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Does the Impact of China's Outward Foreign Direct Investment on Reverse Green Technology Process Differ across Countries?

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Abstract: The reverse technology spillover effect of Outward Foreign Direct Investment (OFDI) has been widely discussed. In the context of pursuing green growth, a few scholars began to study the impact of OFDI on home country green technological progress or green total factor productivity. However, few of these papers have made a thorough analysis of how OFDI affects the home country's green technological progress, and have not considered the impact of different types of OFDI on green technological progress. This paper extends the basic analysis framework of technological progress to green technological progress, and discusses for the first time the ways for China to invest in developed and developing countries to achieve green technological progress. Specifically, this paper combines the global Malmquist productivity concept with the directional distance function to construct the global Malmquist Luenberger (GML) index to describe green technological progress of China's provinces, and uses panel data model from 2003 to 2016 to study the impact of China's investment in different types of countries. The results show that: (1) China's investment in developed countries can bring reverse green technology spillovers and promote China's green technology progress. But this is also affected by China's domestic human capital stock, the increase in human capital stock is conducive to the absorption of green technology. (2) OFDI flows to transition or developing countries have failed to bring about green technological progress, but domestic R&D capital stock can produce a control response. (3) Environmental regulation, import trade and domestic R&D capital stock can bring positive effects on green technology progress, while foreign direct investment, fiscal decentralization and economic growth hinder green technology progress. (4) There is regional heterogeneity in the impact of OFDI with different directions on green technological progress. Because of environmental regulation and economic development, the eastern region of China is easier to obtain reverse green technology progress than the central and western regions in the process of OFDI.

Keywords: OFDI; green technology progress; environmental regulation; GML

1. Introduction

Since reform and opening up, China's economy has maintained rapid growth for a long time. Even under the global economic downturn, China's economy is still outstanding. However, high economic growth is achieved by high energy consumption and high pollution. Despite the unprecedented strengthening of China's laws and policies in the field of environmental protection in recent years, the situation of resource shortage and environmental degradation is still grim. According to China's Eco-environmental Status bulletin, 239 of the 338 cities in China exceeded the national standard in air quality in 2017, accounting for 70.7%. At present, a question of great concern is that: If China's environmental protection and economic growth can replaces each other? The

innovative empirical study of Grossman and Krueger [1] found that the relationship between pollution intensity and per capita income was an inverted U-shaped curve. This hypothesis of Environmental Lorenz curve (EKC) was subsequently verified by a large number of empirical studies in China [2–4]. EKC means that when economic growth reaches a certain level, the relationship between environmental protection and economic growth may be positive, so economic growth is a prerequisite for improving environmental quality. Generally speaking, there are two direct reasons for the decline of environmental pollution with economic growth: firstly, the transfer of pollution-intensive industries from developed countries to developing countries can produce Pollution Haven Effect [5] in developing countries, while the developed countries reduce pollution through structural effects; Secondly, the green technology progress effect of energy conservation and cleaner production. Both of these are due to people's increasing environmental quality requirements as their income levels rise, but waiting for the Kuznets turning point has been unable to cope with the increasing environmental pressure [6]. As a big developing country, China needs to take the progress of green technology as the main channel of sustainable development. China has a relatively complete industrial system, and pollution intensive enterprises will continue to exist in the future. At the same time, the bias technological progress has a profound impact on the environmental results of economic activities, which are constrained and motivated by economic activities and environmental regulation. New technologies may increase pollution, or reduce and replace pollution activities. This bias is inherent in the process of economic growth, which affects the cost and benefits of environmental regulation policies [7]. Therefore, this paper focuses on green technology progress.

There are two ways to promote green technology progress in a country: domestic R&D activities and foreign R&D spillovers. Outward Foreign Direct Investment (OFDI) as an important channel to obtain foreign green technology spillovers has also received attention [8,9]. The World Investment Report issued by United Nations Conference on Trade and Development (UNCTAD) in 2005 pointed out that R&D activities caused by OFDI have a positive impact on enhancing the technological innovation capability of home countries. China's OFDI flows exceeded Foreign Direct Investment (FDI) in 2014, and OFDI stock exceeded FDI in 2016. In 2016, China's OFDI stock in developing economies was 84.2%, OFDI stock in developed economies was 14.1%, and another 1.7% was in transition economies. It can be seen that most of China's OFDI flows to transformation and developing countries. There are fundamental differences in R&D capital and technology level between developed and developing countries, so the reverse green technology spillover effect of the two kinds of countries to China can not be lump together. However, the existing studies on OFDI reverse green technology spillover effect tend to regard investment in different countries as the same [9], or only explore the technology spillover effect of investment in different countries without considering its environmental bias [10]. Therefore, in order to make up for the shortcomings of existing research, this paper establishes an analytical framework of the impact of China's investment in different countries on green technology progress, and conducts theoretical and empirical research on this.

The rest of this article is structured as follows. Section 2 reviews the existing literature, mainly including the impact of OFDI on the environment and technological progress, as well as the specific measurement of green technological progress. Section 3 analyzes the impact mechanism of OFDI on green technology progress, and analyzes the influencing factors of green technology progress by expanding the existing analysis framework. Section 4 is Research methods and variable descriptions, which uses the slacks-based measure (SMB) model with unexpected output and global Malmquist Luenberger (GML) index to solve the green technology progress index, and constructs the corresponding panel data model based on the third part of the analysis. Then construct the various variables. Section 5 is the empirical results analysis, by using the panel data of 29 provinces in China to analyze the impact of China's investment in different countries on green technology progress. Section 6 is conclusions and policy recommendations.

2. Literature Review

At present, there are relatively few literatures that systematically study the impact of OFDI on green technological progress. The impact of OFDI on home country's green technological progress involves the impact of OFDI on technological progress and environment as well as the measurement of green technological progress. This paper is particularly related to three strands of literature.

OFDI and technological progress. Lichtenberg [11] was the first to carry out the theoretical study of OFDI international reverse technology spillover under the framework of Grossman and Helpman [12]. He added OFDI and FDI into the analytical framework, expanded the channels of international technology spillover, and found that OFDI and international trade have the same technology spillover effect. Since then, a large number of studies have examined this issue from different perspectives in different countries and drawn different conclusions. One view is that OFDI can generate positive reverse technological spillovers and promote technological progress in home country. Braconier [13] tested the technology spillover effect of OFDI and FDI by using Swedish multinational enterprise micro-data. The results showed that there is a significant positive correlation between OFDI and technology spillover effect. Further study showed that the reverse technology spillover effect is also positively correlated with the developed degree of investment countries and R&D resource intensity. Vahter and Masso [14] used Estonia company panel data for research and found that there is a positive correlation between OFDI and home country productivity. Driffield et al. [15] examined the reverse technology spillover effect of UK OFDI from 1978 to 1994 and found that investing in R&D intensive countries is benefit to increasing domestic productivity. Branstetter [16] studied the reverse technology spillover effect of Japanese firms'investment in the United States through company-level data. The results showed that OFDI in the United States significantly improves the technological innovation capability of Japanese firms. Similar conclusions were drawn by Branstetter [16] and Zhao et al. [17]. On the contrary, another view is that OFDI not only can not bring technical progress to the home country, but also inhibits the improvement of the total factor productivity level of the home country. Bitzer and Kerekes [18] based on industrial data from OECD countries showed that non-Western seven countries' OFDI has a significant negative impact on home country productivity. Bitzer and Görg [19] found that OFDI not only has a significant inhibitory effect on total factor productivity (TFP) in OECD countries, but also has obvious country differences. In addition, some scholars believe that the relationship between OFDI and the total factor productivity of the home country is not statistically significant. In addition, some scholars believed that the relationship between OFDI and the total factor productivity of the home country is not statistically significant. The study of Lee [20] showed that the reverse technology spillover of OFDI in OECD countries is not obvious. Bertrand and Betschinger [21] has also verified the above conclusions through the study of Russian multinationals.

