

Article

Two-Way FDI Synergy and Water Environmental Management Efficiency—An Empirical Study on the Mediating Effect of Heterogeneous Technological Innovation

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Abstract: In the context of China's synergistic development of import and export strategies and water environmental protection, this paper analyzes the role of two-way FDI synergistic development in water environmental governance efficiency based on panel data of 30 provinces, municipalities and autonomous regions in China from 2004 to 2021. The paper uses a fixed effect model and analyzes the role of heterogeneous technological innovation using the mediation effect model and the panel threshold model. The results of the study show the following: (1) overall, two-way FDI synergistic development helps to improve China's water environmental governance efficiency; (2) there is regional heterogeneity in the effect of two-way FDI synergistic development on China's water environmental governance efficiency, with a significant positive effect in areas along the coast and with high FDI synergistic development levels and an inhibitory effect in inland areas; and (3) the two-way FDI synergy enhances the efficiency of China's water environmental governance by improving the levels of independent innovation and imitation innovation.

Keywords: two-way FDI synergy; water environmental governance efficiency; heterogeneous technological innovation; fixed effect; mediation effect



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1. Introduction

In recent years, along with the acceleration of China's "bringing in" and "going out" processes, China's investment environment has continued to improve, and both the outward foreign direct investment (OFDI) of domestic enterprises and China's attraction of foreign direct investment (IFDI) have shown a booming trend. "Bringing in" refers to the introduction of foreign capital, technology, human resources and management experience, and "going out" refers to adherence to the basic national policy of opening up to the outside world. In 2022, China's utilization of OFDI flows reached USD 146.5 billion, and IFDI flows reached USD 189.1 billion. The considerable development of China's open economy is associated with the serious problem of water environmental pollution (Zhang Yu and Jiang Dianchun, 2014) [1]. The tragedy of the commons refers to the misuse of public resources by individuals seeking to maximize their profits, which ultimately leads to the depletion of resources. Water is the source of life, the key to production and the foundation of ecology, and due to its natural public attributes, it is difficult to prevent the excessive exploitation and utilization of water and sewage discharge by enterprises or individuals, thus causing the "tragedy of the commons" (Gu Shuzhong et al., 2022) [2]. According to statistics, from 2011 to 2022, on average, more than 8% of China's water bodies presented a poor, class V water quality, and the health risks caused by water pollution became an issue of considerable social concern (Song Min et al., 2023) [3]. Hence, increasing the investment in water pollution control and improving the efficiency of water environmental management constitute effective means to prevent pollution, and the protection of water resource security has become an important practical choice. Since the beginning of the 21st century, the

Chinese government has made remarkable achievements in water pollution control by introducing a series of policies and regulations for strict environmental access, but due to the shortage of water resources, insufficiently comprehensive regulation and uneven regional distribution, China's water resource control remains inefficient, and improving the efficiency of water environmental control has become an urgent problem to be solved (Shao Shuaibuai and Liu Lifen, 2023) [4]. The scale effect brought by the synergistic development of two-way FDI is accompanied by the aggravation of environmental pollution, while the technology spillover effect is conducive to the improvement in the environment (Wang Yafei et al., 2022) [5]. Exploring the relationship between the two-way FDI synergism and the efficiency of water environmental governance and analyzing whether this synergism can address the problem of water pollution are essential to China's efforts in protecting the water environment, formulating a reasonable international economic and trade policy, and adopting a path of sustainable development that supports coordinating mechanisms among the economy, ecology and environment. It is necessary to answer the question of whether the two-way FDI synergy can solve the water pollution problem.

