function of H:

$$S^{FDI} = S^{FDI}(H) \quad (3)$$

After substituting equations (2) and (3) into (1), we can get the final model of the impact of two-way FDI on China's technological progress:

$$TFP = F(S^D, S^{FDI}(H), S^{OFDI}, S^{IM}) \quad (4)$$

IV. Data and Methodology

1. Analytical Method and Data Selection

The statistics of China's provincial OFDI data began in 2003. Many literatures have studied in detail the impact of FDI and OFDI technology spillover on China's technology progress from 2003 to 2013. Therefore, this dissertation chooses the latest panel data of China's 30 provinces (excluding Tibet, Hong Kong, Macao and Taiwan) from 2009 to 2018 to build an econometric model of the impact of two-way FDI on China's scientific and technological progress, and makes an empirical study.[1]

According to the mechanism analysis of Chapter III and the previous literature statement, this paper will use the interaction term of H and S^{FDI} to measure the effect of China's absorptive capacity from FDI spillovers, and use the interaction term of S^{FDI} and S^{OFDI} to examine the systematic impact of FDI spillover and OFDI reverse technology spillover on China's technology progress. Therefore, the final regression equation is as follows:

$$\ln(TECHit) = \alpha_i + \beta 1\ln(S^{D}_{it}) + \beta 2\ln(S^{FDI}_{it}) + \beta 3\ln(S^{OFDI}_{it}) + \beta 4\ln(S^{IM}_{it}) + \beta 5\ln(H_{it}) + \beta 6\ln(S^{FDI}_{it})*\ln(S^{OFDI}_{it}) + \beta 7\ln(S^{FDI}_{it})*\ln(H_{it}) + \mu_t + \varepsilon_{it} \quad (5)$$

where i = 1, 2, … N stands for different provinces, t = 2009, 2010, … T stands for year. $\beta 1 \sim \beta 7$ are coefficients of variables. α_i is individual effects of different provinces, μ_t is time fixed effects, and ε_{it} is a random error term.

[1] See the appendix for a list of 30 provinces.

2. Variables

TECHit is the technology development of province i in year t. This paper uses Malmquist productivity index model (by DEA and DEAP 2.1 software) to estimate the TFP index of 30 provinces. Output: real GDP - Since the data of 2008 is needed to calculate Malmquist index of each province from 2009 to 2018, GDP is deflated by GDP index and converted into constant price based on 2008. The data of GDP and provincial GDP index are from China Statistical Yearbook. Input: (1) K (capital stock of each province) - the calculation method here referred to that of Shan (2008): the depreciation rate is 10.96%. Based on the capital stock in 1978 in Shan (2008), it is converted into the capital stock with 2009 as the new base period. The data source here is basically consistent with Shan (2008). (2) L (the number of workforce in each year), sourcing from China Population and Employment Statistics Yearbook.

$\mathbf{S^{D}_{it}}$ is domestic R&D capital stock of province i in year t。 Based on the method of Griliches (1992), this paper divides the R&D disbursement of each province in 2009 by the depreciation rate and the average growth rate of the next nine years as the R&D capital stock in 2009:

$$S^{D}_{i2009} = R\&D_{i2009} / (\delta + g_i) \qquad (6)$$

where $R\&D_{i2009}$ is the domestic R&D stock in the base year 2009, δ is the depreciation rate of research expenditure, and we generally use 5% referring to Coe and Helpman (1995), g_i is the average logarithmic growth rate of technology research capitals between 2009 and 2018.

Then use the perpetual inventory method to get the domestic research capital stock for the next 9 years:

$S^{D}_{it} = R\&D_{it} + (1-\delta) S^{D}_{i(t-1)}$ (7)

where $R\&D_{it}$ is the real domestic research disbursement of each place in years by 2009 price. The data of domestic R&D expenditure of provinces is from China Statistical Yearbook on Science and Technology and Statistical Communiqué of provinces。

$\mathbf{S^{FDI}_{it}}$ is the foreign technology research capital stock brought by the inward FDI of each place. According to the method of Lichtenberg and Pottelsberghe (1996):

$$S^{FDI}_{it} = \frac{FDIit}{Kwt} * S^{D}_{wt} \quad (8)$$

where FDI_{it} is the total inward FDI of province i in year t，K_{wt} is the sum of the gross fixed capital formation of other countries except China during t period, S^{D}_{wt} is the research stock of the rest of the world in year t, the way to calculate S^{D}_{wt} is the same with that of S^{D}_{it}. The FDI data of each province comes from the China Statistical Yearbook and Statistical Yearbook of each province. The data of K comes from the World Bank, and the total research disbursement data of countries derives from UNESCO.

$\mathbf{S^{OFDI}_{it}}$ is foreign research capital stock reflected in the OFDI of province i in year t. The calculation way is similar with that of S^{FDI}_{it}:

$$S^{OFDI}_{it} = \frac{OFDIit}{Kwt} * S^{D}_{wt} \quad (9)$$

where $OFDI_{it}$ is the outward FDI stock of each place in year t, the data comes from China Statistical Yearbook and provincial statistical yearbooks. Since stocks are able to catch hold of long-term technology overflows, this paper uses OFDI stocks rather than OFDI flows.

$\mathbf{S^{IM}_{it}}$ is foreign research capital stock reflected in the import of province i in year t. In the same way, we use the method of Lichtenberg and pottelsberghe (1996) for calculation:

$$S^{IM}_{it} = \frac{IMit}{GDPwt} * S^{D}_{wt} \qquad (10)$$

where IM_{it} is the flow of import commerce of province i in year t， GDP_{wt} is GDP of the rest of the world in year t。The total import data of each province comes from the China Statistical Yearbook, and the GDP data of countries comes from the World Bank.

