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Threshold Effect of Two-Way FDI Synergy on Regional Green Technology Innovation under Heterogeneous Environmental Regulation: Evidence from China's Provincial Panel Data

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Abstract: The green technology innovation system is a fundamental method for China to achieve its goals of carbon peak and carbon neutrality. Clarifying the relationship between two-way foreign direct investment (FDI) synergy and regional green technology innovation is key to the green transformation and sustainable development of regional innovation systems. Based on panel data from 30 provinces in China from 2009 to 2020, a threshold-panel-regression technique is used. Command-controlled environmental regulation (CER), market-incentive environmental regulation (MER), and public-participation environmental regulation (PER) are taken as threshold variables, and the threshold effect of two-way FDI synergy on regional green technology innovation under heterogeneous environmental regulation is empirically explored. The results show the following. (i) The effects of two-way FDI synergy on regional green technology innovation exhibit significant threshold characteristics with heterogeneous environmental regulation as a double threshold. (ii) As the threshold values of CER and PER increase, the promoting effect of two-way FDI synergy on regional green technology innovation first increases and then decreases. (iii) As the MER threshold value increases, the promoting effect of two-way FDI synergy on regional green technology innovation continues to increase. (iv) Under the medium-threshold condition of PER, the promoting effect of two-way FDI synergy reaches its greatest value. (v) The intensity of intellectual property protection, the number of regional innovation institutions, and the level of transportation infrastructure all have significant positive effects on regional green technology innovation, and the number of regional innovation institutions exhibits the greatest promoting effect. This study provides new insights into two-way FDI synergy and methods to promote green technology innovation, and these findings can help the government formulate future policies and strategies to promote regional green technology innovation.

Keywords: two-way FDI synergy; regional green technology innovation; heterogeneous environmental regulation; regional innovation system; threshold effect

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1. Introduction

Over the past 40 years of reform and development, China has made tremendous economic achievements, and its economic scale ranks second in the world. However, the country has paid a high price for its resources and environment, facing serious sustainability problems, such as high emissions, energy consumption, and pollution. China urgently needs to find a new scientific method to promote high-quality development to prevent its economic growth from falling into the middle-income trap. The 14th Five-Year Plan of China clearly states that the long-term goal of socialist modernization will be realized by 2035. One subgoal is to leverage the advantages of green technology innovation in innovation-driven and green development fields and to accelerate the promotion of green and low-carbon development projects. The Chinese government has set the goals of achieving a carbon peak by 2030 and carbon neutrality by 2060. In this green economy era, green technology innovation has become a key driving force for China to achieve its double carbon goal and to promote sustainable economic development [1]. Possessing the dual benefits of technological progress and environmental protection, it is a circular ecological paradigm that achieves synergy between energy conservation, emission reduction, and high-quality economic development. Stimulating regional green innovation projects can effectively remove the constraints of resources and the environment, and green innovation is an effective means to achieve economic development and environmental protection [2]. However, China's regional green technology innovation still has some challenges, such as technological and institutional lock-in, weak innovation foundations, and insufficient innovation capacities, which severely restrict the high-quality development of the field [3]. Considering this background, it is important to explore methods to stimulate regional green technology innovation to resolve the great conflict between China's economic growth and environmental protection needs and to promote the construction of innovative power projects and an eco-friendly civilization.

In the knowledge economy era, the promotion of regional green technology innovation no longer simply relies on the input of material resources, and knowledge resources often play a key role [4]. From a practical point of view, there are two main techniques to improve regional green technology innovation: relying on domestic research and development (R&D) investment and knowledge flow and acquiring foreign advanced technology and knowledge through international knowledge spillover channels [5]. In an open economy environment, the new economic growth theory regards domestic R&D investments and international knowledge spillovers as important factors for green innovation development [6]. Amidst China's newly increasing openness to the outside world, inward foreign direct investment (IFDI) and outward foreign direct investment (OFDI), as two major channels of international knowledge spillover, have become important methods to improve green technology innovation and high-quality economic development in the country. According to the Statistical Bulletin of China's IFDI and the Statistical Bulletin of China's OFDI issued by the Chinese Ministry of Commerce, China's IFDI increased from essentially zero in 1978 to $149.34 billion in 2020. China's OFDI has also increased [7], reaching $153.71 billion in 2020 [8]. China has become the world's second largest country in terms of two-way cross-border capital flows, and IFDI and OFDI are the bridges and links between domestic and international markets in a double-cycle development strategy. Consequently, the levels and trends of two-way foreign direct investment (FDI) synergy practices are increasingly significant [9,10]. In the 2019 guidance on building a market-oriented green technology innovation system, China emphasized implementing the strategic concepts of bringing in and going out, increasing two-way openness, and promoting comprehensive improvements. Therefore, two-way FDI synergy has become an important method to acquire foreign advanced green technology and improve regional green technology innovation. However, researchers usually separate IFDI and OFDI and discuss their green technology innovation effects individually; there is very little research on the green technology innovation effects of two-way FDI from a synergistic perspective. In this new era, what is the degree of the effects of two-way FDI synergy? What are its impacts on regional green technology innovation? Under what circumstances can it best enhance regional green technology innovation? Accurate answers to these questions can help reveal the specific situation of green technology innovation in China, examine the mechanism of two-way FDI synergy, and help increase the incentive effect of two-way FDI synergy on green technology innovation to realize high-quality green technology innovation achievements. These are the original goals of this paper.

Under the conditions of a market economy, due to the negative effects of environmental pollution and the positive effects of innovation, it is difficult for innovation subjects to spontaneously conduct green innovation activities based on their interests [11,12]. However, appropriate environmental regulation is an important tool to stimulate regional green innovation [13]. To date, the Chinese government has adopted increasingly strict environmental regulation policies to reverse the negative impacts of economic development on the environment. Existing studies have shown that two-way FDI synergy is influenced and constrained by environmental regulation practices during green technology innovation [14,15]. Because the strengths of environmental regulation practices in different regions of China differ dramatically [16], we have reason to believe that the impacts of two-way FDI synergy on regional green technology innovation are limited by heterogeneous environmental regulation; i.e., two-way FDI synergy exhibits a threshold effect on regional green technology innovation under heterogeneous environmental regulation practices. However, when analyzing the impacts of two-way FDI synergy on regional green technology innovation, researchers mainly focus on their linearity and ignore environmental regulation practices, which are important policy factors affecting their nonlinear relationship. This limited scope may bias the conclusions. Furthermore, different types of environmental regulation tools reflect the heterogeneous tendencies and purposes of the government in regulating environmental protection strategies and ignoring the heterogeneity of environmental regulation tools may result in one-sided research results.

The main issue studied in this paper is the differential impact of two-way FDI synergy on regional green technology innovation under heterogeneous environmental regulation, from which we explore ways to enhance regional green technology innovation. The aim is to provide a useful reference for China to achieve carbon peak and carbon neutrality. We first use a capacity-coupled system model to measure the level of two-way FDI synergy and then introduce three types of environmental regulations as threshold variables: command-controlled environmental regulation (CER), market-incentive environmental regulation (MER), and public-participation environmental regulation (PER). Additionally, we use an interaction-regression model and threshold-panel-regression technology to empirically explore the interaction effect and threshold effect of two-way FDI synergy on regional green technology innovation under heterogeneous environmental regulation practices. Our main findings are that two-way FDI synergy always exhibits a significant positive impact on regional green technology innovation, which has a nonlinear relationship, with heterogeneous environmental regulation as a double threshold. More specifically, (i) as the threshold values of CER and PER increase, the promoting effect of two-way FDI synergy on regional green technology innovation first increases and then decreases. (ii) As the MER threshold value increases, the promoting effect of two-way FDI synergy on regional green technology innovation continues to grow. (iii) Under the medium-threshold condition of PER, the promoting effect of two-way FDI synergy is the greatest.

Compared with other published literature, this paper brings two-way FDI synergy, heterogeneous environmental regulation, and regional green technology innovation into a unified analytical framework and uses an interaction-regression model and threshold-regression model to empirically explore the complex relationship among them, which is pioneering and scientific. Our specific contributions, from a theoretical perspective, reveal the influencing mechanisms of two-way FDI synergy on regional green technology innovation under heterogeneous environmental regulation and further enhance the theoretical system of regional green technology innovation and "dual carbon". From a practical perspective, our contributions are based on two-way FDI synergy and heterogeneous environmental regulation, proposing diversified paths to promote regional green technology innovation and providing useful guidance for decision-making to relevant government entities in China. The most surprising finding of this paper is that under the threshold of heterogeneous environmental regulation, two-way FDI synergy always has a significant promoting effect on regional green technology innovation. Moreover, under the medium-threshold condition of PER, the promoting effect of two-way FDI synergy on regional green technology innovation is the greatest. These findings are important additions to the field globally.

The rest of this paper is organized as follows. Section 2 presents an analysis of the research status of two-way FDI synergy and regional green technology innovation globally. Section 3 presents the methods, models, and data used in this paper. Section 4 presents the empirical results and discussion of the threshold effect of two-way FDI synergy on regional green technology innovation under heterogeneous environmental regulation practices. In Section 5, the conclusions, some policy implications, and the limitations are discussed.

2. Literature Review

Two-way FDI synergy includes two elements: IFDI and OFDI. The interaction and coupling of these two elements affect regional green technology innovation. To date, scholars worldwide have mainly studied the relationship between two-way FDI and regional green technology innovation from the perspectives of IFDI and OFDI.