OFDI and environmental efficiency. As noted by Zhou and Pang [22] OFDI has great uncertainty and heterogeneity on the environmental effects in China. The technological and structural effects of OFDI will have a positive and negative impact on the environment of the home country. Xu and Wang Ying [23] believed that every 1% increase in China's OFDI will increase China's CO_2 emissions by 0.5009%.

In recent years, some scholars have begun to consider the impact of OFDI on green total factor productivity (GTFP). Based on the Malmquist Luenberger productivity index of directional distance function, Wang et al. [8] recalculated the green total factor productivity of 29 provinces in China from 2004 to 2013, and found that OFDI significantly improves the green TFP level of the whole and Eastern China. Yang et al. [9] used threshold regression technique to investigate whether OFDI affects green total factor productivity. He found that the effect of OFDI on green total factor productivity showed a positive marginal efficiency increase, and the growth effect of green productivity in China has regional differences. However, the above studies do not discuss whether investment in different countries will have different impacts on green total factor productivity, and the relevant studies are limited to the whole. In fact, investment in different types of countries produces reverse technological advances in different channels and sizes [10]. When different OFDI is regarded as homogeneous, the

total effect can be obtained from the analysis. But it is impossible to make specific analysis when making policies.

In the measurement of green technology progress. There are three representative methods to measure the bias of technological progress. The first method is comparing the rate of change of marginal output between different factors to measure the bias of technological progress which is based on the CES production function [24]. The key of this method is the calculation of factor substitution elasticity. Leon et al. [25] found that the standardized supply-side system method proposed by Klump et al. [26] is relatively effective by building simultaneous equations including standardized CES production functions and factor demand equations to estimate factor substitution elasticity. However, the dependence of this method on the form of production function makes it still have the risk of systematic deviation, and can not take into account the impact of macroeconomic shocks, factor prices and other factors on the bias of technological progress [27]. The second method is based on the super logarithmic cost model constructed by Binswanger [28] to estimate the bias of technological progress. However, this method also needs to strictly restrict the technological progress, and the data of required factor prices, costs and others are often difficult to obtain, which limits the method's application. The third method is to use the DEA-Malmquist index proposed by Fare et al. [29] to measure the total factor productivity, and then decompose the total factor productivity into green technology progress index [24]. Because this method does not need to consider the concrete form of production function, it reduces the deviation caused by inaccurate model setting to a certain extent, so it has been widely used. Since then, many scholars have developed a variety of extended DEA models to make them more suitable for exponential construction and calculation in different situations. This paper also selects this method to measure the green technological progress index of various provinces in China.

Based on this, this paper combines technological progress with environmental efficiency. The main contribution of this paper is to study the reverse green technological progress produced by OFDI investment in different countries under the unified framework for the first time. Specifically, this paper analyzes the impact of OFDI investment in different countries on green technology progress based on the theoretical mechanism and extended basic analysis framework. And then combines the global Malmquist productivity concept with the directional distance function (which is used in slacks-based measure model) to construct the global Malmquist Luenberger (GML) index to describe the green technological progress of China's provinces. Finally, the panel data model is used for empirical analysis.

3. Reverse Technology Spillover Mechanism and Analysis Framework of OFDI

Developed countries are the birthplace of global technological innovation. Compared with most transitional and developing countries, developed countries have significant advantages in R&D investment, intellectual capital stock and technological progress. Therefore, the technology spillover effect of investment in developed countries is different from that of investment in transition and developing countries. Each country has different investment purposes, such as: seeking technical cooperation from developed countries; expanding markets to developing countries; and transferring investment to developing countries because of environmental regulation of the home country. These differences will also have an impact on the domestic environmental efficiency. Therefore, on the basis of previous studies, this paper puts forward the mechanism of China's investment in different countries to promote the home country's green technology progress, and makes a simple extension of OFDI reverse technology spillover model.

3.1. The Impact Mechanism of China's OFDI on Green Technology Progress in Different Countries

China's investment in developed countries mainly obtains reverse green technology spillover through the following two ways. Firstly, R&D elements absorption mechanism. Developed countries have higher environmental thresholds than developing countries. Chinese enterprises can embed high-tech cluster network in the process of investment in developed countries. They can continuously absorb the R&D elements of the host country through imitation, resource sharing and personnel

communication. In this process, they can acquire the most advanced knowledge and grasp the frontier technology. Secondly, R&D results feedback mechanism. Overseas subsidiaries deliver their green technology, knowledge, information and research results to their parent companies. The parent companies digest, absorb and utilize the new technology, and ultimately promotes the home country's green technology progress through spillovers and demonstration effects [8,10]. The study shows that the digestive and absorptive capacity of the home country is the prerequisite for OFDI to obtain technology spillover [9]. Only if the home country has a certain digestive and absorptive capacity, can it fully learn, utilize and transform new knowledge and technology, and transform into real productive forces. Therefore, the reverse green technology spillover obtained by Chinese multinational corporations from the above two channels will eventually get a part of the total spillover through home country digestion and absorption.

The green technology progress in transitional countries is roughly equivalent to that in China, while that in many developing countries is generally lower than that in China. Therefore, the mechanism of green technology spillover from China's investment in transition and developing countries is quite different from that of OFDI in developed countries, that is, China seldom gets reverse green technology spillover from transition and developing countries. On the contrary, when China invests directly in the transition and developing countries, some of China's applicable technologies will spread to these countries, producing positive green technology exports to these countries. But China can still get some green technology recovery from the transformation and investment of developing countries through the following two aspects: China can expand the market scale and form scale economies. China's investment in transition and developing countries is mostly targeted at the purpose of market expansion, which is conducive to generating economies of scale, thereby increasing corporate profits and returning profits to their home countries for R&D and innovation. This has a cost-sharing effect on parent companies. In addition, in pursuit of cheap resources and lower enterprise costs, China invests in many less developed countries such as Africa and South America [30] and establishes production bases in these countries. Which can reduce the production costs of transnational corporations, increases enterprise profits, and also has a cost-sharing effect on parent companies. When China invests in the transition and developing countries, the direction of technology spillover is China's flow to the transition and developing countries. However, through the above two ways, China's total positive green technology exports to the transition and developing countries can be recovered and hedged to a certain extent.