$\mathbf{H_{it}}$ is human capital stock of province i in year t. At present, the main method for measuring human capital is the lifetime income framework of Jorgenson and Fraumeni (1989). The main advantage of J-F income framework is that it has sufficient theoretical basis, and the required data and variables are relatively easy to obtain, so J-F income framework has been widely used in the field of human capital measurement. Based on J-F income framework and according to China's national conditions, China Human Capital Index Report has effectively improved the measurement of human capital to ensure the reliability of the estimated data. Therefore, the data of China Human Capital Index Report 2020 is used here.

3. Data Description

It can be found from Table 1 that even in the same country, there are great imparities of technology research expenditure level and technology spillovers from FDI and OFDI among different provinces. Therefore, it is necessary to make a more detailed comparison among these 30 provinces. According to the standard of economic development policy, the NDRC of China divides those provinces into three groups: the eastern region, the central region and the western region. The eastern region refers to the provinces that first implemented the coastal open policy and has a higher level of economic development, the central region refers to the less developed region, and the western region refers to the least developed region[2].

Table 1. Descriptive Statistics of All Provinces

VARIABLES	N	min	max	mean	SD
TECH	300	0.881	1.114	0.997	0.0468
Sd	300	38,339	1.682e+07	3.110e+06	3.398e+06
Sfdi	300	474.0	3.592e+06	837,137	821,036
Sofdi	300	847.4	2.132e+07	1.097e+06	2.525e+06
Sim	300	3,931	1.022e+07	1.314e+06	2.205e+06
H	300	362,904	3.239e+07	8.482e+06	5.996e+06

Source: author's derivation from dataset

From Table 2-Table 4, it can be seen clearly that the economic indicators of the eastern region are far ahead of the central and western regions, while the central region is slightly better than the western region. In order to further see the impact of two-way FDI on China's scientific and technological progress, this paper will make a more detailed regression analysis according to the grouping of eastern, central and western regions on the basis of the whole country.

Table 2. Descriptive Statistics of Eastern Provinces

VARIABLES	N	min	max	mean	SD
TECH	110	0.908	1.114	1.012	0.0404
Sd	110	38,339	1.682e+07	5.788e+06	4.179e+06
Sfdi	110	79,131	3.592e+06	1.495e+06	868,043
Sofdi	110	12,706	2.132e+07	2.470e+06	3.786e+06
Sim	110	86,712	1.022e+07	3.148e+06	2.814e+06
H	110	973,210	3.239e+07	1.180e+07	6.925e+06

Source: author's derivation from dataset

Table 3. Descriptive Statistics of Central Provinces

VARIABLES	N	min	max	mean	SD
TECH	80	0.890	1.106	0.991	0.0464
Sd	80	537,744	5.351e+06	2.205e+06	998,811

[2] The specific grouping list is shown in the appendix.

Sfdi	80	55,647	1.928e+06	770,732	528,716
Sofdi	80	11,275	1.428e+06	362,721	323,347
Sim	80	113,030	751,793	318,861	150,432
H	80	2.556e+06	2.201e+07	8.577e+06	4.533e+06

Source: author's derivation from dataset

Table 4. Descriptive Statistics of Western Provinces

VARIABLES	N	min	max	mean	SD
TECH	110	0.881	1.089	0.987	0.0496
Sd	110	71,521	5.453e+06	1.091e+06	1.234e+06
Sfdi	110	474.0	1.118e+06	227,115	277,311
Sofdi	110	847.4	1.278e+06	258,638	268,535
Sim	110	3,931	923,264	203,296	205,149
H	110	362,904	1.795e+07	5.097e+06	3.621e+06

Source: author's derivation from dataset

4. Hypothesis

According to the previous analysis, there are the following hypotheses for the research results:

Hypothesis 1: The technology spillover brought by two-way FDI will promote China's technology progress, but there may be a certain difference of significance level between them.

Hypothesis 2: The technology spillovers caused by FDI and OFDI mutually positively promote each other's positive influence on China's technology progress.

Hypothesis 3: Due to the large differences in the level and stage of economic development, the regression results of different regions may also have large differences.

V. Empirical Results and Discussion

1. Full Sample Regression Analysis

First of all, according to Hausman test[3], this dissertation selects the time fixed effect model for the whole sample regression. See the regression results in Table 5. From the models (1) ~ (4) of table 5, it can be seen that both domestic research capital stock and import spillover bring prominently active influence on the development of China's technology, while human capital has significant hindrance on technology development. It can be seen from models (1)~(3) that the coefficient of ln_Sfdi is remarkably active without considering the interaction terms, which means that it is possible for China to receive technology spillovers from the foreign technology stock of FDI to promote its own technology progress and the direction of technology spillover is from foreign countries to China; while the coefficient of ln_Sofdi is indistinctively subtractive, which indicates that it is hard to transport reverse spillover to China through OFDI, so as to promote domestic technology progress. On the contrary, it is China that exports technology to foreign countries. But this effect is as weak as negligible among so many factors.

According to the results of model (4), we need to further explore the impact of two-way FDI on China's technological progress. Firstly, the results of two interaction terms show that there is a significant interaction effect between Sfdi and Sofdi, and the technology spillovers through FDI and OFDI offset each other's impact on China's technology progress. However, human capital can promote the impact of technology spillover caused by FDI on China's technology development,

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[3] See Appendix for Hausman test results.

but the effect is very weak. Then we further discuss the net impact of Sfdi and Sofdi on China's technology development, and we take the partial derivative of ln(Sfdi) and ln(Sofdi):

$$α((TFP)/ α(Sfdi) = 0.009-0.003*ln(Sofdi)+0.001*ln(H) \quad (11)$$

If the value is greater than 0, it means that the technology spillover caused by FDI will ultimately put an active influence on China's technology development, otherwise it will have a negative impact. Substituting the mean values of ln(Sofdi) = 12.7 and ln(H) = 15.7 into equation (11), we can get: α((TFP)/ α(Sfdi) = 0.068. It shows that the total amount of technology spillovers China obtains from FDI, through the comprehensive adjustment of human capital and Sofdi, will eventually still be absorbed to promote China's technology progress. We deal with Sofdi in the same way:

$$α((TFP)/ α(Sofdi) = -0.007-0.003*ln(Sfdi) \quad (12)$$

Obviously, the result is a negative number, indicating that, on the overall level, China is currently unable to form an effective reverse technology spillover through OFDI to promote its own technology development, but the increase in FDI will impair the adverse influence of OFDI technological spillover on China's technology progress.