First, the research on IFDI in regional green technology innovation reaches two main types of conclusions: the pollution halo hypothesis and the pollution haven hypothesis [17,18]. (i) The pollution halo hypothesis states that IFDI can bring advanced green technology to a region to reduce regional pollution emissions and improve regional green technology innovation through simultaneous demonstration, competition, and linkage effects [19]. Research by most scholars supports the pollution halo hypothesis [20]. For instance, Song et al. (2015) found that IFDI can promote the rapid economic growth and green innovation output of host countries [21]. Yang et al. (2020) proposed that with increased IFDI technology spillover, industrial enterprises' green technology innovation is more likely to succeed [22]. Li and Cao (2020) noted that IFDI can provide financial and technical support for regional green technology innovation [23]. Deng and Jia (2020) showed that the capital and material inflow of IFDI promotes green technology innovation through a scale effect, while the technology inflow of IFDI promotes green technology innovation through a technology effect [24]. Song and Xue (2022) found that IFDI has a significant role in promoting green technology innovation in manufacturing [25]. (ii) The pollution haven hypothesis states that to pursue rapid, short-term economic growth, developing countries introduce the high-energy-consumption and high-pollution industries of developed countries into their economies, increasing their environmental pollution, in a practice that is not conducive to green technology innovation. For example, Jia (2015) found that the IFDI introduced by most provinces in China did not achieve the goal of promoting green technology innovation [26]. Huang and Liu (2020) proposed that the entry method of IFDI affects its green technology spillover effect and that IFDI entering through joint ventures dramatically hinders green technology innovation [27]. Behera and Sethi (2022) noted that IFDI inhibits the promotion of green technology innovation in Organization for Economic Co-operation and Development (OECD) countries [28]. In addition, the research results of a few scholars have shown that IFDI's impact on green technology innovation is not significant and that there is not necessarily a connection between the two [29,30].

Second, most scholars have affirmed the positive impact of OFDI in the research on OFDI in regional green technology innovation. For instance, Jia et al. (2017) found that OFDI invested in both developed and developing countries can promote green technology innovation [31]. Gong et al. (2017) showed that OFDI can promote the efficiency of industrial green technology innovation through an agglomeration structure lightening effect, an agglomeration scale effect, and an agglomeration resource allocation effect [32]. Han et al. (2020) noted that the reverse green technology innovation spillover effect of OFDI in China shows regional heterogeneity [33]. Lun and Han (2022) confirmed that China's OFDI can promote improved green technology innovation capabilities for countries of the Belt and Road Initiative [34]. However, the findings differ from the above research conclusions. Nie and Qi (2019) found that OFDI significantly improves the efficiency of green technology innovation in the technology R&D stage of industrial enterprises but that the efficiency improvement in the achievement transformation stage is not significant [35]. Pan et al. (2020) proposed that China's OFDI reverse green technology spillovers are only significant in economically developed regions and not in economically underdeveloped regions [36].

Third, studies considering both IFDI and OFDI on regional green technology innovation reach starkly different conclusions. Liang and Luo (2019) studied the data of 22 OECD countries and showed that IFDI raised the level of green technology innovation, while

OFDI had little effect [37]. Luo et al. (2021) found that both IFDI and OFDI have significant positive effects on regional green technology innovation [38]. Zheng et al. (2022) proposed that IFDI and OFDI, as important channels for international technology spillovers, exhibit positive effects on China's green technology innovation output [39]. Wang et al. (2022) found that both IFDI and OFDI have universal effects on green technology innovation in the manufacturing industry using a dynamic fuzzy-set qualitative comparative analysis (fsQCA) method [40].

The differences in the above research conclusions reflect the fact that the impact of two-way FDI on regional green technology innovation is not a simple linear effect. Therefore, some scholars have begun to study the heterogeneous effects of various factors, such as environmental regulation, government support, marketization level, and intellectual property protection, on this impact from a nonlinear perspective [41–43]. Among these factors, environmental regulation is the most critical [44]. For instance, Feng et al. (2018) found that environmental regulation can change the effect direction of two-way FDI on green innovation in manufacturing [45]. Tian and Hao (2020) proposed that the effect of IFDI on green technology innovation efficiency is related to the intensity and type of environmental regulation practice [46]. Hu et al. (2021) showed that IFDI does not actively exert green technology spillover effects and that green technology innovation needs to be promoted through environmental regulation practices [47]. Liu et al. (2021) found that the moderating effect of environmental regulation on OFDI's reverse technology spillover effects has natural and regional heterogeneity [48]. Han and Song (2022) noted that heterogeneous environmental regulation plays a positive regulatory role during OFDI reverse green innovation; imperative environmental regulation has the strongest impact, followed by economic environmental regulation, and voluntary environmental regulation is the weakest [49].

Scholars have conducted more in-depth research of the relationship between two-way FDI and regional green technology innovation, which has laid a solid foundation for this paper. However, some issues still require discussion. (i) The selection of research objects is a concern. Researchers usually explore the relationship between IFDI or OFDI and regional green technology innovation separately. However, from the perspective of synergy, the research on two-way FDI synergy on regional green technology innovation is insufficient. As China's two-way FDI synergy is continuously developing, it is critical to study its effect on green technology innovation. (ii) A threshold perspective should be considered. Because environmental regulation is a key factor affecting the relationship between IFDI or OFDI and regional green technology innovation, it is necessary to further explore the threshold effect of two-way FDI synergy on regional green technology innovation under the condition of environmental regulation. (iii) Studying heterogeneous perspectives is another challenge. While environmental regulation practices are discussed in industry-level discussions, there is very little research on the threshold relationship between two-way FDI synergy and green technology innovation under heterogeneous environmental regulations from a regional perspective. Due to China's unbalanced regional economic development and the characteristics of its dual economic structure, there must be regional differences in the formulation and implementation of environmental regulations. Therefore, it is necessary to explore the relationship between two-way FDI synergy and regional green technology innovation from the perspective of heterogeneous regional environmental regulation.

Based on the above factors, we aim to expand on the following aspects. (i) We choose two-way FDI synergy as the research topic and use the capacity-coupled-system model to measure it. (ii) We introduce environmental regulation as the threshold variable and empirically study the threshold mechanism of two-way FDI synergy on regional green technology innovation. (iii) Based on the perspective of heterogeneous regional environmental regulation, we divide heterogeneous environmental regulation into CER, MER, and PER. Then, we compare and analyze the threshold differentiation effect of two-way FDI synergy on regional green technology innovation under different environmental regulation tools. This study addresses the specific gap in two-way FDI synergy-driven green technology innovation. Our findings contribute to clarifying the mechanism of two-way FDI synergy, promoting regional green technology innovation, and formulating rational and effective heterogeneous environmental regulation policies. The research framework is illustrated in Figure 1.

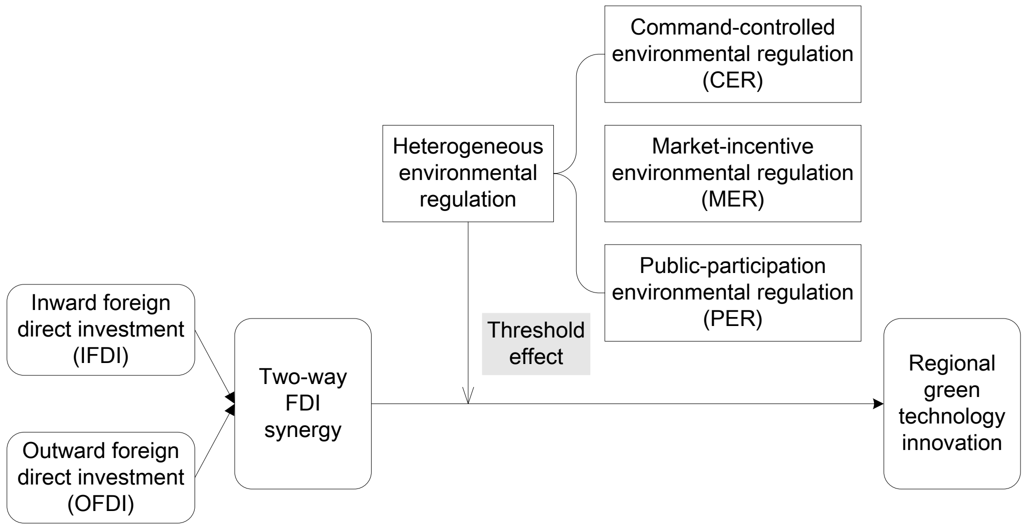

Figure 1. Research framework of this paper.

3. Methodology and Model

3.1. Model

The main methods for estimating nonlinear relationships between variables include interaction and threshold-regression tests. The interaction-regression test is conducted by using interaction terms in a linear-regression model, which has the advantage of being simple and intuitive. However, it cannot objectively determine the threshold value, threshold interval, and corresponding confidence interval, or test the significance and authenticity of the threshold value, while the threshold-pane-regression technique proposed by Hansen (1999, 2000) [50,51] can just overcome these shortcomings. Compared with the interaction regression, the threshold regression can more clearly reflect the differential effects of the independent variable on the dependent variable caused when the third-party relationship variable reaches different threshold values. Therefore, we adopt the Hansen threshold-panel-regression model, use heterogeneous environmental regulation practices as the threshold variable, and construct the threshold-panel-regression model of two-way FDI synergy affecting regional green technology innovation. However, the interaction-regression test should also be discussed as an alternative to study the effect of two-way FDI synergy on regional green technology innovation under heterogeneous environmental regulation because it can provide a basis for constructing a threshold-regression model.

Consequently, this paper first constructs the interaction-regression model of two-way FDI synergy on regional green technology innovation under heterogeneous environmental regulation and then constructs the threshold-regression model. In addition, to reduce the possibility of biased estimation results due to missing variables, we use various factors, such as the intensity of intellectual property protection, the number of regional innovation institutions, and the level of transportation infrastructure, that may affect regional green technology innovation as control variables and introduce them into the regression model.