3.2. The Basic Model of OFDI Reverse Green Technology Spillover in China

Similar to Coe and Helpman [31] in their analysis of international reverse technology spillovers, it is assumed that a country's technological progress is related not only to domestic R&D activities, but also to international R&D spillovers. Because environmental efficiency is related to environmental regulation, this paper assumes that environmental regulation will also affect the progress of green technology. Therefore, the following basic models are obtained:

$$GTFP = F\left(S^{D}, S^{F}, R\right) \tag{1}$$

$GTFP$ is green technology progress, S^{D} and S^{F} are domestic R&D capital and foreign R&D spillovers respectively, R is environmental regulation. Environmental regulation plays a guiding role in green technology spillovers both at home and abroad. Foreign R&D spillovers are generally obtained through the following ways: reverse green technology spillovers in the process of OFDI; foreign direct investment gets green technology spillovers; and import trade's green technology spillovers. Therefore, this paper further defines S^{F} as follows:

$$S^{F} = G\left(S^{OFDI}, S^{FDI}, S^{IM}\right) \tag{2}$$

where S^{OFDI}, S^{FDI} and S^{IM} represent foreign R&D spillovers from OFDI, FDI and import trade respectively. Further, according to the analysis of the mechanism mentioned above, S^{OFDI} can be

divided into green technology spillover S^{OFDI1} from developed countries and green technology spillover S^{OFDI2} from developing countries. Therefore, the Formula (2) is further defined as:

$$S^F = G\left(S^{OFDI1}, S^{OFDI2}, S^{FDI}, S^{IM}\right) \tag{3}$$

The green technology spillover from OFDI in developed countries must be based on the absorptive capacity of the home country. This paper takes the stock of human capital H as the proxy variable of the absorptive capacity of the home country. That is: $S^{OFDI1} = S^{OFDI1}(H)$. Green technology spillovers from OFDI in transition and developing countries are mainly obtained through home country R&D cost allocation, $S^{OFDI2} = S^{OFDI2}(S^D)$. Therefore, the final OFDI reverse green technology spillover model in China is as follows:

$$GTFP = F\left(S^D, S^{OFDI1}(H), S^{OFDI2}(S^D), S^{FDI}, S^{IM}, R\right) \tag{4}$$

4. Research Methods and Variable Descriptions

4.1. Measurement of GTFP

In order to include environmental factors in the measurement of total factor productivity, Chung et al. [32] introduced a directional distance function which can consider both expected and unexpected outputs. Based on this function, a ratio-based Malmquist Luenberger productivity index was constructed. This study allows the measurement of green total factor productivity to be widely used without knowing the price information and assuming the form of production function. Considering the non-zero relaxation of input or output, the traditional directional distance function underestimates the inefficiency level of the evaluation object. Tone [33], Fukuyama and Weber [34] developed slack-based measurement (SBM) based on relaxation and adopted Luenberger index with additive structure proposed by Chambers et al. [35]. However, the use of directional distance function to measure the change of TFP is based on a relative concept, and previous studies have constructed a corresponding technological frontier in each phase, which makes it difficult to measure the change of technological inefficiency (especially long-term changes). To overcome this problem, this paper uses the research method of Oh [36] to construct the global Malmquist Luenberger (GML) index by combining the global Malmquist productivity concept with the directional distance function. This method constructs a global production frontier by detecting the production technology in the whole time period, thus avoiding the "technical backward" situation, and avoiding the problem of traditional ML exponential linear programming without solution. The specific form of SBM directional distance function is as follows:

$$S^{G,k'}\left(x^{t,k'}, y^{t,k'}, b^{t,k'}\right) = \max_{s_x, s_y, s_b}\left[\frac{1}{2N}\sum_{n=1}^{N}\frac{s_{n,x}^{G,k'}}{x_n^{t,k'}} + \frac{1}{M+I}\left(\sum_{m=1}^{M}\frac{s_{m,y}^{G,k'}}{y_m^{t,k'}} + \sum_{i=1}^{I}\frac{s_{i,b}^{G,k'}}{b_i^{t,k'}}\right)\right] \tag{5}$$

$$s.t. \sum_{t=1}^{T}\sum_{k=1}^{K} z^{t,k} x_n^{t,k} + S_{n,x}^{G,k'} = x_n^{t,k'} \quad \sum_{t=1}^{T}\sum_{k=1}^{K} z^{t,k} y_m^{t,k} - S_{m,y}^{G,k'} = y_m^{t,k'} \quad \sum_{t=1}^{T}\sum_{k=1}^{K} z^{t,k} b_i^{t,k} + S_{i,b}^{G,k'} = b_i^{t,k'}$$

$$z^{t,k} \geq 0; \quad S_{n,x}^{G,k'} \geq 0; \quad S_{m,y}^{G,k'} \geq 0; \quad S_{i,b}^{G,k'} \geq 0; \quad n = 1, \cdots, N; \quad m = 1, \cdots, M; \quad i = 1, \cdots, I$$

Among them, $S^{G,k'}$ denotes the distance between the decision-making unit and the "global" production frontier, and its value of 0 indicates that the decision-making unit is in the production frontier, and there is no technical inefficiency. $S_{n,x}^{G,k'}$, $S_{m,y}^{G,k'}$ and $S_{i,b}^{G,k'}$ represent the relaxation slack vectors of the factor input, the expected output and the unexpected output respectively. The GML index for measuring the non efficiency change of technology is as follows:

$$GML_t^{t+1} = S^{G,k'}(t) - S^{G,k'}(t+1) \tag{6}$$

Although previous studies have usually decomposed TFP changes into technical changes and efficiency changes based on their measurement principles. But similar to Jing and Zhang [6], Zhu and Ye [37], this paper argues that technological progress should still be measured by the sum of technological change and efficiency change.

4.2. Panel Data Model for the Impact of OFDI on Green Technology Progress

To study the impact of China's investment in different countries on green technology progress under a unified framework. According to the third part of the basic model of OFDI reverse green technology spillovers, this paper uses the interaction terms of H and $OFDI^1$ to measure China's absorptive capacity of reverse green technology spillovers in the process of investment in developed countries. The main purpose of China's investment in transition and developing countries is to gain profits by expanding the market and acquiring cheap resources. The profits gained can be invested in the R&D of the home company, which can play a certain role in sharing the R&D cost of the home company. But this process is mainly reflected by influencing the R&D capital of the home country. Therefore, we use the interaction terms of S^D and S^{OFDI2} to measure the role of China's R&D cost allocation in the process of investment in transition and developing countries which it is similar to the research of Chen and Wu [10]. Finally, the regression equation of green technology progress of China's OFDI is set to:

$$\ln(\text{GTFP}_{it}) = \alpha_i + \beta_1 \ln(S_{it}^D) + \beta_2 \ln(S_{it}^{OFDI1}) + \beta_3 \ln(S_{it}^{OFDI2}) + \beta_4 \ln(S_{it}^{FDI}) + \beta_5 \ln(R_{it})$$
$$+ \beta_6 \ln(S_{it}^{IM}) + \beta_7 \ln(H_{it})\ln(S_{it}^{OFDI1}) + \beta_8 \ln(S_{it}^D)\ln(S_{it}^{OFDI2}) + \phi\ln(X_{it}) + \varepsilon_{it} \tag{7}$$

The definition of related variables is as mentioned above. X_{it} is the control variable vector, including the economic growth and fiscal decentralization of province i in the t period. α_i, β_i, ϕ are the corresponding coefficients or coefficient vectors of each variable, and ε_{it} is random disturbance term vector.