Table 5. Estimate Results with Focus on Overall Sample

	(1) ln_TECH	(2) ln_TECH	(3) ln_TECH	(4) ln_TECH
ln_Sd	0.014^{***}	0.016^{***}	0.016^{***}	0.016^{***}
	(3.68)	(4.35)	(4.25)	(4.22)
ln_Sfdi	0.011^{***}	0.009^{***}	0.008^{***}	0.009^{***}
	(4.25)	(3.52)	(3.16)	(3.54)
ln_Sofdi	-0.002	-0.006^{*}	-0.002	-0.007^{**}
	(-0.71)	(-1.91)	(-0.74)	(-1.99)
ln_Sim	0.011^{***}	0.015^{***}	0.011^{***}	0.015^{***}
	(2.92)	(3.86)	(3.03)	(3.88)
ln_H	-0.059^{***}	-0.063^{***}	-0.063^{***}	-0.063^{***}

	(-10.84)	(-11.77)	(-11.38)	(-11.46)
ln_Sfdi_Sofdi		-0.003***		-0.003***
		(-4.29)		(-3.09)
ln_Sfdi_H			-0.004***	0.001
			(-2.97)	(0.58)
c	0.468***	0.541***	0.535***	0.533***
	(9.04)	(10.19)	(9.58)	(9.67)
N	300	300	300	300
adj. R^2	0.285	0.326	0.304	0.325
p	0.000	0.000	0.000	0.000

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Source: author's derivation from dataset

2. Full Sample Regression on Provincial Differences

As mentioned above, two-way FDI spillover effects can be different among different regions. To observe it more directly, this paper then includes two dummy variables to distinguish three regions, and interact them with lnSfdi and lnSofdi. The result shows in Table 6[4]. From Table 6., it is clear that time fixed effect model behaves better than OLS model. It shows that in both central and western regions FDI technology spillover has less positive effect than eastern region, and western region's reduction is a little more significant, while OFDI reverse technology spillover has more positive effect than eastern region, and western region's surpassing effect is more significant.

Table 6. Estimate Results with Focus on Provincial Differences

	FE-Time	OLS
ln_Sd	0.016***	0.018***
	(4.00)	(4.10)
ln_Sfdi	0.022***	0.020***
	(5.03)	(4.02)
Center*ln_Sfdi	-0.016**	-0.015**
	(-3.19)	(-2.60)
West*ln_Sfdi	-0.016***	-0.016**

4 See Appendix for Hausman test results.

	(-3.66)	(-3.15)
ln_Sofdi	-0.017***	0.007*
	(-4.12)	(2.09)
Center*ln_Sofdi	0.016**	0.015*
	(2.95)	(2.48)
West*ln_Sofdi	0.015***	0.015**
	(3.40)	(3.02)
ln_Sim	0.009*	-0.009
	(2.12)	(-1.95)
ln_H	-0.058***	-0.054***
	(-9.48)	(-7.85)
ln_Sfdi_Sofdi	-0.001	0.001
	(-0.99)	(0.88)
ln_Sfdi_H	-0.002	-0.005
	(-0.62)	(-1.66)
c	0.497***	0.351***
	(8.83)	(5.76)
Adj. R^2	0.407	0.337
N	300.000	300.000

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Source: author's derivation from dataset

3. Comparison of Regression Results by Region

To make sure the impact of FDI and OFDI on China's technology progress in detail, this paper does regression for three regions respectively and compares each impact carefully one by one. First of all, as above, the Hausman test[5] is used to determine the model that should be used in each region for regression. According to this result of Hausman test, this paper uses fixed effect model on eastern and central regions' regression, and conducts random effect model on western region's regression. The regression results of each region are shown in Table 6 ~ Table 8.

[5] See Appendix for Hausman test results.

3-1. Analysis of Regression Results in the Eastern Region

From the models (1) to (4) in Table 6, we can see that in the eastern region, human capital and technology spillovers caused by import trade both play significant positive roles in promoting technology progress in the region, while the stock of domestic R&D capital does not promote technology development, and even has a slight hindrance.

According to models (1) ~ (3) in Table 6, without considering the interaction terms, technology spillovers through FDI get a remarkably active effect on technology development in the eastern region, while OFDI spillover put a prominently inhibitory impact on the technology development of the region.

Therefore, we need to further study the impact of two-way FDI on domestic technology progress in the eastern region through model (4). The coefficients of ln_Sfdi_Sofdi and ln_Sfdi_h are both negative, which indicates that the technology spillover caused by FDI and the technology spillover caused by OFDI, the technology spillover caused by FDI and the human capital restrain each other's impact on domestic technology progress. By using the same calculation method as above, we can get the net effect of international technology spillover by two-way FDI on domestic technology progress in eastern China: α(TFP)/ α(Sfdi)=0.007, α((TFP)/ α(Sofdi)=-0.020. Therefore, the total amount of technology spillovers obtained from FDI in the eastern region, through the comprehensive adjustment of human capital and Sofdi, will eventually be digested and absorbed to promote technology progress in the region; while the technology spillover from OFDI not only does not promote domestic technology progress, but also exports domestic technology to other countries. Limei (2016) has verified the impact of technology spillovers obtained by OFDI from 2003 to 2013 on the technological progress of eastern China, and the results obtained in the paper shows a significant boosting effect. Combined with the regression results of the latest data in this paper, we can speculate that after several years of rapid development, the eastern region has rapidly narrowed the technology gap with developed countries, and has transformed from acquiring reverse technology spillovers by OFDI to exporting technology to other countries through OFDI.