3.1.1. Interaction-Regression Model

First, we construct the interaction-regression model of CER as follows:

$$\ln GTI_{it} = C + \beta_1 \ln COR_{it} + \alpha_1 \ln IPR_{it} + \alpha_2 \ln INS_{it} + \alpha_3 \ln TRA_{it} + \mu_i + \nu_t + \varepsilon_{it} \quad (1)$$

$$\ln GTI_{it} = C + \beta_1 \ln COR_{it} + \beta_3 \ln COR_{it} \times \ln CER_{it} + \alpha_1 \ln IPR_{it} + \alpha_2 \ln INS_{it} + \alpha_3 \ln TRA_{it} + \mu_i + \nu_t + \varepsilon_{it} \quad (2)$$

$$\ln GTI_{it} = C + \beta_1 \ln COR_{it} + \beta_2 \ln CER_{it} + \beta_3 \ln COR_{it} \times \ln CER_{it} + \alpha_1 \ln IPR_{it} + \alpha_2 \ln INS_{it} + \alpha_3 \ln TRA_{it} + \mu_i + \nu_t + \varepsilon_{it} \quad (3)$$

where C represents the constant term; i represents the province; t represents the year; $\ln GTI_{it}$ is the dependent variable representing the regional green technology innovation; $\ln COR_{it}$ is the independent variable representing two-way FDI synergy; $\ln CER_{it}$ is the third-party relationship variable representing CER; β_1, β_2, and β_3 are the regression coefficients of the core variables; $\ln IPR_{it}$, $\ln INS_{it}$, and $\ln TRA_{it}$ are the control variables representing the intensity of intellectual property protection, the number of regional innovation institutions, and the level of transportation infrastructure, respectively; α_1, α_2, and α_3 are the regression coefficients of the control variables; μ_i is the individual fixed effect; ν_t is the time fixed effect; and ε_{it} is the random interference.

Second, we construct the interaction-regression model of MER as follows:

$$\ln GTI_{it} = C + \beta_1 \ln COR_{it} + \beta_3 \ln COR_{it} \times \ln MER_{it} + \alpha_1 \ln IPR_{it} + \alpha_2 \ln INS_{it} + \alpha_3 \ln TRA_{it} + \mu_i + \nu_t + \varepsilon_{it} \quad (4)$$

$$\ln GTI_{it} = C + \beta_1 \ln COR_{it} + \beta_2 \ln MER_{it} + \beta_3 \ln COR_{it} \times \ln MER_{it} + \alpha_1 \ln IPR_{it} + \alpha_2 \ln INS_{it} + \alpha_3 \ln TRA_{it} + \mu_i + \nu_t + \varepsilon_{it} \quad (5)$$

where $\ln MER_{it}$ is the third-party relationship variable representing MER; the other variables and symbols are the same as those in Equation (3).

Third, we construct the interaction-regression model of PER as follows:

$$\ln GTI_{it} = C + \beta_1 \ln COR_{it} + \beta_3 \ln COR_{it} \times \ln PER_{it} + \alpha_1 \ln IPR_{it} + \alpha_2 \ln INS_{it} + \alpha_3 \ln TRA_{it} + \mu_i + \nu_t + \varepsilon_{it} \quad (6)$$

$$\ln GTI_{it} = C + \beta_1 \ln COR_{it} + \beta_2 \ln PER_{it} + \beta_3 \ln COR_{it} \times \ln PER_{it} + \alpha_1 \ln IPR_{it} + \alpha_2 \ln INS_{it} + \alpha_3 \ln TRA_{it} + \mu_i + \nu_t + \varepsilon_{it} \quad (7)$$

where $\ln PER_{it}$ is the third-party relationship variable representing PER; the other variables and symbols are the same as those in Equation (3).

3.1.2. Threshold-Regression Model

(1) Threshold-Regression Model of CER. First, we construct a single threshold-panel-regression model of two-way FDI synergy affecting regional green technology innovation with CER as the threshold variable.

$$\ln GTI_{it} = C + \alpha_1 \ln IPR_{it} + \alpha_2 \ln INS_{it} + \alpha_3 \ln TRA_{it} + \beta_1 \ln COR_{it} \times I(\ln CER_{it} < \gamma) + \beta_2 \ln COR_{it} \times I(\ln CER_{it} \geq \gamma) + \mu_i + \nu_t + \varepsilon_{it} \quad (8)$$

where $\ln CER_{it}$ is the threshold variable representing CER, $I(*)$ is the indicator function, γ is the threshold value, and the other variables and symbols are the same as those in Equation (3).

Accordingly, we construct a multiple threshold-panel-regression model of two-way FDI synergy affecting regional green technology innovation with CER as the threshold variable. By taking the double threshold as an example, we rewrite the equation as follows:

$$\ln GTI_{it} = C + \alpha_1 \ln IPR_{it} + \alpha_2 \ln INS_{it} + \alpha_3 \ln TRA_{it} + \beta_1 \ln COR_{it} \times I(\ln CER_{it} < \gamma_1) + \beta_2 \ln COR_{it} \times I(\gamma_1 \leq \ln CER_{it} < \gamma_2) + \beta_3 \ln COR_{it} \times I(\ln CER_{it} \geq \gamma_2) + \mu_i + \nu_t + \varepsilon_{it} \quad (9)$$

where γ_1 and γ_2 represent the double-threshold values; the other variables and symbols are the same as those in Equation (8).

(2) Threshold-Regression Model of MER. First, we construct a single threshold-panel-regression model of two-way FDI synergy affecting regional green technology innovation with MER as the threshold variable.

$$\begin{aligned}\ln GTI_{it} = \; & C + \alpha_1 \ln IPR_{it} + \alpha_2 \ln INS_{it} + \alpha_3 \ln TRA_{it} + \beta_1 \ln COR_{it} \times I(\ln MER_{it} < \gamma) \\ & + \beta_2 \ln COR_{it} \times I(\ln MER_{it} \geq \gamma) + \mu_i + \nu_t + \varepsilon_{it}\end{aligned} \tag{10}$$

where $\ln MER_{it}$ is the threshold variable representing MER; the other variables and symbols are the same as those in Equation (8).

Accordingly, we construct a multiple threshold-panel-regression model of two-way FDI synergy affecting regional green technology innovation with MER as the threshold variable. By taking the double threshold as an example, we rewrite the following equation.

$$\begin{aligned}\ln GTI_{it} = \; & C + \alpha_1 \ln IPR_{it} + \alpha_2 \ln INS_{it} + \alpha_3 \ln TRA_{it} + \beta_1 \ln COR_{it} \times I(\ln MER_{it} < \gamma_1) \\ & + \beta_2 \ln COR_{it} \times I(\gamma_1 \leq \ln MER_{it} < \gamma_2) + \beta_3 \ln COR_{it} \times I(\ln MER_{it} \geq \gamma_2) \\ & + \mu_i + \nu_t + \varepsilon_{it}\end{aligned} \tag{11}$$

where γ_1 and γ_2 are the double-threshold values; the other variables and symbols are the same as those in Equation (10).

(3) Threshold-Regression Model of PER. First, we construct a single threshold-panel-regression model of two-way FDI synergy affecting regional green technology innovation with PER as the threshold variable.

$$\begin{aligned}\ln GTI_{it} = \; & C + \alpha_1 \ln IPR_{it} + \alpha_2 \ln INS_{it} + \alpha_3 \ln TRA_{it} + \beta_1 \ln COR_{it} \times I(\ln PER_{it} < \gamma) \\ & + \beta_2 \ln COR_{it} \times I(\ln PER_{it} \geq \gamma) + \mu_i + \nu_t + \varepsilon_{it}\end{aligned} \tag{12}$$

where $\ln PER_{it}$ is the threshold variable representing PER; the other variables and symbols are the same as those in Equation (8).

Accordingly, we construct a multiple threshold-panel-regression model of two-way FDI synergy affecting regional green technology innovation with PER as the threshold variable. By taking the double threshold as an example, we rewrite the following equation.

$$\begin{aligned}\ln GTI_{it} = \; & C + \alpha_1 \ln IPR_{it} + \alpha_2 \ln INS_{it} + \alpha_3 \ln TRA_{it} + \beta_1 \ln COR_{it} \times I(\ln PER_{it} < \gamma_1) \\ & + \beta_2 \ln COR_{it} \times I(\gamma_1 \leq \ln PER_{it} < \gamma_2) + \beta_3 \ln COR_{it} \times I(\ln PER_{it} \geq \gamma_2) \\ & + \mu_i + \nu_t + \varepsilon_{it}\end{aligned} \tag{13}$$

where γ_1 and γ_2 are the double-threshold values; the other variables and symbols are the same as those in Equation (12).

The estimation process of the Hansen threshold-panel-regression model is as follows. First, the threshold estimate is determined. Given the candidate threshold value γ, the least squares method is used to estimate each parameter and the corresponding residual sum of squares $S_1(\gamma)$. The estimate of the threshold value γ, $\hat{\gamma} = \underset{\gamma}{\operatorname{argmin}} S_1(\gamma)$, can be obtained from the least residual sum of squares $S_1(\gamma)$. Second, we test the significance and authenticity of the threshold estimate. Since the F-statistic constructed in the Hansen threshold-panel-regression model is nonstandard, the corresponding critical value cannot be obtained from the table. As a result, the bootstrap method is used to obtain the p-value for the significance test. For a single threshold, the original assumption is $H_0 : \gamma = \gamma_0$; that is, the estimated threshold value is equal to the true value. The authenticity of the threshold is tested by constructing the likelihood ratio statistic $LR(\gamma) = [S_0 - S_1(\hat{\varphi})]/\sigma_\varepsilon^2$. When $LR(\gamma) \leq c(\alpha) = -2\ln\left(1 - \sqrt{1-\alpha}\right)$ (α is the significance level; under a 95% confidence interval, $c(\alpha) = 7.35$), the original hypothesis is accepted. The principles of the double threshold test and multiple threshold test are similar. Third, the threshold interval and confidence interval of the threshold estimate are determined.