4.3. Variable Description

The OFDI statistics of China's provinces mainly began in 2003, so this paper selects 29 provinces in China from 2003 to 2016 (due to the lack of statistical data, excluding Tibet and Chongqing), constructs the measurement model of OFDI on the home country's green technological progress, and carries out empirical research. On the basis of comprehensive consideration of the availability of China's OFDI, FDI, total imports and R&D expenditures, this paper selects nine developed economies and 18 developing and transition economies according to the economic division criteria of the United Nations Conference on Trade and Development. Developed countries include: the United States, Australia, the Netherlands, the United Kingdom, Canada, Germany, France, Sweden, Japan. Developing and transition economies include Russia, Indonesia, Mexico, South Africa, South Korea, Kazakhstan, Vietnam, Pakistan, Zambia, Thailand, Singapore, Turkey, Mongolia, Malaysia, Iran, India, Argentina and Brazil. China has sustained investment in these countries, and its data can be obtained (Which is mentioned in variable construction). By the end of 2016, China's OFDI stock to the above 27 countries accounted for 74.48% of the total OFDI stock, of which 9 developed countries accounted for 44.71%, 18 transition and developing countries accounted for 29.77% of the total OFDI stock.

In this paper, we use SBM model and GML index to calculate GTFP. Input variables: the same as most studies, choose labor, capital and energy consumption as input variables. Labor input is expressed by the sum of the end employment figures in various industries. Capital investment is obtained according to the calculation method of Zhu and Ye [37]. Energy input is expressed in terms of total energy consumption in each province. Expected output variables: the actual GDP of each province is used. Unexpected outputs include wastewater, exhaust gas and solid waste, which are measured by provincial industrial wastewater discharge, industrial waste gas discharge and industrial solid waste production respectively. The above data are from the official statistical yearbook of China.

S_{it}^{D} represents the domestic R&D capital stock in the t period of i province. Taking 2003 as the base period, the calculating formula is $S_{i2003}^{D} = R\&D_{i2003}/(\delta + g_i)$, in which $R\&D_{i2003}$ is the R&D expenditure of province i in 2003, δ is the depreciation rate 5%, g_i is the average logarithmic growth rate of R&D expenditure of province i from 2003 to 2012. The R&D capital stock in the last 12 years is calculated according to the perpetual inventory method. Provincial R&D expenditure data comes from the "China Statistical Yearbook of Science and Technology" and the consumer price index comes from the "China Statistical Yearbook".

S_{it}^{OFDI1} represents the foreign R&D capital stock acquired by i Province during the t period through investment in developed countries. According to Lichtenberg's [38] method, this paper firstly calculates the foreign R&D capital stock obtained from OFDI to developed countries at the national level in the t period: $S_t^{OFDI1} = \sum_{j=1}^{9}(OFDI/GDP_{jt})S_{jt}^{D}$, of which $j = 1, \cdots, 9$ is the sample of nine developed countries selected in this paper, $OFDI_{jt}$ is the OFDI stock of China in the t period received from country j and GDP_{jt} is the GDP of the j country in the t period. For the domestic R&D capital stock of country j in the t period is S_{jt}^{D}, its calculation method is the same as that of domestic R&D capital stock (S_{it}^{D}). Secondly, to calculate the foreign R&D capital stock obtained by each province by investing in developed countries: $S_{it}^{OFDI1} = \left(\dfrac{OFDI_{it}*\varphi_i}{OFDI_i}\right)S_t^{OFDI1}$, of which $OFDI_{it}$ is the OFDI stock of province i in the t period. Because the data of provincial investments in developed countries are not available, this paper calculates the proportion (φ_i) of provincial investments in developed countries by the end of 2013 according to China's "List of Overseas Investment Enterprises (Institutions)". Using $OFDI_{it}*\varphi_i$ approximation to calculate the investment stock of i province in developed countries in t period, $OFDI1_t$ is the stock of the national investment in the developed countries in the period of t. The R&D expenditure of each country comes from UNESCO database and OECD database. Some missing data are estimated by the average value of last year or the ratio of R&D expenditure to GDP. The GDP and consumer price index of each country comes from the World Bank database. The data of foreign direct investment in China and other provinces are derived from China's foreign direct investment statistics bulletin.

S_{it}^{OFDI2} represents the foreign R&D capital stock acquired by i Province during the t period through investment in transition and developing countries. The calculation method is similar to S_{it}^{OFDI1}. Firstly, we calculate the R&D capital stock of OFDI in transition and developing countries: $S_t^{OFDI2} = \sum_{j=1}^{18}(OFDI_{jt}/GDP_{jt})S_{jt}^{D}$, in which $j = 1, 2, \cdots, 18$ is the sample of 18 transition and developing countries. Then we get the foreign R&D capital stock obtained by the provinces through investment in the transition and developing countries: $S_{it}^{OFDI2} = \left[\dfrac{OFDI_{it}*(1-\varphi_i)}{OFDI2_t}\right]S_t^{OFDI2}$, $1-\varphi_i$ is the proportion of provincial enterprises in the transition and developing countries by the end of 2013, $OFDI2_t$ is the national OFDI stock in the transition and developing countries in the t period.

S_{it}^{FDI} represents the foreign R&D capital stock acquired by foreign direct investment in the t period of i province. $S_{it}^{FDI} = (FDI_{it}/FDI_t)S_t^{FDI}$, $S_t^{FDI} = \sum_{j=1}^{27}(FDI_{jt}/GDP_{jt})S_{jt}^{D}$, FDI_{jt} is the total foreign direct investment of country j in China in the t period, and FDI_{it}/FDI_t is the proportion of foreign direct investment of province i in China's total foreign direct investment in the t period. The calculation method of S_{it}^{IM} is the same as this. The data comes from the China Statistical Yearbook, and Chinese regional statistical yearbook.

Environmental regulation (R). There are two main ways to measure environmental regulation in existing literature [38]. One is to use environmental taxes, emission reduction costs or pollution control investments to represent the severity of environmental regulation. The other is to estimate the environmental regulation by using the rate of pollution removal. At present, China has not made detailed statistics on emission reduction costs and investment in pollution control, and China's environmental tax was only implemented in 2018. Therefore, this paper uses the second method to measure environmental regulation, but there are many kinds of pollution emissions in reality. Antiweiler et al. [40] considers sulfur dioxide as a good research object for the following reasons. Firstly, sulfur dioxide is the main pollutant in the production process. It has a strong local effect. Secondly, it is harmful to the human body and is under the control of the government. Thirdly, there are many pollution reduction technologies in this area. Therefore, in the same way as Wang (2016), the sulfur dioxide removal rate is used as the surrogate variable of environmental regulation which is the same as the study of Wang et al. [8]. The data comes from the China Environmental Statistical Yearbook and NBSC [41].