Table 7. Estimate Results with Focus on Eastern Sample

	(1) ln_TECH	(2) ln_TECH	(3) ln_TECH	(4) ln_TECH
ln_Sd	0.018^{***}	0.007	-0.010	-0.010
	(2.75)	(1.06)	(-1.24)	(-1.17)
ln_Sfdi	0.018^{***}	0.132^{***}	0.419^{***}	0.405^{***}
	(2.72)	(3.94)	(5.29)	(4.85)
ln_Sofdi	-0.023^{***}	0.091^{***}	-0.019^{***}	0.004^{**}
	(-3.20)	(2.72)	(-2.92)	(2.50)
ln_Sim	0.011	0.018^{**}	0.026^{***}	0.026^{***}
	(1.58)	(2.58)	(3.73)	(3.72)
ln_H	-0.056^{***}	-0.047^{***}	0.303^{***}	0.271^{***}
	(-6.08)	(-5.15)	(4.25)	(2.99)
ln_Sfdi_Sofdi		-0.008^{***}		-0.002^{*}
		(-3.46)		(-1.57)
ln_Sfdi_H			-0.025^{***}	-0.023^{***}
			(-5.08)	(-3.53)
c	0.546^{***}	-1.089^{**}	-4.995^{***}	-4.807^{***}
	(6.02)	(-2.27)	(-4.56)	(-4.19)
N	110	110	110	110
adj. R^2	0.376	0.441	0.505	0.502
p	0.000	0.000	0.000	0.000

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Source: author's derivation from dataset

3-2. Analysis of Regression Results in the Central Region

According to the models (1) ~ (4) in Table 7, domestic technology investment capital, international technology spillover through import trade and human capital all promote technology progress in the central region, but the former two are not obvious. It can be seen from models (1) ~ (3) that, without considering the interaction terms, technology spillovers through FDI can promote technology progress in the central region, while technology spillovers through OFDI inhibit technology progress in the region, but the effect of both are very weak. Therefore, we need to further study the impact of two-way FDI on domestic technology development in the central region through model (4). The coefficients of ln_Sfdi_Sofdi and ln_Sfdi_h are greater than 0 and less than 0, respectively, and both are significant, indicating that the technology spillover brought by FDI and OFDI mutually promote each other's impact on domestic technology progress, while human capital restrains the influence of technology spillovers brought about by FDI on domestic technology progress.

By using the same calculation method as above, we can get the net effect of international technology spillover by two-way FDI on domestic technology progress in central China: α((TFP)/ α(Sfdi)=-0.008, α((TFP)/ α(Sofdi)=-0.011。

Therefore, in the central region, the international technology spilled through FDI and OFDI cannot promote the technology progress, but has a certain inhibitory effect.

Table 8. Estimate Results with Focus on Central Sample

	(1) ln_TECH	(2) ln_TECH	(3) ln_TECH	(4) ln_TECH
ln_Sd	-0.042	-0.088	-0.023	0.056
	(-0.78)	(-1.38)	(-0.28)	(0.69)
ln_Sfdi	0.020	-0.086	0.110	0.936**
	(0.83)	(-1.01)	(0.38)	(2.44)
ln_Sofdi	-0.018	-0.136	-0.018	-0.490***
	(-1.48)	(-1.49)	(-1.39)	(-3.14)

ln_Sim	-0.011	-0.021	-0.007	0.008
	(-0.63)	(-1.08)	(-0.34)	(0.37)
ln_H	0.175^{**}	0.241^{**}	0.227	1.211^{***}
	(2.18)	(2.55)	(1.25)	(3.30)
ln_Sfdi_Sofdi		0.009		0.036^{***}
		(1.30)		(3.03)
ln_Sfdi_H			-0.006	-0.088^{***}
			(-0.32)	(-2.73)
c	-2.078^{***}	-0.914	-3.187	-13.944^{***}
	(-3.24)	(-0.83)	(-0.89)	(-2.85)
N	80	80	80	80
adj. R^2	0.241	0.249	0.231	0.316
p	0.000	0.000	0.000	0.000

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Source: author's derivation from dataset

3-3. Analysis of Regression Results in the Western Region

According to the models (1) ~ (4) of Table 8, in the western region, domestic R&D investment has a certain promotion effect on domestic technology progress, while human capital and international technology spillover through import trade have a weak inhibitory effect on it. It can be seen from models (1) ~ (3) that, without considering the interaction terms, technology spillovers through FDI get a remarkably inhibitory effect on development of technology in the western region, while technology spillovers through OFDI have a prominently active effect on technology evolution in this region. Therefore, we need to further study the impact of two-way FDI on domestic technology progress in the central region through model (4). The coefficients of ln_Sfdi_Sofdi and ln_Sfdi_h are greater than 0 and less than 0, respectively, indicating that technology spillover caused by FDI and technology spillover caused by OFDI obviously promote each other's influence on domestic technology progress, while human capital can restrain the influence of technology spillover caused by FDI on domestic technology progress to a negligible extent. By using the same calculation method as above, we can get the net effect of international technology spillover by two-way FDI on domestic technology progress in western China: α((TFP)/ α(Sfdi)=-0.016 α((TFP)/ α(Sofdi)=0.078. Therefore, the total amount of technology spillover from FDI in the western region, through the comprehensive offsetting effect of human capital and Sofdi, does not leave any part that promotes the technology progress in the region; while the international technology spillover through OFDI will eventually promote the domestic technology progress in the region, and the promotion effect will be strengthened with the increase of technology spillover through FDI. After obtaining the analysis results of Sofdi in the eastern region, Limei (2016) proposed the hypothesis of the possible impact of Sofdi of both central and western areas in the next few years: in the future, as more provinces shorten the technology gap with developed countries, the central and western provinces will also be able to emulate the progressive technologies from host countries through OFDI. The results of this part verify the hypothesis of Limei (2016).