3.2. Variable Descriptions

3.2.1. Dependent Variable: Regional Green Technology Innovation (GTI)

Researchers have yet to develop a unified standard regarding the method of measuring regional green technology innovation. Summarizing previous studies, the method of measurement is based mainly on the following three perspectives. (i) From the perspective of innovation input, indicators such as human capital input and physical capital input are used to represent regional green technology innovation. (ii) For innovation output, indicators such as the number of regional green patent applications are used to represent it. (iii) For the innovation input—output process, the efficiency of regional green technology innovation is used to measure it. We mainly discuss the threshold effect of two-way FDI synergy on regional green technology innovation under the heterogeneous environmental regulation threshold involving multiple control variables, such as the number of regional innovation institutions. If we choose the first or third measurement method, multicollinearity among variables is likely to occur, which affects the accuracy and reliability of the empirical results. Therefore, we measure regional green technology innovation from the perspective of innovation output. In fact, green invention patents can reflect not only the level and scale of regional green technology innovation but also its practice and application [52]. Moreover, in view of the integrity and objectivity of China's green invention patents, we use the number of regional green invention patent applications to measure regional green technology innovation [53,54].

3.2.2. Independent Variable: Two-Way FDI Synergy (COR)

Two-way FDI includes IFDI and OFDI. The essence of synergy is the coordination and coupling of IFDI and OFDI. There are two main techniques to measure two-way FDI synergy in the existing research. One is to assess it through the interaction between IFDI and OFDI. The second is to introduce the capacity-coupled-system model [55]. Starting from the actual connotation of two-way FDI synergy, we adopt the second method to measure two-way FDI synergy. The specific steps are as follows.

First, the equation for measuring the two-way FDI coupling is as follows:

$$C_{it}(IO) = \frac{IFDI_{it} \times OFDI_{it}}{(\sigma IFDI_{it} + \varphi OFDI_{it})^{\lambda}} \tag{14}$$

where $C_{it}(IO)$ represents the coupling degree of IFDI and OFDI; $IFDI_{it}$ represents IFDI, characterized by the actual amount of regional foreign capital utilized; $OFDI_{it}$ represents OFDI, characterized by the amount of regional outward direct investment; and σ and φ are specific weight coefficients. As China views bringing in and going out as equally important, we let σ = φ = 0.5; λ is the adjustment coefficient, and its value range is generally $2 \leq \lambda \leq 5$ [56]. According to the capacitive-coupling model in physics [57], the system-coupling-degree model of n subsystems can be expressed as follows:

$$C_n = n\left\{[(u_1 \times u_2 \times \cdots \times u_n)]/\left[\prod(u_i + u_j)\right]\right\}^{\frac{1}{n}} \tag{15}$$

where u_i and u_j represent different subsystems, n represents the number of subsystems, and C_n represents the system coupling degree of n subsystems. Since this study discusses the synergetic relationship between IFDI and OFDI, we let λ = 2 in Equation (14) [56].

Second, based on two-way FDI coupling, we measure the coordination degree and introduce the index of coordination development:

$$COR_{it}(IO) = \left[C_{it}(IO) \times \frac{IFDI_{it} + OFDI_{it}}{2}\right]^{\frac{1}{2}} \tag{16}$$

where $COR_{it}(IO)$ represents the coupling coordination degree of IFDI and OFDI; the other variables and symbols are the same as those in Equation (14).

Third, combining Equations (14) and (16), the measurement of the two-way FDI synergy level is as follows:

$$COR_{it} = \left[\frac{IFDI_{it} \times OFDI_{it}}{(IFDI_{it} + OFDI_{it})/2} \right]^{\frac{1}{2}} \tag{17}$$

where the larger the value of COR_{it} is, the greater the two-way FDI synergy is.

To intuitively show how the index of coordinated development depends on the two directional FDI measures, this paper takes Beijing as an example and draws a relationship diagram of IFDI, OFDI and COR in Beijing from 2009 to 2020, as shown in Figure 2.

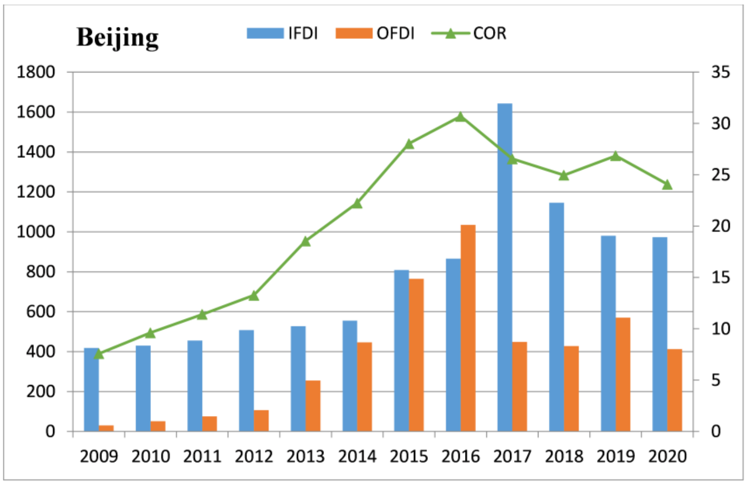

Figure 2. Relationship diagram of IFDI, OFDI and COR in Beijing from 2009 to 2020.

Figure 2 shows that the size of COR mainly depends on the following two factors: first, the absolute amount of IFDI and OFID, and second, their gap amount. When the absolute amount of IFDI and OFID is relatively large and their gap amount is small, the COR of the two tends to be larger. For example, although the absolute amount of IFDI and OFID in Beijing in 2016 is slightly less than that in 2017, their gap amount in 2017 is far greater than that in 2016, so the COR in 2016 is greater than that in 2017. In addition, the COR in Beijing shows a trend of rising and then falling and remains high. As the capital of China, Beijing has obvious advantages in political resources, economic strength, innovation, and innovation culture and can make full use of the innovation-driven effects of IFDI and OFDI.

3.2.3. Threshold Variable: Heterogeneous Environmental Regulation

There are many types of environmental regulation policy tools, and their operating mechanisms differ. Therefore, there must be differences in the threshold-effect mechanism of two-way FDI synergy on green technology innovation under heterogeneous environmental regulation. Following Shi (2021) [58], Liu et al. (2022) [59], and Wang et al. (2022) [60], we divide heterogeneous environmental regulation into three dimensions: CER, MER, and PER.

1. CER means that the government enforces and restrains economic entities that harm the environment by formulating laws and regulations on environmental protection. We use the number of environmental administrative penalty cases to measure CER.
2. MER refers to the government guiding economic entities to reduce environmental pollution through various means, such as the collection of sewage charges based on the polluter-pays principle and market regulation. We use the total investment in pollution control to measure MER.
3. PER refers to the public's active participation in environmental governance and supervision based on environmental awareness. This kind of environmental regulation comes from the pursuit of survival, which is not imposed by the government. We

use the numbers of National People's Conference (NPC) proposals and Chinese People's Political Consultative Conference (CPPCC) proposals related to environmental protection to measure PER.

3.2.4. Control Variables

To more accurately explore the threshold effect of two-way FDI synergy on regional green technology innovation, we select some relevant variables to control.

1. Intensity of intellectual property protection (IPR). As an important component of the institutional environment, intellectual property protection is critical to promoting green technology innovation, knowledge spillover, and green economic development. Strengthening intellectual property protection can provide a good technological environment and institutional support for the effective use of foreign capital, reduce the risk of the illegal imitation of advanced technology, and promote improvement in green technology innovation. Following Yang and Han (2021), we use the turnover of technology market contracts to express IPR [61].
2. Number of regional innovation institutions (INS). Enterprises, universities, and R&D institutions are the three main bodies of the regional green innovation system. These bodies provide R&D funds, personnel, equipment, and other resources for green innovation activities and are an important mechanism for promoting green innovation. Hence, we take INS as the control variable; drawing on Su et al. (2020), we use the sum of the numbers of enterprises, universities, and institutions with R&D activities to represent green innovation [62].
3. Level of transportation infrastructure (TRA). Differences in the level of regional transportation infrastructure have different impacts on green technology innovation. A good TRA is conducive to the rapid flow and productive exchange of innovation elements between regions, promotes the optimal allocation of innovation resources, and better realizes green technology innovation. Drawing on Démurger (2001), we use the ratio of the total mileage of railways, highways, and inland waterways to the area of each region to measure TRA [63].

3.3. Data Sources and Processing

We take the panel data of 30 provinces in China (Tibet, Hong Kong, Macao, and Taiwan were not analyzed due to the lack of data) from 2009 to 2020 as the research sample. These original data were mainly derived from the China Statistical Yearbook (2010–2021), China Environmental Statistical Yearbook (2010–2021), China Environmental Yearbook (2010–2021), Statistical Bulletin of China's Outward Foreign Direct Investment (2010–2021), Chinese Research Data Services (CNRDS) Platform, and Statistical Yearbooks of China's provinces. Among these datasets, missing individual data were supplemented by interpolation. Consequently, a total of 360 samples were obtained in this study. The descriptive statistical results of each variable are shown in Table 1.

Table 1. Descriptive statistics of the variables.