H_{it} represents the human capital stock in the t period of i province. According to the general method, this paper multiplies the population at each educational level by the number of years of study corresponding to each educational level for approximate calculation. The proportion of educational staff in each province is derived from the Yearbook of China's labor statistics (According to macroeconomic growth theory, labor force is an important variable affecting total factor productivity and should be put into the model. But it is highly correlated with the stock of human capital which is concerned in this paper (the correlation coefficient is greater than 0.9), so we consider it in the robustness test).

Fiscal Decentralization (FD). As for the measurement of fiscal decentralization, the academic community has not yet reached a broad consensus. Considering that the empirical data selected in this paper is after the tax-sharing system in 1994, in order to accurately describe the changes in fiscal relations, this paper refers to the methods of Zhang and Gong [41] to construct the index of fiscal decentralization. Economic growth is characterized by provincial GDP. The data comes from the China Statistical Yearbook. Descriptive statistics for each variable are shown in Table 1.

Table 1. Descriptive statistics of variables.

Variables	Sample Size	Mean Value	Standard Deviation	Minimum Value	Maximum Value
ln(GTFP)	406	0.052	0.026	−0.412	0.511
ln(S^D)	406	4.161	1.621	−1.309	7.296
ln(S^{OFDI1})	406	−1.985	2.235	−8.354	3.252
ln(S^{OFDI2})	406	−3.652	2.986	−11.937	1.627
ln(S^{FDI})	406	0.258	2.098	−7.323	3.841
ln(R)	406	−0.627	0.635	−0.355	−1.712
ln(S^{IM})	406	2.766	1.856	−1.542	6.775
ln(H)	406	6.884	0.145	6.421	7.189
ln(FD)	406	1.391	0.612	−0.607	3.122
ln(GDP)	406	3.105	0.220	0.981	4.406

5. The Empirical Analysis of OFDI Investment in Different Countries on Green Technological Progress

5.1. Analysis of Green Technology Progress in China

The GTFP constructed by SBM model and GML index is a noteworthy variable. Before carrying out the empirical analysis, it is necessary for us to discuss and analyze it. This paper compares the GTFP measured by different methods and analyzes the progress of green technology in China.

5.1.1. The Comparative Analysis of China's GTFP Index Based on Different Measurement Methods

Figure 1 shows China's GTFP index from 2003 to 2016 which is based on three different measurement methods. The M (Malmquist) index is calculated by data envelopment analysis (DEA), and the undesired output is not considered in the calculation. The M index is generally higher than ML and GML, indicating that technological progress will be overestimated without considering pollution emissions. Comparing with GML and ML index, we can get: On the one hand, the measurement of green technological progress under ML index is generally higher than GML index. On the other hand, ML index shows greater flexibility than GML index, while GML index tends to be more stable. From 2010 to 2011, the ML index showed a sharp decline. This is because the use of the current technological frontier to measure the rate of technological progress will cause the production frontier to shift inward, resulting in a "technical retrogression" situation, making the GTFP measurement deviate. Measured by the GML index, the rate of green technology progress between 2010 and 2011 was 98.3%, while the rate of green technology progress calculated by the ML index was underestimated by 2%. At the same time, we find that some provinces have no solution to linear programming when calculating ML index in some years, so it is more convincing to use GML index to measure GTFP.
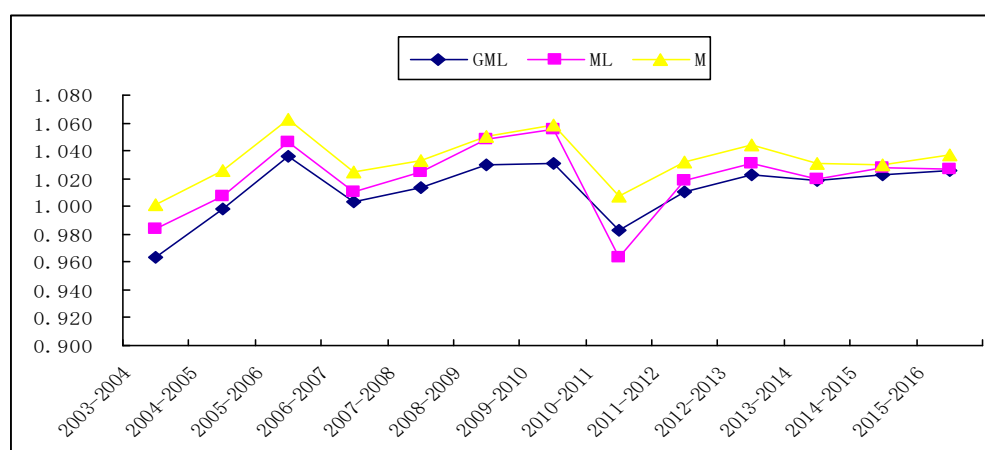

Figure 1. China's GTFP index measured by three different methods (2003–2016).

5.1.2. The Analysis of China's GTFP Index

Next, we analyze the GTFP changes of 29 provinces in China in different periods (2003–2007; 2008–2012; 2013–2016) based on the GML index. In order to make a comparative analysis of different regions, this paper divides China into eastern, central and western regions according to the traditional criteria (The eastern region: Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Hainan. The central region: Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, Hunan. Western Regions: Inner Mongolia, Guangxi, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Ningxia, Qinghai, Xinjiang). The specific results are shown in Table 2.

Table 2. Changes of GTFP in different provinces in China.

Provinces	GML (2003–2007)	GML (2008–2012)	GML (2013–2016)	Provinces	GML (2003–2007)	GML (2008–2012)	GML (2013–2016)
Beijing	1.048	1.037	1.032	Hubei	1.064	1.026	1.009
Tianjin	1.034	1.025	1.022	Hunan	0.975	0.992	1.028
Hebei	0.977	1.018	1.029	Guangdong	1.023	1.013	1.016
Shanxi	0.985	1.011	1.026	Guangxi	0.957	0.991	1.014
Inner Mongolia	0.982	1.012	1.023	Hainan	1.039	1.042	0.996
Liaoning	0.939	0.999	1.018	Sichuan	1.026	1.016	1.020
Jilin	0.978	1.019	1.011	Guizhou	0.987	1.025	1.018
Heilongjiang	0.980	1.029	1.048	Yunnan	1.031	0.991	1.013
Shanghai	1.042	1.041	1.035	Shaanxi	0.992	1.018	1.023
Jiangsu	1.032	1.033	1.033	Gansu	0.961	0.987	1.009
Zhejiang	1.033	0.975	1.027	Qinghai	1.060	1.028	1.040
Anhui	0.919	0.990	1.020	Ningxia	0.980	1.022	0.991
Fujian	1.048	1.047	1.032	Xinjiang	0.979	0.991	1.020
Jiangxi	1.010	0.975	1.032	Eastern Region	1.023	1.024	1.024
Shandong	1.033	1.028	1.022	Central Region	0.985	1.001	1.022
Henan	0.971	0.963	1.003	Western Region	0.995	1.008	1.017

On the whole, the progress of green technology in China shows a rising trend over time. The main reason is that the public and the government pay more and more attention to the quality of life and growth with the improvement of people's living standards and the continuous development of economic aggregate [37]. The Chinese government's supervision and protection of the environment has been greatly improved since 2013. We can also find from Table 2 that China's overall green technological progress has been greatly improved with the strengthening of environmental regulation, which indicates that environmental regulation can promote the progress of green technology.