Table 9. Estimate Results with Focus on Western Sample

	(1) ln_TECH	(2) ln_TECH	(3) ln_TECH	(4) ln_TECH
ln_Sd	0.035*	0.031	0.034	0.035*
	(1.87)	(1.64)	(1.61)	(1.82)
ln_Sfdi	-0.013**	-0.013**	-0.013**	-0.014**
	(-2.20)	(-2.13)	(-2.00)	(-2.14)
ln_Sofdi	0.018***	0.020***	0.018***	0.021***
	(3.20)	(3.51)	(3.09)	(3.68)
ln_Sim	0.003	0.000	0.004	-0.002
	(0.38)	(0.00)	(0.48)	(-0.21)
ln_H	-0.042*	-0.038*	-0.041*	-0.040*
	(-1.91)	(-1.69)	(-1.69)	(-1.84)

ln_Sfdi_Sofdi		0.003		0.005*
		(1.58)		(1.71)
ln_Sfdi_H			0.002	-0.004
			(0.37)	(-0.74)
c	0.053	0.041	0.042	0.061
	(0.31)	(0.24)	(0.23)	(0.36)
N	110	110	110	110
p	0.000	0.000	0.000	0.000

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Source: author's derivation from dataset

3-4. Comparison of Different Regions

The impact of domestic R&D investment, human capital and technology spillover caused by import trade on domestic technology progress is very different in different regions. These differences are closely related to the differences of economic development level, geographical location and human capital quality in these regions.

As mentioned above, the eastern region includes the most economically developed provinces in China, and most of them are close to the coastline, which has inherent advantages in the contact degree of international trade. And whether the famous schools or countless well-known enterprises at home and abroad have attracted a large number of Chinese top talents to study and live here. The economic development level of the central region is lower than that of the eastern region, and the distance to the coastline is also slightly farther. There are many famous universities and international top enterprises here as well, so they also attract excellent talents. The economic development level of the western region is the lowest, and it is also the farthest from the coastline. They are all inland cities. Therefore, their ability to attract top talents is significantly lower than that of the eastern and central regions, and they even need to face the crisis of the exodus of top talents at any time. Therefore, we can clearly see that domestic R&D investment not only does not promote the technology progress in the eastern region, but also has a weak inhibitory effect. It has a very weak promoting effect on the technology progress in the central region, but only maintains a certain degree of promoting effect on the development of technology in the western area. This is for the reason that the highly developed level of science and technology development in the eastern region cannot be sustained by domestic scientific research investment alone, followed by the central region, while the level of science and technology in the western region is relatively backward, so domestic scientific research investment still has some promoting effects. The technology spillover caused by import commerce has a remarkable promoting effect on the technology development in the eastern region, and also has a promoting effect on the technology development in the central area, but it is very weak, while has a weak inhibitory effect on the technological development in the western area. This is owing to the advantages of the coastal areas, which make it very easy for the eastern region to accept the high and new technology from foreign countries, while the western region far away from the coastline can only flinch. Human capital plays a significant part while facilitating the development of technology in the eastern and central regions, but has a weak inhibitory effect on the western region, which is the result of the above differences in the quality of human capital.

Table 10. Estimate Results Comparison of Different Samples

	East	Center	West
ln_Sd	-0.010	0.056	0.035^{*}
	(-1.17)	(0.69)	(1.82)
ln_Sfdi	0.405^{***}	0.936^{**}	-0.014^{**}
	(4.85)	(2.44)	(-2.14)

ln_Sofdi	0.004**	-0.490***	0.021***
	(2.50)	(-3.14)	(3.68)
ln_Sim	0.026***	0.008	-0.002
	(3.72)	(0.37)	(-0.21)
ln_H	0.271***	1.211***	-0.040*
	(2.99)	(3.30)	(-1.84)
ln_Sfdi_Sofdi	-0.002*	0.036***	0.005*
	(-1.57)	(3.03)	(1.71)
ln_Sfdi_H	-0.023***	-0.088***	-0.004
	(-3.53)	(-2.73)	(-0.74)
c	-4.807***	-13.944***	0.061
	(-4.19)	(-2.85)	(0.36)
N	110	80	110
p	0.000	0.000	0.000

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Source: author's derivation from dataset

4. Robustness Test

In order to ensure the dependability of the estimation results, this dissertation will test the robustness through considering the lag effect. International technology spillover through FDI and OFDI channels may have a time lag effect, that is, the lag term of variables Sfdi and Sofdi will have an impact on the current TFP. Therefore, it is necessary to replace the current Sfdi and Sofdi in the model with the corresponding lag 2 term for regression[6]. The IV-2SLS estimation method is used for regression, and the Sfdi and Sofdi with two lag periods are used as the instrumental variables of Sfdi and Sofdi in the current period to effectively reduce the estimation bias caused by the endogeneity of variables Sfdi and Sofdi. The test results are shown in table 10 and table 11: no matter in the robustness test results of the whole sample or the regional samples, the coefficients and significance of

[6] In the research process, the lag of 2, 5 and 7 phases were used to test, and the other test results found that the impact was not significant. In order to simplify the research, only the results of introducing the lag of 2 phases were reported here.

almost every item are consistent with the benchmark model, or even more optimized. Only part of the test results in the central region are slightly in and out of the benchmark model, which may be caused by the small number of individuals in the central region. Therefore, considering the lag effect, the regression results of core variables are robust.