Variable	Mean	Std. Dev.	Min	Max	Obs.
Regional green technology innovation (ln*GTI*)	7.216	1.485	2.565	10.382	360
Two-way FDI synergy (ln*COR*)	2.091	0.844	−0.842	3.696	360
Command-controlled environmental regulation (ln*CER*)	7.651	1.358	0.000	10.718	360
Market-incentive environmental regulation (ln*MER*)	2.609	1.063	−3.045	4.953	360
Public-participation environmental regulation (ln*PER*)	5.857	1.014	0.000	8.673	360
Intensity of intellectual property protection (ln*IPR*)	4.513	1.833	−0.588	8.751	360
Number of regional innovation institutions (ln*INS*)	7.043	1.310	4.025	10.228	360
Level of transportation infrastructure (ln*TRA*)	−0.239	0.786	−2.453	0.921	360

4. Empirical Results and Discussion

4.1. Results and Discussion of the Interaction-Regression Model

The main methods of estimating linear relationships between variables are mixed regression (OLS), fixed effects (FE), and random effects (RE). To ensure the accuracy of the estimation of the interaction-regression model, this paper uses the *F*, *LM*, and *Hausman* tests to judge and select the estimation methods. The regression results of the interaction-effect model are shown in Table 2.

Table 2. Regression results of the interaction model.

Variable	Model (1)	CER		MER		PER	
		Model (2)	Model (3)	Model (4)	Model (5)	Model (6)	Model (7)
ln*COR*	0.463 *** (0.055)	0.222 ** (0.108)	0.278 * (0.149)	0.361 *** (0.072)	0.342 *** (0.081)	0.340 *** (0.101)	0.145 (0.199)
ln*CER*			0.021 (0.038)				
ln*MER*					−0.030 (0.061)		
ln*PER*							−0.084 (0.074)
ln*COR* × ln*CER*		0.028 ** (0.011)	0.019 (0.019)				
ln*COR* × ln*MER*				0.030 ** (0.014)	0.041 (0.026)		
ln*COR* × ln*PER*						0.020 (0.014)	0.056 (0.034)
ln*IPR*	0.214 *** (0.031)	0.207 *** (0.031)	0.209 *** (0.031)	0.227 *** (0.031)	0.224 *** (0.032)	0.211 *** (0.031)	0.214 *** (0.031)
ln*INS*	0.372 *** (0.058)	0.353 *** (0.058)	0.359 *** (0.059)	0.339 *** (0.059)	0.337 *** (0.060)	0.366 *** (0.058)	0.346 *** (0.060)
ln*TRA*	2.816 *** (0.281)	2.876 *** (0.279)	2.826 *** (0.294)	2.925 *** (0.284)	2.932 *** (0.284)	2.857 *** (0.282)	2.914 *** (0.286)
C	3.331 *** (0.402)	3.558 *** (0.409)	3.353 *** (0.549)	3.574 *** (0.415)	3.660 *** (0.450)	3.408 *** (0.405)	3.996 *** (0.656)
F Test	16.34 ***	16.65 ***	16.17 ***	16.23 ***	16.19 ***	16.44 ***	16.41 ***
LM Test	255.29 ***	252.98 ***	260.71 ***	229.59 ***	227.86 ***	254.32 ***	247.76 ***
Hausman Test	86.78 ***	89.35 ***	82.91 ***	91.76 ***	91.56 ***	87.94 ***	88.90 ***
N	360	360	360	360	360	360	360

Notes: ***, ** and * represent significance at the 1%, 5% and 10% levels, respectively; the numbers in brackets are standard errors.

Table 2 shows that the *F*, *LM*, and *Hausman* tests of the interaction-regression model of two-way FDI synergy on regional green technology innovation under heterogeneous environmental regulation pass the significance test at the 1% level. According to the discriminant rule of the linear model, the fixed-effect model is selected for estimation in this paper. Therefore, Table 2 lists only the estimation results of the interaction-regression model under fixed effects.

Table 2 shows the following. First, two-way FDI synergy always has a significant promoting effect on regional green technology innovation, indicating that simply increasing it can effectively promote improved regional green technology innovation. As a high-quality innovation achievement, regional green technology innovation has great demand for knowledge resources. Two-way FDI synergy can bring advanced technology, cutting-edge knowledge and high-end talent to somewhat compensate for the lack of high-quality development of regional green technology innovation. Second, models (2), (4), and (6) show that the regression coefficients of ln*COR*×ln*CER*, ln*COR*×ln*MER*, and ln*COR*×ln*PER* are 0.028 **, 0.030 **, and 0.020, respectively, which are all positive, indicating that the three types of heterogeneous environmental regulation can enhance the promotion of two-way FDI synergy on regional green technology innovation. Third, models (3), (5), and (7) show that CER, MER, and PER have no significant effect on regional green technology innovation, as a result of which the interactions of the three types of heterogeneous environmental regulation and two-way FDI synergy fail the significance test. This indicates that simply increasing the three types of environmental regulation does not promote regional green technology innovation. Consequently, it is obviously flawed to take heterogeneous environmental regulation as a general independent variable to estimate the model. Fourth, regarding the control variables, IPR, INS, and TRA all have significant positive effects on regional green technology innovation. A more in-depth analysis of the relationships between these control variables and regional green technology innovation will be presented in the subsequent part of this paper.

Overall, the estimated results of the interaction-regression model provide the overall mean impact of two-way FDI synergy on regional green technology innovation under heterogeneous environmental regulation and verify the accuracy and scientific validity of the heterogeneous environmental regulation cited as a third-party relationship variable (i.e., threshold variable) in this paper. This provides a basis for the subsequent regression analysis of the threshold effect.

4.2. Results and Discussion of the Threshold-Regression Model

According to the estimation method of the Hansen threshold-panel model, this paper takes heterogeneous environmental regulation as the threshold variable and empirically analyses the threshold effect of two-way FDI synergy on regional green technology innovation under CER, MER, and PER.

4.2.1. Results and Discussion of the CER Threshold-Regression Model

(1) Test Results and Discussion of the CER Threshold Effect. First, the significance test results and threshold estimates based on CER as the threshold variable are shown in Tables 3 and 4, respectively.

Table 3. Significance of the CER threshold-effect test results.

Model	*F*-Value	*p*-Value	BS Time	Critical Value		
				1%	5%	10%
Single threshold	22.981 ***	0.001	800	19.535	14.425	12.207
Double threshold	13.812 ***	0.000	800	8.033	4.603	3.548
Triple threshold	0.000	0.275	800	0.000	0.000	0.000

Notes: *** represents significance at the 1% level.

Table 4. Results of the CER threshold estimators and confidence intervals.

Model	Threshold Estimators	95% Confidence Intervals
Single threshold	7.182	[6.829, 8.272]
Double threshold	7.182	[6.829, 7.482]
	8.974	[8.407, 9.190]
Triple threshold	7.508	[7.375, 8.723]

Table 3 shows that under the condition of 800 repeated samplings by the bootstrapping (BS) method, the self-sampling *p*-values corresponding to the single and double thresholds are 0.001 and 0.000, respectively, and both pass the significance test at the 1% level. According to the HANSEN threshold theory, we suggest that the impact of two-way FDI synergy on regional green technology innovation has significant threshold characteristics, and the economic significance of the double threshold is greater. Table 4 shows that the double-threshold estimates are 7.182 and 8.974, and they are within the 95% confidence intervals [6.829, 7.482] and [8.407, 9.190], respectively.

Second, we use the likelihood ratio statistic LR of least squares to further test the authenticity of the double-threshold estimates. The test results are shown in Figures 3 and 4.

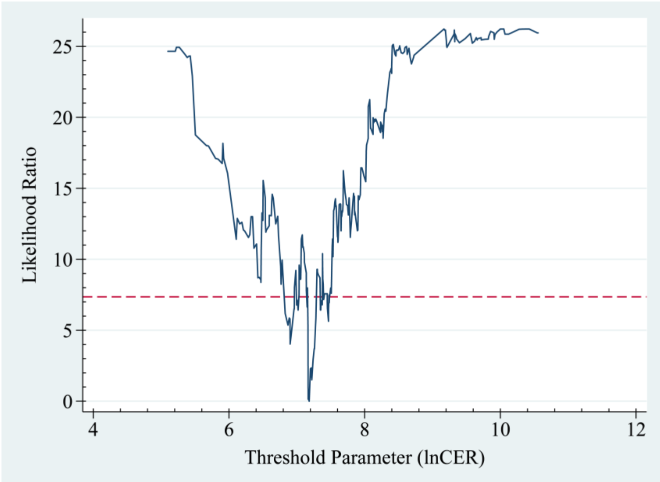

Figure 3. Likelihood ratio function of CER threshold 7.182.

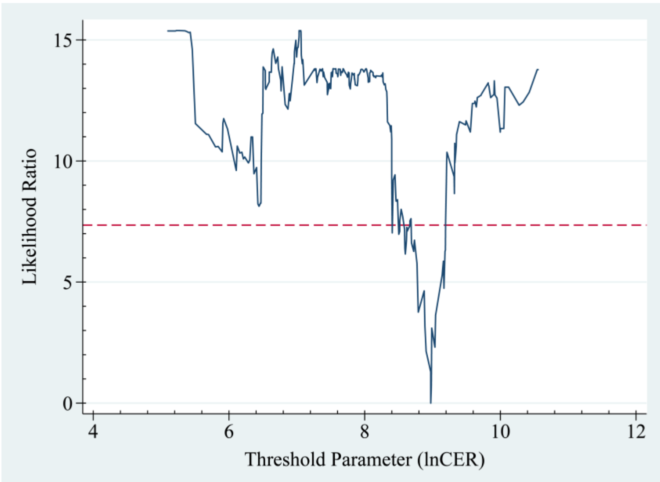

Figure 4. Likelihood ratio function of CER threshold 8.974.