At the regional level, the growth rate of green technology progress in eastern China is faster than that in central and Western China, but there is little difference between central and Western China. On the one hand, since the reform and opening up, the eastern region has developed rapidly relying on its geographical position and policy advantages. The long-term accumulation of regional development differences makes the eastern region have more advantages in the R&D capital stock and technological level than that in central and western regions. On the other hand, regions with better economic development will also pay more attention to environmental protection. Therefore, the development of green technology in the eastern region is faster than that in the central and western regions. In the first two periods, the development of green technology in the central region was slower than that in the western region, but it was faster than that in the western region after 2013.

The reason may be that the central region has been trading for economic growth at the expense of more energy input and environmental pollution, but developing green technology is more advantageous when subject to stringent environmental controls. The above conclusions can also be correspondingly verified in various provinces. The eastern provinces such as Beijing, Shanghai, Fujian and Hainan are faster than most of the central and western provinces in the growth rate of green technology.

5.2. The Empirical Results Analysis

5.2.1. Selection of Estimation Methods

Firstly, F test is used to determine whether mixed least squares estimators are used, and then Hausman test is used to verify whether the model chooses fixed effect or random effect. F test results show that mixed least squares estimators should be rejected, and Hausman test shows that fixed effect estimators should be used in both general and regional discussions. In fixed-effect panel data model, if there is an autocorrelation problem, the estimation results will not be effective. In this paper, Wooldridge's method [43] is used to test intra-group autocorrelation, Pesaran's method [44] and friedman's method [45] are used to test inter-group autocorrelation. The test results are shown in Table 3.

Table 3. Results of inter group and intra group autocorrelation test.

wooldridge test for autocorrelation in panel data
$F(1, 28) = 67.344$　　Prob > F = 0.000
Cross-sectional dependence test
Friedman's test of cross sectional independence = 25.696, Pr = 0.589
Pesaran's test of cross sectional independence = 0.774, Pr = 0.439

As shown in Table 3, the Wooldridge test strongly rejects the hypothesis that there is no first-order intra-group autocorrelation, while the Pesaran and Friedman tests accept the hypothesis that there is no inter-group autocorrelation. The results indicates that there is a first order intra-group autocorrelation in the data, but there is no correlation among groups. Therefore, in order to solve this problem, we adopt the feasible generalized least squares method for parameter estimation.

5.2.2. The Regression Analysis of Total Samples

The regression results in Table 4 show that R&D spillovers obtained through different channels have different impacts on China's green technology progress. China's investment in different types of countries has significantly different impacts on China's green technological progress. Regression results from column (1) to column (4) show that: the coefficient of $\ln(S^{OFDI1})$ is significantly positive, indicating that China can obtain reverse green technology spillover from investment in developed countries, and the direction of green technology spillover is flowing to China. The coefficient of $\ln(S^{OFDI2})$ is significantly negative, indicating that China can not obtain reverse green technology spillover when investing in transition and developing countries. China's domestic R & D capital stock and import trade have a significant positive impact on green technology progress. However, the technology spillovers produced by FDI have a weak impact on China's reverse technological progress, and even hinder it. The results also resonates with the proposition of Wang et al. [8]. In addition, the coefficient of environmental regulation is significantly positive, indicating that reasonable environmental regulation is conducive to promoting the progress of green technology and guiding China to embark on the road of green development. At the same time, this paper also finds that fiscal decentralization and economic growth have a certain negative impact on green technology progress. In the long-term process of rapid and extensive development, China has overemphasized the growth rate and neglected the quality of development. Different from the result of Li et al. [43] that fiscal decentralization is benefit to green total factor productivity, this paper argues that fiscal decentralization gives local governments greater economic and political freedom. In the face of

performance appraisal, local governments are more likely to choose the development model of "pollution first and then control", ignoring the sustainable development goals, resulting in the blockage of green technology innovation.

The result of column (4) shows that when China invests in developed countries, human capital can absorb and digest the reverse technology spillover effect. The coefficients of $\ln(S^{OFDI1})$ and $\ln(H)\ln(S^{OFDI1})$ are significant. In order to further discuss the net impact of investment in developed countries on China's green technology progress, the partial derivative of $\ln(S^{OFDI1})$ is derived in column (4), and the mean value of human capital stock is substituted into the calculation: $\partial \ln(GTFP) / \partial \ln(S^{OFDI1}) \approx 0.853$. It indicates that the reverse green spillover effect obtained by China's investment from developed countries is helpful to the promotion of green technology progress through the absorption of human capital, which also shows that the higher the human capital, the stronger the absorption of green technology progress. Similarly, the partial derivative method of column (4) can be used to research. However, China's investment in transition and developing countries will produce green technology export, but this export effect can be partially recovered through domestic R&D cost allocation. The purpose of investing in transition and developing countries is to expand the scale of overseas markets and seek cheap resources, reduce production costs, and increase corporate profits. These profits will be returned to parent companies for R&D and innovation activities, which will ultimately reduce R&D costs and promote green technology progress in the home country.

Table 4. The regression results of reverse green technology spillover effect of China's OFDI.

Variables	(1)	(2)	(3)	(4)
C	−0.725 ***	−0.692 ***	−0.745 ***	−0.769 ***
	(0.151)	(0.146)	(0.153)	(0.154)
$\ln(S^D)$	0.046 **	0.047 ***	0.044 **	0.069 ***
	(0.021)	(0.019)	(0.022)	(0.021)
$\ln(S^{OFDI1})$	0.194 ***	0.421 ***	0.267 ***	0.502 **
	(0.034)	(0.119)	(0.038)	(0.254)
$\ln(S^{OFDI2})$	−0.201 **	−0.195 ***	−0.281 ***	−0.237 ***
	(0.092)	(0.027)	(0.045)	(0.038)
$\ln(S^{FDI})$	−0.056	−0.251	−0.118	−0.013 **
	(0.069)	(2.623)	(0.157)	(0.006)
$\ln(R)$	0.601 **	0.795 ***	0.682 ***	0.737 ***
	(0.292)	(0.225)	(0.093)	(0.298)
$\ln(S^{IM})$	0.065 *	0.073 ***	0.076 ***	0.075 ***
	(0.041)	(0.027)	(0.028)	(0.012)
$\ln(H)\ln(S^{OFDI1})$		0.041 *		0.051 ***
		(0.026)		(0.024)
$\ln(S^D)\ln(S^{OFDI2})$			0.002	0.038 **
			(0.003)	(0.019)
$\ln(FD)$	−0.005	−0.006	−0.012 *	−0.019 **
	(0.004)	(0.007)	(0.009)	(0.009)
$\ln(GDP)$	−0.247	−0.322	−0.321 *	−0.287 ***
	(0.256)	(0.487)	(0.214)	(0.119)
R^2	0.562	0.589	0.571	0.612
F value (Wald)	42.471 ***	41.954 ***	39.883 ***	36.952 ***
Hausman test	25.622 ***	23.142 **	21.214 **	19.367 **
sample size	406	406	406	406

Note: R^2 is the goodness of fit within the group, and '***', '**', '*' are significant at the levels of 1%, 5% and 10% respectively. The figures in parentheses are panel-corrected standard errors. The same in Table 5.