Table 11. Estimate Result of Robustness Test with Focus on Overall Sample

	Original	Lag-2
ln_Sd	0.016***	0.019***
	(4.22)	(4.30)
ln_Sfdi	0.009***	0.012***
	(3.54)	(3.65)
ln_Sofdi	-0.007**	-0.003***
	(-1.99)	(-3.47)
ln_Sim	0.015***	0.023***
	(3.88)	(3.97)
ln_H	-0.063***	-0.071***
	(-11.46)	(-11.20)
ln_Sfdi_Sofdi	-0.003***	-0.003**
	(-3.09)	(-2.03)
ln_Sfdi_H	0.001	-0.001
	(0.58)	(-0.13)
c	0.533***	0.610***
	(9.67)	(9.62)
N	300	240

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Source: author's derivation from dataset

Table 12. Estimate Result of Robustness Test Comparison of Different Regions

	Lag-2	Original	Lag-2	Original	Lag-2	Original
	East	East	Center	Center	West	West
ln_Sfdi	0.716***	0.405***	0.969**	0.936**	-0.008	-0.014**
	(4.82)	(4.85)	(2.10)	(2.44)	(-0.93)	(-2.14)
ln_Sofdi	0.205**	0.004**	-0.948*	-0.490***	0.029***	0.021***

	(2.04)	(2.50)	(-1.79)	(-3.14)	(4.41)	(3.68)
ln_Sfdi_Sofdi	-0.014**	-0.002*	0.224*	0.036***	0.014**	0.005*
	(-2.08)	(-1.57)	(1.79)	(3.03)	(2.50)	(1.71)
ln_Sfdi_H	-0.031***	-0.023***	-0.095*	-0.088***	-0.011	-0.004
	(-3.15)	(-3.53)	(-1.88)	(-2.73)	(-1.38)	(-0.74)
ln_Sd	-0.025**	-0.010	0.076*	0.056	0.037**	0.035*
	(-2.41)	(-1.17)	(1.82)	(0.69)	(2.52)	(1.82)
ln_Sim	0.015	0.026***	0.086	0.008	-0.008	-0.002
	(1.59)	(3.72)	(0.55)	(0.37)	(-0.78)	(-0.21)
ln_H	0.377***	0.271***	1.418***	1.211***	-0.037**	-0.040*
	(2.75)	(2.99)	(3.45)	(3.30)	(-2.38)	(-1.84)
c	-9.096***	-4.807***	-12.474	-13.944***	0.104	0.061
	(-4.29)	(-4.19)	(-1.39)	(-2.85)	(0.76)	(0.36)
N	88	110	64	80	88	110

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Source: author’s derivation from dataset

VI. Conclusion and Limitations

1. Conclusion

Since the reform and opening up, China's international economic strategy has roughly gone through the following stages: first, attracting a large number of FDI through policy dividends and resource advantages. Attracting investment was one of the focuses of Chinese governments at all levels at that time, so the characteristics of this time were dominated by the amount of FDI. With the continuous progress of economy and science and technology of China, policy dividend, demographic dividend and land dividend are less and less, and the traditional development model has been difficult to sustain. Therefore, it is more and more important to adjust the structure of FDI to adapt to the sustainable development of social economy. Therefore, the characteristic of this stage is to ensure the quantity of FDI while paying attention to the quality management of FDI. With the development to the current new stage and the increasing improvement of comprehensive national strength, the strength of Chinese domestic enterprises has become more competitive in the international market. With the positive encouragement of national policies, excellent Chinese enterprises have gone abroad to seek opportunities in the broader international market, optimize the distribution of resources in the global scope, and liberate the constraints of production resources. The typical feature of the current stage is to pay attention to the selection of FDI countries, enterprise nature and industry category, and at the same time, to gradually guide the development of OFDI from quantity oriented to quality oriented. One Belt One Road Initiative since 2013 is one of the typical policies to achieve the ultimate goal of the current stage.

In the past, many literatures have studied and analyzed the relationship between China's FDI and China's technological progress from a detailed and multi angle, and have achieved rich research results. In the last few years, with the unceasing development of China's OFDI, there are many literatures on the technology spillover brought by OFDI as well. However, as mentioned above, China's international economic strategy clearly includes two parts: "bringing in" and "going out". Therefore, only by organically combining the two parts for research and analysis can we more systematically and objectively grasp the implementation effect of China's international economic strategy and see the future trend.

Based on the above problems, this paper makes a both theoretical and empirical study on the effect of two-way FDI on China's scientific and technological progress. In theory, the paper constructs the mechanism that FDI technology spillover is affected by domestic absorptive capacity (human resources) and interacts with reverse technology spillover through OFDI to promote domestic technological progress. Based on the FDI-OFDI organic combination model, empirical research was conducted, and the following conclusions were obtained:

(1) From the overall sample, the technology spillover caused by FDI, domestic R&D investment and technology spillover realized through import trade play significant roles in promoting domestic technological progress, while the technology spillover of OFDI and human capital have an inhibitory effect on domestic technological progress, which shows that on the whole, China cannot promote domestic technological progress through the OFDI reverse spillover, but stays in the stage of exporting technology to underdeveloped areas.

(2) From the analysis results of different regions, the economic development advantages and geographical advantages of the eastern region have been brought

into full play in the impact of two-way FDI on domestic technological progress. Domestic R&D investment has shown insufficient stamina for the development of science and technology in the eastern and central areas, and it can only continue to play a role in the western region. The technology spillover from import trade is completely in accordance with the difference of distance from the coastline, forming a situation of high in the East and low in the West. Human capital not only has no promoting effect on the western region, but also slightly inhibits it. And the fact that the promotion intensity of the central region is slightly stronger than that of the eastern region may be a true reflection of the fact that the national policy has continuously strengthened the importance and development of the central region in recent years. The promotion of technology spillover through FDI to domestic technological progress is weakening from east to west. The eastern region can absorb and use high and new technology to promote its own development, while the central and western regions cannot make profits due to the large technology gaps between them and developed countries. The promotion of reverse technology spillover formed by OFDI to domestic technological progress has weakened from west to East. At present, it is the time for the western region to make all-round profits from it.

(3) In general, due to the influence of the absolute advantage of the eastern region's economic and technological development, plus the country's high standard screening work for FDI, the technology spillover from FDI is generally at a high level. Therefore, on the whole, the technology spillover from FDI promotes China's technological progress. On the other hand, due to the limited development of science and technology in the western region and the limitation of reverse technology spillover from OFDI with lower screening criteria, on the whole,

reverse technology spillover caused by OFDI still cannot promote China's technological progress at present.