Figures 3 and 4 show that when the LR value is 0, the corresponding two threshold parameters are 7.182 and 8.974, which are the estimated threshold values. When all the LR values are less than 7.35 (the red dotted line is 7.35 in the figure), the confidence intervals of the two threshold estimates are [6.829, 7.482] and [8.407, 9.190], both of which are within the corresponding confidence intervals. The double-threshold estimates pass the authenticity test. Consequently, we choose the double-threshold model for empirical analysis.

(2) Regression Results and Discussion of the CER Threshold Model. Under the double threshold of CER, Table 5 shows the estimation results of the threshold-effect model of two-way FDI synergy on regional green technology innovation.

Table 5. Regression results of the CER threshold model.

Variable	Coef.	Std. Err.	*t*-Value	*p*-Value	[95% Conf. Interval]	
ln*IPR*	0.327 ***	0.023	14.15	0.000	0.281	0.372
ln*INS*	0.584 ***	0.042	13.86	0.000	0.501	0.667
ln*TRA*	0.177 **	0.074	2.40	0.017	0.032	0.323
ln*COR* (ln*CER* < 7.182)	0.394 ***	0.059	6.68	0.000	0.278	0.510
ln*COR* (7.182 ≤ ln*CER* < 8.974)	0.534 ***	0.055	9.65	0.000	0.425	0.643
ln*COR* (ln*CER* ≥ 8.974)	0.442 ***	0.056	7.88	0.000	0.331	0.552
C	0.664 ***	0.250	2.66	0.008	0.172	1.156

Notes: *** and ** represent significance at the 1% and 5% levels, respectively.

Table 5 shows that under the condition of a double threshold, when CER is below 7.182, the regression coefficient of two-way FDI synergy is 0.394; when CER is between 7.182 and 8.974, the regression coefficient of two-way FDI synergy is 0.534; and when CER is over 8.974, the regression coefficient of two-way FDI synergy is 0.442. All three regression coefficients are significant at the 1% level. These results show that there are significant threshold differences in the effect of two-way FDI synergy on regional green technology innovation. Table 5 presents the following findings.

First, the three regression coefficients are all significantly positive, which indicates that under the condition of CER, two-way FDI synergy always has a significant promoting effect on regional green technology innovation. The purposes of two-way FDI synergy include acquiring knowledge, technology, and other innovative resources. Specifically, IFDI is the foundation of OFDI, and OFDI provides strong support for IFDI [64]. The technology spillover effect of IFDI and the reverse technology spillover effect of OFDI can promote the accumulation of high-end production factors, such as knowledge, technology, and experience in the region, leading to learning, absorption, imitation, and even secondary innovation. Under the role of CER, two-way FDI synergy can guide the concentrated flow of innovation elements to green innovation activities, effectively realize the rational allocation of innovation resources, and promote improvement in regional green technology innovation.

Second, the three regression coefficients first increase and then decrease, indicating that with the gradual strengthening of CER, the promoting effect of two-way FDI synergy on regional green technology innovation first increases and then decreases. The moderate enhancement of CER can effectively eliminate strategic rigidity in regional innovation and exert a positive influence on regional green technology innovation. When a region lacks vitality and market competition is moderate, CER can produce dramatic innovation compensation effects [65]. On the one hand, mandatory environmental protection laws and regulations have improved the access conditions of IFDI, hindering developed countries from transferring low-end manufacturing industries to other regions, which is conducive to the demonstration and correlation effects of high-quality IFDI. However, IFDI further stimulates OFDI. A region develops advanced green technology during OFDI, reduces production energy consumption, and moves some low-end industries outside it to attract higher-quality IFDI inflows. The high-quality synergy of IFDI and OFDI promotes regional green technology innovation. However, excessive CER inhibits the promoting effect of two-way FDI synergy. This phenomenon is mainly due to the lack of flexibility and incentives in CER. Excessive CER makes it more difficult for innovation entities to obtain incentives from regional green innovation activities, thus slowing green innovation.

4.2.2. Results and Discussion of the MER Threshold-Regression Model

(1) Test Results and Discussion of the MER Threshold Effect. The significance test results and threshold estimates based on the threshold variable MER are shown in Tables 6 and 7, respectively.

Tables 6 and 7 show that the double threshold of MER passes the significance test at the 5% level. The double-threshold estimates, 1.609 and 3.232, lie within the corresponding 95% confidence intervals, respectively. Therefore, we choose the double-threshold model for empirical analysis.

Table 6. Significance of the MER threshold-effect test results.

Model	*F*-Value	*p*-Value	BS Time	Critical Value		
				1%	5%	10%
Single threshold	8.056	0.169	800	17.276	12.099	9.800
Double threshold	9.206 **	0.036	800	11.263	8.408	6.973
Triple threshold	0.000	0.286	800	0.000	0.000	0.000

Notes: ** represents significance at the 5% level.

Table 7. Results of the MER threshold estimators and confidence intervals.

Model	Threshold Estimators	95% Confidence Intervals
Single threshold	3.236	[1.406, 3.726]
Double threshold	1.609	[0.470, 4.094]
	3.232	[0.095, 4.839]
Triple threshold	2.230	[1.792, 4.839]

The likelihood ratio functions of the estimated thresholds of MER are shown in Figures 5 and 6, respectively. Figures 5 and 6 show that the estimated value of the MER threshold is the same as its actual value.

(2) Regression Results and Discussion of the MER Threshold Model. Under the double threshold of MER, Table 8 shows the estimation results of the threshold-effect model of two-way FDI synergy on regional green technology innovation.

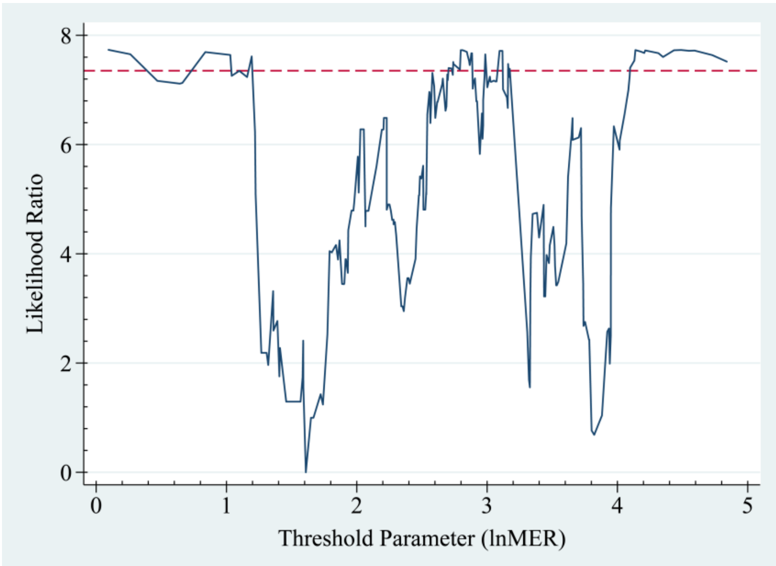

Figure 5. Likelihood ratio function of MER threshold 1.609.

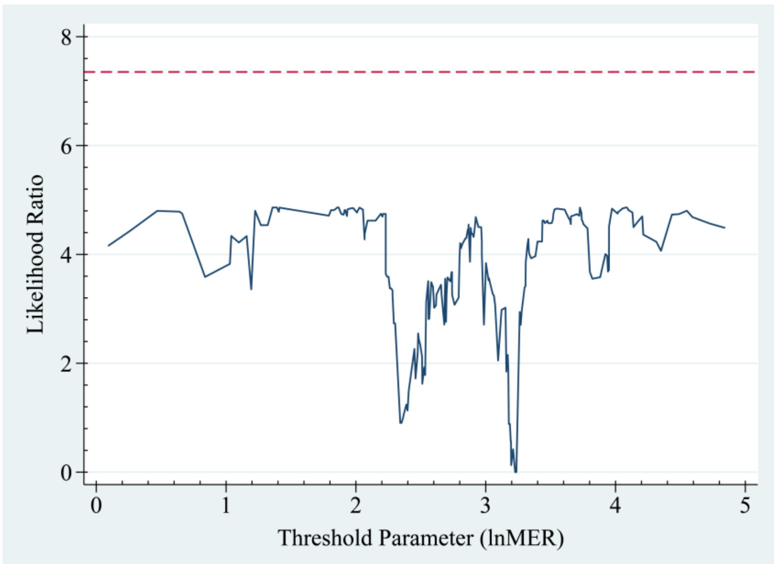

Figure 6. Likelihood ratio function of MER threshold 3.232.

Table 8. Regression results of the MER threshold model.

Variable	Coef.	Std. Err.	t-Value	p-Value	[95% Conf. Interval]	
lnIPR	0.348 ***	0.024	14.64	0.000	0.301	0.395
lnINS	0.553 ***	0.042	13.19	0.000	0.471	0.636
lnTRA	0.217 ***	0.076	2.87	0.004	0.069	0.366
lnCOR (lnMER < 1.609)	0.343 ***	0.068	5.04	0.000	0.209	0.477
lnCOR (1.609 ≤ lnMER < 3.232)	0.450 ***	0.056	8.02	0.000	0.340	0.560
lnCOR (lnMER ≥ 3.232)	0.499 ***	0.057	8.71	0.000	0.386	0.611
C	0.849 ***	0.241	3.53	0.000	0.375	1.322

Notes: *** represents significance at the 1% level.