Two-way FDI synergies include both foreign direct investment (FDI) and outward foreign direct investment (OFDI), which are interactively coupled with environmental governance (Dong Wan-yi et al., 2021) [6]. Under severe environmental pressure, the environmental effect of IFDI has received scholarly attention, and research on the impact of IFDI on the host country's environment mainly focuses on the pollution haven hypothesis and the pollution halo hypothesis. The former hypothesis posits that developed countries face more stringent environmental regulations and have higher nonproductive costs of investing in environmental protection, so developed countries tend to transfer pollution-intensive industries through international trade to developing countries that have more relaxed environmental regulations, resulting in environmental degradation in undeveloped countries [7,8]. The latter hypothesis suggests that foreign direct investment does not lead to environmental degradation but is conducive to improving environmental quality [9–11] (Letchumanan and Kodama 2000; Antweiler et al., 2001; Mert and Boluk 2016). Possible reasons for the existence of a pollution halo rather than a pollution haven are that enterprises investing in developing countries transfer cleaner production technologies to the host country, thus improving the host country's productivity and saving the host country's factor inputs, and the eco-innovation spillovers from foreign investment play a role as the host country's environmental protection level improves [12,13] (Wayne and Shadbegia, 2002; Huo Weidong et al., 2019). In 2013, Chinese President Xi Jinping proposed a cooperative initiative to build the "New Silk Road Economic Belt" and the "21st Century Maritime Silk Road", or the "Belt and Road Initiative", which aims to actively develop China's economic partnerships with other countries. In the context of the "Belt and Road" initiative, scholars have begun to focus on the impact of OFDI on the ecological environment of the home country, but they have mainly followed the theoretical framework of the impact of IFDI on the ecological environment. For example, Yang's (2021) [14] study showed that the home country's carbon dioxide emissions can be reduced through the technology level effect and the industrial structure effect; Hao et al. (2019) [15] suggested that OFDI can have a positive effect on the domestic ecological environment through structural optimization and reverse technology spillover. Other scholars believe that the reverse technology spillover effect of OFDI is low and cannot affect the home country's environment but may even increase pollution and, hence, would have a negative impact on the home country's ecological environment; this stream of research focuses on the field of carbon emissions [16,17] (Liu Haiyun and Li Min, 2016; Wang Yiji and Duan Yangzhou, 2023). In addition, scholars have explored the conditions or related factors of OFDI's effect on the environment of the home country. For example, Bai Zixin et al. (2022) [18] explored the mediating effect of industrial structure advancement and technological innovation progress, and Zhou Li and Pang Chenchen (2013) [19] argued that the structural optimization effect and the technological spillover effect differ across regions. In the context of China's economy, which is entering the stage of high-quality development and promoting in-depth development

through the synergistic development strategy of “bringing in” and “going out,” research on the synergistic development of the two-way FDI has gradually been emphasized by the academic community. Studies have indirectly explored the impact of two-way FDI synergy on the economic environment in terms of the technology spillover effect [20], total factor abatement effect [21], green innovation [22] and low-carbon total factor productivity [23] (Wang Lijuan et al., 2019; Gong Mengqi et al., 2020; Yang Shidi and Han Pioneer 2021; Wang Hui et al., 2020). However, only a few scholars have directly explored the impact of domestic two-way FDI synergistic development on the ecological environment, and related studies have focused on the carbon emission reduction effect [17,24] (Zhu Yuke et al., 2022; Wang Yiqi and Duan Yangzhou, 2023) or the impact on haze pollution [25] (Han Y. H. et al., 2021), with only a few studies having examined the utility of two-way FDI synergism in overall environmental efficiency [26] (Liu Haiyun and Yao Wei-wei, 2022).

To summarize, current studies have conducted more in-depth research on the environmental effects of foreign direct investment (IFDI) and outward foreign direct investment (OFDI), and in the study of the relationship between two-way FDI synergistic development and the environment, researchers have mainly focused on the impact of two-way FDI synergistic development on overall environmental efficiency or the breakdown of carbon emissions, with few studies focusing on the impact on the water environment. To bridge this knowledge gap, this paper analyzes the role of the two-way FDI synergistic development in China’s water environmental management efficiency based on panel data of 30 Chinese provinces, municipalities and autonomous regions for 2004–2021 and applies mediated effect models to analyze the mechanism of heterogeneous technological innovations. The possible marginal contributions of this paper are as follows: First, this paper applies the unguided, unexpected output superefficiency SBM model to measure China’s provincial-level water environmental governance efficiency and explores the impact of China’s two-way FDI synergistic development on water environmental governance efficiency. Second, this paper analyzes the heterogeneity of the impact of two-way FDI on water environmental governance efficiency between coastal and noncoastal regions, while taking the average development level of the two-way FDI synergy as the dividing line to analyze regional heterogeneity. Third, this paper incorporates heterogeneous technological innovation into the analytical framework that includes the threshold effect to analyze the intermediary mechanism played by China’s autonomous technological innovation and imitation technological innovation to provide policy recommendations for the benign, synergistic development of two-way FDI, improve the water environment and promote China’s high-quality development.