2. Implications

As for the "bringing in" policy, while maintaining high standards and strictly screening FDI, China shall attach more importance to the development of own scientific and technological level, especially to the central and western areas. The successful realization of technology spillover effect is conditional, that is, local enterprises must have a certain absorptive capacity to effectively imitate, absorb and digest the imported advanced technology. Therefore, the cultivation of high-quality human capital is the key, which is also the significance of the strategy of “reinvigorating China through human resource development”.

As for the "going out" policy, China should continue to enhance the depth of "going out" and the domestic independent R&D capacity, so as to achieve a significant breakthrough in the national level of technology. China needs to continue to adjust the development mode of OFDI and change to the quality-oriented direction as soon as possible.

3. Limitations

First of all, because of the lack of some data, Tibet is excluded from this sample. If a complete data sample can be obtained, the research results may be more perfect. Second, as mentioned in this paper, most of China's FDI comes from developed countries and regions, and the technology spillovers from these regions need the digestion and absorption of human capital to achieve the purpose of promoting domestic scientific and technological progress. Therefore, further study can screen out the data from major developed countries and regions and do further research. Third, due to the limitation of official data, this paper can only use the flow of FDI for empirical research, and further study can make a more perfect regression analysis after obtaining the stock data of FDI.

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Appendix

Table A-1. The List of Provinces

Beijing	Tianjin	Hebei	Shanxi	Liaoning	Shanghai	Jiangsu
Anhui	Fujian	Zhejiang	Jiangxi	Shandong	Henan	Hubei
Hunan	Guangdong	Hainan	Chongqing	Sichuan	Guizhou	
Yunnan	Gansu	Ningxia	Xinjiang	Jilin	Shaanxi	Qinghai
Guangxi	Inner Mongolia	Heilongjiang				

Source: author's arrangement

Table A-2. Correlation Matrix of All Provinces

	TECH	Sd	Sfdi	Sofdi	Sim	H
TECH	1					
Sd	0.099*	1				
Sfdi	0.125**	0.762***	1			
Sofdi	0.058	0.692***	0.489***	1		
Sim	0.042	0.838***	0.674***	0.682***	1	
H	-0.075	0.797***	0.762***	0.629***	0.673***	1

*** p<0.01, ** p<0.05, * p<0.1

Source: author's derivation from dataset

Table A-3. Correlation Matrix of Eastern Provinces

	TECH	Sd	Sfdi	Sofdi	Sim	H
TECH	1					
Sd	-0.230**	1				
Sfdi	-0.106	0.622***	1			
Sofdi	-0.146	0.635***	0.365***	1		
Sim	-0.301***	0.774***	0.542***	0.596***	1	
H	-0.396***	0.805***	0.600***	0.668***	0.699***	1

*** p<0.01, ** p<0.05, * p<0.1

Source: author's derivation from dataset

Table A-4. Correlation Matrix of Central Provinces

	TECH	Sd	Sfdi	Sofdi	Sim	H
TECH	1					
Sd	0.179	1				

Sfdi	-0.072	0.581***	1			
Sofdi	0.380***	0.677***	0.752***	1		
Sim	0.073	0.647***	0.594***	0.535***	1	
H	-0.218*	0.606***	0.936***	0.636***	0.638***	1

*** p<0.01, ** p<0.05, * p<0.1

Source: author's derivation from dataset

Table A-5. Correlation Matrix of Western Provinces

	TECH	Sd	Sfdi	Sofdi	Sim	H
TECH	1					
Sd	0.180*	1				
Sfdi	0.127	0.831***	1			
Sofdi	0.334***	0.478***	0.339***	1		
Sim	0.217**	0.702***	0.657***	0.613***	1	
H	0.010	0.780***	0.770***	0.573***	0.836***	1

*** p<0.01, ** p<0.05, * p<0.1

Source: author's derivation from dataset

Table A-6. Classification of Provinces by Region

East	Center	West
Beijing	Shanxi	Inner Mongolia
Tianjin	Jilin	Guangxi
Hebei	Anhui	Chongqing
Liaoning	Jiangxi	Sichuan
Shanghai	Henan	Guizhou
Jiangsu	Hubei	Yunnan
Zhejiang	Hubei	Shaanxi
Fujian	Heilongjiang	Gansu
Shandong		Qinghai
Hainan		Ningxia
Guangdong		Xinjiang

Source: author's arrangement

Table A-7. Hausman Test Result with Focus on Overall Sample

	(1)	(2)
VARIABLES	RE	FE
ln_Sd	0.019**	-0.011
	(0.008)	(0.038)
ln_Sfdi	-0.001	-0.006

	(0.004)	(0.005)
ln_Sofdi	0.015***	-0.001
	(0.003)	(0.005)
ln_Sim	-0.001	0.004
	(0.005)	(0.008)
ln_H	-0.040***	0.074
	(0.011)	(0.047)
ln_Sfdi_Sofdi	-0.002*	-0.003**
	(0.001)	(0.002)
ln_Sfdi_H	0.002	0.004
	(0.003)	(0.005)
Constant	0.190*	-0.971***
	(0.098)	(0.284)
Observations	300	300
R-squared		0.238
Hausman		37.44
p-value		9.53e-06

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: author's derivation from dataset

Table A-8. Hausman Test Result with Focus on Provincial Differences

VARIABLES	(1) RE	(2) FE
ln_Sd	0.019**	0.034
	(0.008)	(0.037)
ln_Sfdi	0.012**	0.001
	(0.005)	(0.008)
Center*ln_Sfdi	-0.013**	0.044**
	(0.006)	(0.019)
West*ln_Sfdi	-0.021***	-0.033***
	(0.005)	(0.011)
ln_Sofdi	0.005	-0.005
	(0.004)	(0.006)
Center*ln_Sofdi	0.014**	-0.003
	(0.006)	(0.008)
West*ln_Sofdi	0.021***	0.020***
	(0.005)	(0.006)
ln_Sim	-0.003	0.004