5.2.3. The Comparative Analysis of Reverse Green Technology Progress of OFDI in Different Regions of China

There are great differences in R&D capital, R&D capability and development level among different regions in China. A comparative analysis of different regions is helpful to clarify the impact of OFDI on green technology progress in different regions. The regression results are shown in Table 5.

Regression results show that OFDI investment in different countries has regional heterogeneity on the impact of green technology progress. Specifically, firstly, OFDI flows to developed countries have positive impacts on green technology progress in all regions, but there is a decreasing trend from east to west. The higher the human capital stock is, the stronger the absorptive capacity of general technology is [10]. Column (7), (10) and (13) show that the human capital stock in the eastern region is higher than that in other regions, and the absorption of green technology progress in this region is also stronger. In terms of environmental control. The eastern region has a more developed economy, a lower tolerance for pollution and a significantly stronger environmental control than other regions, which makes technological progress in the eastern region more environmentally biased [6]. Secondly, in the process of investment in developing and transitional countries, the cost-sharing effect of green technology progress in the western region is higher, mainly because the western region lags behind the central and eastern regions on the basis of R&D capital and the marginal effect of R&D investment is greater. Therefore, the profits from overseas investment will be more conducive to the development of green technology. Thirdly, similar to OFDI, the impact of import trade on green technology progress is positive, which is also determined by the absorptive capacity of new technology in each region.

In addition, it is found that FDI still has a certain inhibitory effect on green technological progress. This is different from the result obtained by Yue et al. [47]. The main reason is that this paper is based on the basic framework of green technology progress to construct an empirical analysis model, compared with the direct use of FDI flow or stock to analyze its impact on green technology progress from the perspective of R&D capital stock is more scientific. Finally, the results of subregional regression show that fiscal decentralization and economic growth still have negative impacts on green technology progress.

5.3. The Endogeneity Problem and Robustness Test

This paper estimates the panel data of each province from 2003 to 2016. An important condition to ensure the reliability of the above empirical results is that the explanatory variables are not related to the random disturbance term, that is, there is no serious endogenous problem in the model, otherwise the estimation results will be biased and inconsistent. Endogenous problems are generally caused by measurement errors, omission of important variables and reverse causality. In order to avoid measurement errors, reliable data and processing methods are adopted as far as possible. Therefore, we need to focus on the following two situations that generate endogenous problems. One is reverse causality, that is, green technological progress will affect the explanatory variables in turn. The other is omitted variables, that is, the omitted variables in the model are related to the explained variable. Next, we examine and deal with these two kinds of endogeneity problems.

We divides China's OFDI into two types: one is invested in developed countries, the other is invested in developing countries and economies in transition. According to the analysis above, these two kinds of OFDI have different effects on green technological progress. We believe that the progress of green technology will not affect China's foreign investment, even if the progress of technology, it is difficult to affect a country's foreign investment decision [10]. The possible cause of the reverse causality problem in this paper is the explanatory variables (import and FDI) related to opening up. Provinces with rapid development of green technology are generally subject to reasonable constraints of environmental regulation and high cleanliness of production, which may affect their attractiveness to FDI and the scale of imports. In addition, provinces with rapid green technology progress often have demonstration effect in China, which will be recognized by the central government, thus stimulating the R&D investment in green technology. Therefore, this paper takes $\ln(S^{FDI})$, $\ln(S^{IM})$ and

ln(S^D) as endogenous variables, and takes their first-order and second-order lag values as tool variables for generalized moment estimation (GMM). The results are reported in column (14) in Table 6, and all coefficient symbols are in line with expectations and have good significance. The validity of tool variables still needs to be tested. In this paper, the value of Hansen's J overrecognition test is 0.43 and accepts the original assumption that all tool variables are exogenous. In the test, we found that the Shea's partial R^2 [48] is greater than 0.2, and the minimum eigenvalue statistic is 12.6 bigger than 10, which satisfies the empirical thumb. This indicates that the tool variables selected in this paper are effective.

For the problem of omitted variables, the first-order lag of the explained variable is put into the model as an explanatory variable. This method can not only depict the possible dynamic characteristics of green technological progress, but also include other factors affecting green technological progress to effectively reduce the model setting errors. We use the System GMM method to estimate the model dynamically. The results of the regression report are listed in column (4) in Table 6. Arellano-Bond's residual sequence correlation test [49] shows that the System GMM can be used for estimation. The Sargan test [50] accepts the null hypothesis that all instrumental variables are valid. Therefore, it can be considered that the estimation results are reliable. From the regression results, except the coefficients of ln(S^{FDI}), ln(FD) and ln(GDP) are not significant, the estimates of other variables are consistent with column (4) in Table 4, and have good significance.

We also perform robustness tests by replacing variables and adding other variables. Specifically, labor force is used to replace capital stock, and the provincial export volume, urbanization index [51] and financial development degree [52] are added to test the robustness of regression results. The result is as shown in Column (16): The coefficients and significance of each variable do not change significantly as we add the explanatory variables to the model in turn. This shows that the empirical results of this paper are stable.

Table 5. Comparative analysis of reverse green technology progress of OFDI in different regions of China.