Table 8 shows that under the double-threshold conditions of MER, the regression coefficients of two-way FDI synergy are 0.343, 0.450, and 0.499, which are all positive numbers, and all pass the significance test at the 1% level. When two-way FDI synergy increases by 1%, regional green technology innovation increases by 0.343%, 0.450% and 0.499%, respectively. This result shows that two-way FDI synergy exhibits a significant positive threshold effect on regional green technology innovation, and the positive effect of MER with a high threshold is the largest among the tested options. MER encourages regional innovation entities to conduct green innovation activities through market-based means, such as pollution discharge fees, subsidies, and tradable pollution discharge permits. Under the role of MER, IFDI can inject advanced knowledge into regional green innovation activities, and the host country both imitates innovation and independently innovates through learning by doing and other methods, thereby enhancing regional green technology innovation. Additionally, innovation subjects can obtain foreign technical resources through OFDI, pass them to their own countries, and engage in regional green innovation activities. The new knowledge and technology brought by two-way FDI synergy can significantly promote improvement in regional green technology innovation. Furthermore, the impact of MER is often persistent and long-term; therefore, the compliance costs of regional innovation entities are low. With the gradual increase in the MER threshold value, the promoting effect of two-way FDI synergy on regional green technology innovation gradually strengthens.

4.2.3. Results and Discussion of the PER Threshold-Regression Model

(1) Test Results and Discussion of the PER Threshold Effect. The significance test results and threshold estimates based on the threshold variable PER are shown in Tables 9 and 10, respectively.

Table 9. Significance of the PER threshold-effect test results.

Model	F-Value	p-Value	BS Time	Critical Value		
				1%	5%	10%
Single threshold	16.083 ***	0.001	800	10.794	7.565	5.542
Double threshold	12.639 ***	0.004	800	9.142	5.418	3.968
Triple threshold	0.000	0.725	800	0.000	0.000	0.000

Notes: *** represents significance at the 1% level.

Table 10. Results of the PER threshold estimators and confidence intervals.

Model	Threshold Estimators	95% Confidence Intervals
Single threshold	5.861	[5.771, 6.125]
Double threshold	5.861	[5.572, 6.430]
	6.856	[6.692, 7.055]
Triple threshold	6.180	[6.004, 6.784]

Tables 9 and 10 show that the single and double thresholds of PER pass the significance test at the 1% level, and the economic significance of the double threshold is large. The double-threshold estimates are 5.861 and 6.856, which are within the corresponding 95% confidence intervals. Hence, we choose the double-threshold model for empirical analysis.

The likelihood ratio functions of the estimated thresholds of PER are shown in Figures 7 and 8. Figures 7 and 8 show that the estimated value of the PER threshold is the same as its actual value.

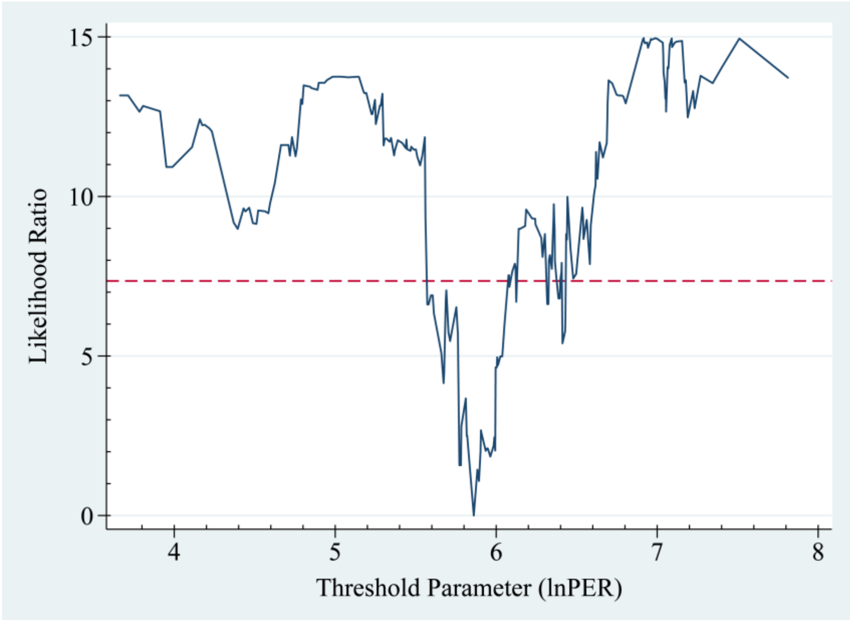

Figure 7. Likelihood ratio function of PER threshold 5.861.

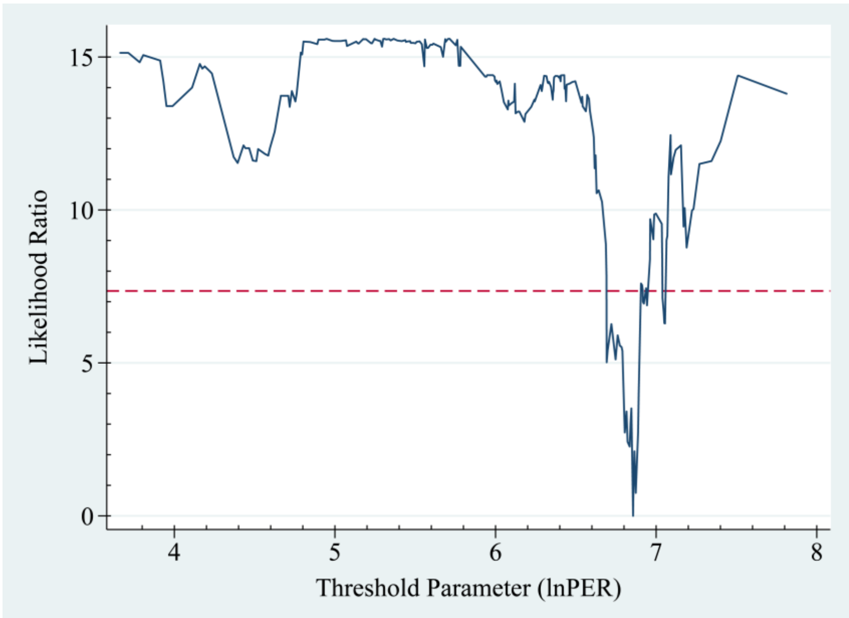

Figure 8. Likelihood ratio function of PER threshold 6.856.

(2) Regression Results and Discussion of the PER Threshold Model. Under the double threshold of PER, Table 11 shows the estimation results of the threshold-effect model of two-way FDI synergy on regional green technology innovation.

Table 11. Regression results of the PER threshold model.

Variable	Coef.	Std. Err.	*t*-Value	*p*-Value	[95% Conf. Interval]	
ln*IPR*	0.340 ***	0.024	14.38	0.000	0.294	0.387
ln*INS*	0.608 ***	0.045	13.51	0.000	0.520	0.697
ln*TRA*	0.169 **	0.076	2.23	0.027	0.020	0.318
ln*COR* (ln*PER* < 5.861)	0.448 ***	0.056	7.94	0.000	0.337	0.559
ln*COR* (5.861 ≤ ln*PER* < 6.856)	0.553 ***	0.059	9.43	0.000	0.437	0.668
ln*COR* (ln*PER* ≥ 6.856)	0.457 ***	0.059	7.72	0.000	0.340	0.573
C	0.413	0.262	1.58	0.115	-0.102	0.928

Notes: *** and ** represent significance at the 1% and 5% levels, respectively.

Table 11 shows that under the double-threshold conditions of PER, two-way FDI synergy has a significant threshold effect on regional green technology innovation. Specifically, when PER is below 5.861, the regression coefficient of two-way FDI synergy is 0.448. When PER is between 5.861 and 6.856, it increases to 0.553. When PER exceeds 6.856, it decreases to 0.457. These three regression coefficients all pass the 1% significance test; for every 1% increase in two-way FDI synergy, regional green technology innovation increases by 0.448%, 0.553% and 0.457% for the regression coefficients of 0.448, 0.553 and 0.457, respectively. As an informal regulation tool, PER is nonmandatory and ex post. PER can influence the incentive effects of two-way FDI synergy on regional green technology innovation through various channels, such as environmental protection publicity, public environmental supervision and social responsibility. Therefore, with the increase in the PER threshold value, innovation entities are willing to apply funds and technologies obtained through two-way FDI synergy to green innovation activities and rely on green patent achievements to burnish their images, accumulate goodwill, and stimulate strategies for innovation behavior. However, due to information asymmetry, blindness, and conformity, excessive PER restricts the high-quality development of regional green innovation activities, resulting in the inhibition of the promoting effect of two-way FDI synergy on regional green technology innovation.

4.3. Mechanism and Further Analyses

4.3.1. Mechanism Analyses

To further explore the influence mechanism between the variables and fully explore the threshold differentiation effects of two-way FDI synergy on regional green technology innovation under heterogeneous environmental regulations (CER, MER, and PER), we construct Figure 9 based on the threshold-regression results of Tables 5, 8 and 11.

Figure 9 presents the following findings.

First, the regression coefficients of two-way FDI synergy are all significantly positive under the thresholds of the three types of heterogeneous environmental regulation. This phenomenon is explained as follows. (i) The impact of two-way FDI synergy on regional green technology innovation has a significantly complex threshold relationship with heterogeneous environmental regulation as the double threshold. (ii) Under the threshold effect of heterogeneous environmental regulation, two-way FDI synergy always exhibits a significant promoting effect on regional green technology innovation. This phenomenon shows that heterogeneous environmental regulation plays an important role during two-way FDI synergy by driving the development of regional green technology innovation, and the results further confirm the scientificity and rationality of the research framework in this paper.