	(0.006)	(0.008)
ln_H	-0.040***	-0.009
	(0.012)	(0.047)
ln_Sfdi_Sofdi	0.002	0.003
	(0.002)	(0.002)
ln_Sfdi_H	-0.005	-0.012**
	(0.004)	(0.005)
Constant	0.171	-0.436
	(0.104)	(0.290)
Observations	300	300
R-squared		0.325
Number of province	30	30
Hausman		49.26
p-value		1.88e-06

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: author's derivation from dataset

Table A-9. Hausman Test Result with Focus on Eastern Sample

VARIABLES	(1) RE	(2) FE
ln_Sd	0.017	0.026
	(0.011)	(0.074)
ln_Sfdi	0.001	-0.009
	(0.007)	(0.008)
ln_Sofdi	0.011***	-0.013*
	(0.004)	(0.007)
ln_Sim	-0.006	-0.038*
	(0.008)	(0.019)
ln_H	-0.057***	0.072
	(0.014)	(0.107)
ln_Sfdi_Sofdi	0.001	0.004
	(0.003)	(0.004)
ln_Sfdi_H	-0.016*	-0.031**
	(0.009)	(0.014)
Constant	0.617***	-0.682
	(0.147)	(0.538)
Observations	110	110

R-squared	0.172
Hausman	29.21
p-value	0.000291

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: author's derivation from dataset

Table A-10. Hausman Test Result with Focus on Central Sample

	(1)	(2)
VARIABLES	RE	FE
ln_Sd	-0.007	0.056
	(0.016)	(0.081)
ln_Sfdi	0.560**	0.936**
	(0.231)	(0.383)
ln_Sofdi	-0.176	-0.490***
	(0.134)	(0.156)
ln_Sim	0.027*	0.008
	(0.015)	(0.021)
ln_H	0.575**	1.211***
	(0.292)	(0.367)
ln_Sfdi_Sofdi	0.016	0.036***
	(0.010)	(0.012)
ln_Sfdi_H	-0.048**	-0.088***
	(0.021)	(0.032)
Constant	-7.116**	-13.944***
	(3.293)	(4.889)
Observations	80	80
R-squared		0.437
Hausman		22.13
p-value		0.00115

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: author's derivation from dataset

Table A-11. Hausman Test Result with Focus on Western Sample

	(1)	(2)
VARIABLES	RE	FE

ln_Sd	0.035*	0.091
	(0.019)	(0.086)
ln_Sfdi	-0.014**	-0.027***
	(0.007)	(0.008)
ln_Sofdi	0.021***	0.023**
	(0.006)	(0.010)
ln_Sim	-0.002	0.006
	(0.009)	(0.011)
ln_H	-0.040*	-0.115
	(0.022)	(0.097)
ln_Sfdi_Sofdi	0.005*	0.005
	(0.003)	(0.003)
ln_Sfdi_H	-0.004	-0.011
	(0.006)	(0.008)
Constant	0.061	0.490
	(0.169)	(0.499)
Observations	110	110
R-squared		0.435
Hausman		15.39
p-value		0.0519

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: author’s derivation from dataset

국문초록

양방향 외국인직접투자가 중국의 국내 과학기술 발전에 어떤 영향을 미치는가?

본 논문은 FDI 와 OFDI 의 유기적 결합 모델을 사용하여 중국의 "Bringing in"과 "going out" 전략에 대한 체계적인 연구를 보완하고 양방향 FDI 가 중국의 과학 기술 발전에 미치는 전반적인 영향을 평가합니다. 이를 바탕으로 본 논문은 계량 경제 분석 수행을 위해 2009 년부터 2018 년까지 중국의 지방 패널 데이터를 사용하고, 견고성 테스트를 위해 IV-2SLS 회귀 방법을 결합하고, 국가 수준에서의 지역별 비교 연구를 각각 수행하여 티베트를 제외한 중국 30 개성의 과학 기술 발전에 양방향 FDI 가 미치는 영향에 대해 객관적으로 평가합니다.

결과는 다음과 같습니다.

1. 전반적으로 FDI 로 인한 기술 유출은 국내 기술 진보에 큰 영향을 미치지만 OFDI 의 역 기술 유출 강화로 인해 이러한 추진 효과는 약화될 것으로 보입니다. OFDI 의 역 기술 유출은 국내 기술 발전을 억제할 수 있지만 FDI 유출의 증가는 억제 효과를 약화시킬 것입니다. 이는 전체적으로 중국이 OFDI 의 역 기술 유출로 국내 기술 발전을 추진할 수 없지만 저개발 지역에 기술을 수출하는 단계에 머물고 있음을 보여줍니다.

2. 3 개 지역의 회귀 결과에서 동부 지역의 경제 발전과 지리적 이점이 매우 두드러집니다. FDI 를 통한 국내 기술 발전으로의 기술 유출 촉진은 동쪽에서 서쪽으로 약화되고 있습니다. 동부 지역은 첨단 기술과 신기술을 흡수하여 자체 개발을 촉진할 수 있는 반면 중서부 지역은 과학 기술 수준에서 자국과 선진국 간의 큰 차이로 인해 수익을 창출 할 수 없습니다. OFDI 에 의해 형성된 기술 유출은 서방에서 동양으로의 국내 기술 발전 촉진을 약화시켰습니다. 현재는 서부 지역이 이로부터 전반적인 이익을 얻을 때입니다.

3. 회귀 분석 결과가 시사하는 바는 중국이 "bringing in"과 "going out" 국제 전략을 동시에 개발할 때, FDI 프로젝트의 높은 심사 기준을 유지하면서 OFDI 프로젝트 심사 기준의 향상 및 최적화를 가속화할

것이라는 것입니다. 동시에 국내 R & D 투자와 인적 자원의 품질 최적화는 중국, 특히 중서부 지역의 미래 과학 기술 발전에 중요한 역할을 합니다.

주요어: 양방향 FDI, 패널 데이터 분석, 기술 유출, 지역 분석
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