Variables	The Eastern Region			The Central region			The Western Region		
	(5)	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**	**(13)**
C	−1.732 ***	−1.766 ***	−2.112 ***	−0.683 ***	−0.749 ***	−0.863 ***	−0.621 ***	−1.267 ***	−1.778 ***
	(0.257)	(0.502)	(0.653)	(0.152)	(0.294)	(0.231)	(0.204)	(0.653)	(0.414)
ln(SD)	0.047 ***	0.044 **	0.069 ***	0.045 ***	0.042 **	0.76 ***	0.049 ***	0.048 *	0.073 ***
	(0.019)	(0.022)	(0.031)	(0.017)	(0.023)	(0.025)	(0.016)	(0.032)	(0.021)
ln(S^{OFDI1})	0.461 ***	0.294 ***	0.564 **	0.432 ***	0.286 ***	0.532 **	3.417 **	0.211 ***	0.454 **
	(0.117)	(0.049)	(0.244)	(0.149)	(0.072)	(0.261)	(0.156)	(0.047)	(0.268)
ln(S^{OFDI2})	−0.195 ***	−0.281 ***	−0.237 ***	−0.195 ***	−0.281 ***	−0.237 ***	−0.195 ***	−0.281 ***	−0.237 ***
	(0.027)	(0.045)	(0.038)	(0.027)	(0.045)	(0.038)	(0.027)	(0.045)	(0.038)
ln(S^{FDI})	−0.551	−0.321	−0.214	−0.371	−0.135	−0.014	−0.251	−0.123 *	−0.015 **
	(1.581)	(0.355)	(0.331)	(2.443)	(0.158)	(1.106)	(2.623)	(0.078)	(0.007)
ln(R)	0.802 ***	0.784 ***	0.862 ***	0.799 ***	0.581 ***	0.635 ***	0.425 **	0.312 ***	0.611 **
	(0.327)	(0.083)	(0.231)	(0.231)	(0.077)	(0.232)	(0.215)	(0.053)	(0.287)
ln(SIM)	0.098 ***	0.086 ***	0.078 ***	0.076 **	0.072 ***	0.077 ***	0.065 ***	0.066 ***	0.057 ***
	(0.032)	(0.027)	(0.033)	(0.037)	(0.029)	(0.023)	(0.021)	(0.019)	(0.016)
ln(H)ln(S^{OFDI1})	0.051 *		0.049 **	0.045 **		0.032 *	0.042 *		0.029 *
	(0.033)		(0.025)	(0.026)		(0.024)	(0.026)		(0.019)
ln(SD)ln(S^{OFDI2})		0.003	0.028 **		0.004 *	0.138		0.002	0.030 *
		(0.003)	(0.017)		(0.003)	(0.119)		(0.002)	(0.021)
ln(FD)	−0.008	−0.013	−0.021 **	−0.006	−0.013	−0.018 **	−0.009 *	−0.014 *	−0.021 **
	(0.007)	(0.011)	(0.012)	(0.006)	(0.010)	(0.008)	(0.006)	(0.009)	(0.009)
ln(GDP)	−0.221	−0.348 *	−0.289 **	−0.379	−0.323	−0.286 **	−0.198	−0.386 **	−0.288 **
	(0.487)	(0.224)	(0.149)	(0.496)	(0.254)	(0.146)	(0.487)	(0.214)	(0.167)
R^2	0.589	0.571	0.612	0.589	0.571	0.612	0.589	0.571	0.612
F value (Wald)	36.923 ***	37.685 ***	33.458 ***	41.343 ***	38.461 ***	30.214 ***	31.546 ***	30.158 ***	26.241 ***
Hausman test	21.332 **	20.123 **	19.947 **	26.156 ***	27.211 ***	16.367 *	24.121 ***	20.219 **	18.997 **
sample size	154	154	154	112	112	112	140	140	140

Table 6. The endogeneity test and robustness test.

Variables	(14)	(15)	(16)
C	−0.953 ***	−0.652 *	−0.731 *
	(0.243)	(0.323)	(0.378)
ln(SD)	0.046 ***	0.081 *	0.051 *
	(0.011)	(0.042)	(0.026)
ln(S^{OFDI1})	0.606 *	0.496 **	0.433 **
	(0.314)	(0.216)	(0.188)
ln(S^{OFDI2})	−0.153 ***	−0.231 ***	−0.331 **
	(0.042)	(0.052)	(0.144)
ln(SFDI)	−0.018 *	−0.014	−0.160
	(0.009)	(0.012)	(0.202)
ln(R)	0.439 **	0.536 **	0.318 *
	(0.199)	(0.232)	(0.177)
ln(SIM)	0.045 ***	0.061 *	0.072 *
	(0.014)	(0.031)	(0.038)
ln(H)ln(S^{OFDI1})	0.050 *	0.035 *	
	(0.026)	(0.017)	
ln(L)ln(S^{OFDI1})			0.051 **
			(0.022)
ln(SD)ln(S^{OFDI2})	0.045 *	0.039 *	0.046 *
	(0.023)	(0.020)	(0.025)
ln(FD)	−0.021 *	−0.136	−0.216
	(0.011)	(0.192)	(0.392)
ln(GDP)	−0.168	0.258	−0.233
	(0.146)	(0.161)	(0.172)
R^2	0.526		0.63
Control variables	No	No	Yes
Hausman' J test	[0.431]		
Hausman test			18.161 **
GMM C test	[0.192]		
Arellano-Bond test		[0.52]	
Sargan test		[0.26]	

Note: The figures in parentheses in column (14) and (15) is standard error, the figures in parentheses in column (16) is panel-corrected standard errors. The figures in square brackets is *p* value for the corresponding statistics, '***', '**', '*' are significant at the levels of 1%, 5% and 10% respectively.

6. Conclusions and Recommendations

This paper constructs a basic analytical framework for green technological progress and incorporates environmental regulation into it. We discussed the impact of China's investment in different countries on green technological progress for the first time. We also combine the global Malmquist productivity concept with the SBM model to construct the GML index, which is used to describe the green technology progress index of China's provinces. Based on this, this paper uses panel data model to empirically analyze the impact of China's investment in different types of countries on green technology progress from 2003 to 2016. The main conclusions are as follows:

China's investment in developed countries can bring reverse green technology spillovers and promote China's green technology progress, while China's investment in developing countries will hinder China's green technology progress. The main reason for this difference lies in the different channels of reverse green technology spillover in different types of countries. Investment in developed countries can promote the progress of green technology in China through the absorption of R&D elements and the feedback mechanism of results. But this is also affected by China's domestic human capital stock, the increase in human capital stock is conducive to the absorption of OFDI brought green technology. The main purpose of investment in transition or developing countries is

to gain profits or expand markets, and the cost-sharing role in this process is not sufficient to offset the spillover of green technology. From the perspective of R&D capital stock, China's environmental regulation, import trade and R&D investment can promote the progress of green technology, while foreign direct investment, fiscal decentralization and economic growth hinder the progress of green technology. In addition, there are regional differences in the impact of China's OFDI on the reverse green technological progress. Because of environmental regulation and economic development, the eastern region of China can obtain more reverse green technology progress than the central and western regions in the process of OFDI.

Under the background of green growth, this paper gives the following suggestions for China's foreign direct investment. In order to improve green technological progress, China should invest more in developed countries. At the same time, we should invest more in the field of environmental protection or in the technological field with environmental bias. When investing in developing and transition countries, more profits should also be invested in green technology research and development to maintain the sustainability of their own development. As environmental regulation can promote the progress of green technology, China needs to continue to strengthen environmental regulation, guide environmental friendly technological progress, ensure that environmental responsibility is implemented, increase local environmental supervision, and increase the proportion of environmental work in government performance appraisal. In addition, China's provinces can also increase investment in education and scientific research from their own development to enhance their absorption and transformation of green technology progress.

This paper only studies the impact of China's investment in different types of countries on the home country's green technological progress, and there is no rigorous robustness test due to insufficient data sources. Therefore, further research can use microscopic data to test relevant conclusions. It will also be a new research direction to discuss the impact of OFDI on inclusive green technological progress.

Author Contributions: S.Z. conceived and designed the study, and also performed the analytical model. A.Y. reviewed and edited the paper. All authors discussed the results and implications and commented on the paper at all stages.

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