Second, under the double thresholds of the three types of heterogeneous environmental regulation, the changing trends of the regression coefficients of two-way FDI synergy show clear differences. (i) Under the double thresholds of CER and PER, the regression coefficient of two-way FDI synergy first increases and then decreases. The middle threshold interval is the optimal interval for two-way FDI synergy. For the threshold role of CER, the government can initiate rapid environmental improvement by formulating environmental protection policies and enhance the promoting effect of two-way FDI synergy on regional green technology innovation. However, due to information asymmetry and other reasons, excessive CER causes enterprises to pay high compliance costs, squeezes R&D funds, and reduces this promoting effect [66]. For the threshold role of PER, increasing public awareness of environmental protection can enhance the promoting effect of two-way FDI synergy on regional green technology innovation. However, excessive PER leads to excessive constraints and restrictions on the development of regional green innovation, which is not conducive to two-way FDI synergy. Consequently, moderate CER and PER optimize the regional green technology innovation effect of two-way FDI synergy. (ii) Under the double threshold of MER, the regression coefficient of two-way FDI synergy gradually increases. The high threshold interval is the optimal interval for two-way FDI synergy. A higher MER is more conducive to its positive impact on regional green technology innovation. In the MER process, the government continuously invests capital expenditures for regional pollution control supervision and green technology R&D. A good R&D environment and sufficient funds not only attract high-quality IFDI inflows but also facilitate regional green technology innovation and OFDI activities. Therefore, with the increase in the MER threshold value, regional green technology innovation and development continue to improve.

Third, under the middle threshold effect of PER, the regression coefficient of two-way FDI synergy is 0.553; that is, two-way FDI synergy exhibits the greatest promoting effect on regional green technology innovation. When environmental pollution caused by economic production activities threatens public health, the public consciously exercises its environmental supervision rights and citizens' litigation rights granted by environmental protection laws through petitions, news media, and other means. Additionally, the people exert pressure on the government and environmental protection violators, push them to engage in green innovation, and maximize the promoting effect of two-way FDI coordination on regional green technology innovation.

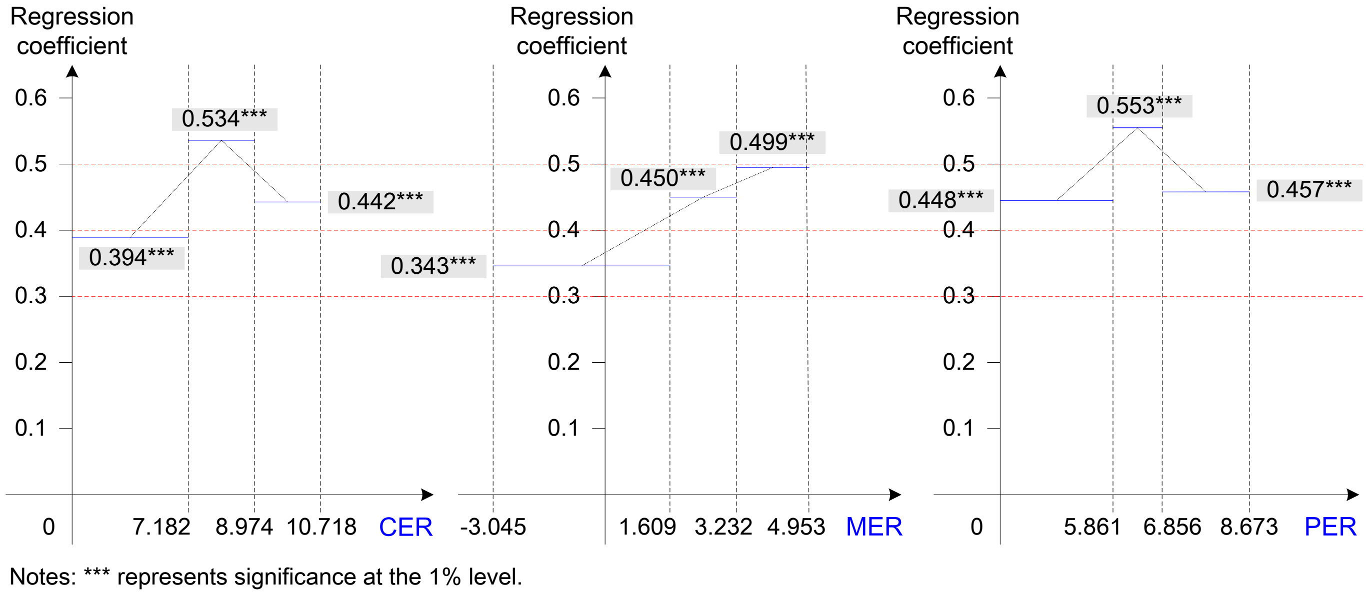

Figure 9. Influencing mechanism among the variables.

4.3.2. Further Analyses

The control variable is an important influencing factor of the independent variable. To present the impacts of IPR, INS, and TRA on regional green technology innovation, we construct Figure 10 based on the threshold-regression results in Tables 5, 8 and 11.

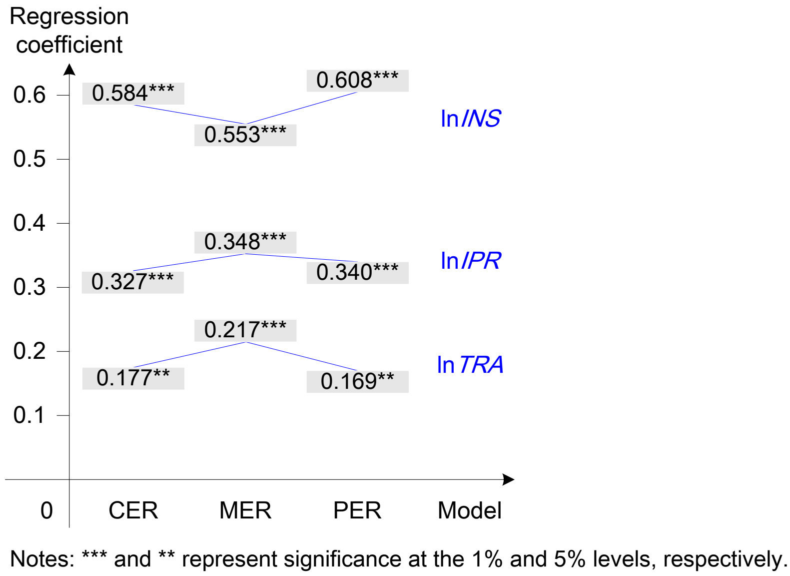

Figure 10. Influencing mechanisms of control variables.

Figure 10 presents the following findings.

First, the regression coefficients of IPR, INS, and TRA are all positive numbers, and all pass the significance test, indicating that these three control variables have significant promoting effects on regional green technology innovation. (i) A sound intellectual property protection system can increase the commercialization benefits of green innovation entities, provide a region with sufficient funds for green technology innovation, and stimulate the vitality of regional green technology innovation. (ii) The number of regional innovation institutions reflects the basic environment for regional innovation. An increase in INS means that the region is more capable of green technology innovation activities, which is conducive to improving regional green technology innovation. (iii) Good transportation infrastructure is conducive to the rapid flow of green innovation elements between regions, and it promotes the optimal allocation of green innovation resources, thereby enhancing regional green technology innovation.

Second, in the threshold models of the three types of heterogeneous environmental regulation, the promoting effect of INS on regional green technology innovation is stronger than IPR and TRA. Enterprises, universities, and research institutions, as the main bodies of green technology innovation, can directly engage in and provide human and physical capital for green technology innovation. Regarding IPR and TRA, their impacts on regional green technology innovation activities are more reflected in an external innovation environment. Although these factors influence regional green technology innovation, their promoting effects are not as direct or strong as that of INS.

5. Concluding Remarks

Based on the panel data of China's provinces from 2009 to 2020, we use the threshold-panel-regression technique, take heterogeneous environmental regulation as the threshold variable, and empirically discuss the threshold differentiation effect of two-way FDI synergy on regional green technology innovation from the three aspects of CER, MER and PER. There are five primary conclusions. (i) The effect of two-way FDI synergy on regional green technology innovation has significant threshold characteristics with heterogeneous environmental regulation as the double threshold. (ii) As the threshold values of CER and PER increase, the promoting effect of two-way FDI synergy on regional green technology innovation first increases and then decreases. (iii) As the MER threshold value increases, this promoting effect continues to grow. (iv) This promoting effect is the greatest under the medium-threshold condition of PER. (v) IPR, INS, and TRA all have significant positive effects on regional green technology innovation, and INS exhibits the greatest promoting effect.

From the above analysis, the policy implications of our findings are twofold. Regarding the theoretical implications, we construct the threshold-effect model of two-way FDI synergy on regional green technology innovation, reveal the influencing mechanism among the variables, and provide a theoretical basis for formulating a path to improving regional green technology innovation. Our study carries several practical implications. First, from the perspective of two-way FDI synergy, the government should use a double-cycle development strategy, strengthen high-quality opening up, further promote two-way FDI synergy, and enhance its promoting effect on regional green technology innovation. Second, from the perspective of heterogeneous environmental regulation, the government should optimize and adjust the intensity of environmental regulation tools in a timely manner consistent with the actual situation of two-way FDI synergy and regional green technology innovation. We should try our best to keep CER and PER at moderate levels. We can improve MER through economic means, such as subsidies or punitive incentives, to maximize the green technology innovation effect of two-way FDI synergy. Third, from the perspective of the control variable, the government should strengthen the protection of intellectual property rights, increase the number of regional innovation institutions, and focus on promoting the construction of transportation infrastructure to promote the high-quality development of regional green technology innovation.

Despite these contributions, our study has some limitations that require future research. First, we mainly focus on research at the regional level in China. We view the industries in a region as a homogeneous whole, and we do not include targeted discussion of specific industries. Future research can refine industry categories for classification and discussion. Second, the impact of two-way FDI synergy on is a complex dynamic process. Based on a threshold investigation, future research can further explore it in stages.

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