2. Materials and Methods

2.1. Theoretical Analysis and Research Hypothesis

In the early stage of reform and opening up, China first developed its economy, relying on the abundant and inexpensive factors of production to introduce numerous low-end manufacturing industry products into developed countries, and the governments of various regions tended to relax the conditions for foreign investment under the pressure of finance and promotion and to carry out “bottom-up” competition. Foreign investment often exacerbated the consumption of energy and resource products; therefore, it could not play an effective role in improving the environment and entailed the risk of circumventing the home country’s environmental regulations to transfer pollution to China. However, after the economy entered the new normal development stage, China emphasized the quality and efficiency of economic growth, and high-quality IFDI had an impact on the environment through the demonstration effect, technology spillover effect and competition effect (Dong Wanyi et al., 2021) [6]. This is specifically manifested as follows: ① Enterprises attract foreign capital and understand and learn foreign advanced clean technology and production standards, forcing China to improve environmental protection standards and production standards and reduce the pollution of the water environment. ② Imported technology and equipment for domestic products have a substitution effect to a certain

degree, changing China's domestic consumption structure, with China's domestic enterprises facing greater competitive pressure. To maintain a favorable position in the face of fierce market competition, domestic enterprises improve their production technology, management efficiency and resource utilization rate based on technological innovation. IFDI stimulates the development of OFDI through the above three effects. The main results are as follows: ① Foreign capital and local capital compete for market share, and local enterprises occupy a stronger market position, with foreign investment expanding the scope of production and operation. ② The demonstration effect and knowledge along with the technology spillover effect brought by IFDI accelerate the growth of local enterprises so that such enterprises have more capital reserves for foreign investment, which allows the local enterprises to have a higher competitive strength and risk tolerance in the wave of economic globalization. ③ With the interactive development of IFDI and OFDI, investing countries can obtain market information and investment experience in target countries at a lower cost, further accelerating the international capital flow. Then, the process of foreign investment by local enterprises has an impact on the quality of water environmental management in the home country; these types of OFDI can be categorized as technology-seeking, resource-acquiring and market-seeking. First, technology-seeking OFDI aims at merging and acquiring foreign advanced production technology and reintroduces advanced green production technology to the home country, which helps to improve China's water pollution control technology and water reuse level. Second, resource-acquisition OFDI helps enterprises in the home country to reduce their dependence on natural endowments, such as water resources; improves the input structure of production factors in domestic industries; and reduces the pollution of the water environment. Third, market-seeking OFDI can transfer sunset industries that are not adapted to the current situation of China's economic development; helps to release production factors, such as knowledge, technology and labor, from low-end- and high-energy-consuming production; supports the development of domestic strategic green water and environmental protection industries; significantly reduces the adverse impact on the water environment during the process of production and distribution; and enhances the efficiency of water environmental protection and governance. The positive impacts of OFDI on the water environment are outlined below. The benign, interactive development of IFDI and OFDI builds a two-way FDI synergy and helps to improve the efficiency of China's water environmental management.

H1: *The synergistic development of the two-way FDI in China contributes to the efficiency of water environmental management.*

One of the core drivers of the synergistic development of two-way FDI is the acquisition of technological resources. The reverse technology spillover effect of OFDI and the technology spillover effect brought about by IFDI contribute to the acquisition and accumulation of high-level factors of production, such as regional knowledge, technology and talent. These effects help Chinese domestic enterprises to learn from the advanced experience of foreign enterprises and then absorb and imitate their advanced production technology, thereby laying the foundation for independent technological innovation in the future. The technological innovation activities brought about by the synergistic development of two-way FDI are characterized by high marginal returns. Such activities help to guide the flow of production factors to the green water environmental protection industry with high technology content and improve the efficiency of water environmental management. Technological innovation can be divided into two types: imitation innovation and independent innovation [27]. How can the externalities brought about by the synergistic development of two-way FDI with respect to the efficiency of water environmental management play their role through these two paths of innovation? On the one hand, along with the mutual promotion of both the domestic and international cycle and in-depth two-way FDI synergistic development, China's domestic enterprises can use lower costs to adopt international advanced clean technology through "dry learning" to reduce the innovation and research and development of trial and error costs; this adoption takes

place as the imitation of innovation progresses, and at the same time, China can gradually accumulate experience in cleaner production. On the other hand, autonomous innovation refers to the ability of domestic firms to enhance their absorption of technological spillovers from advanced foreign firms while acquiring their own core technologies through in-house research and development. Autonomous innovation entails problems, such as high costs and long payback cycles. Foreign capital injection and the proceeds from outward investment by domestic enterprises provide financial support for internal clean production and R&D innovation and enhance the ability of local enterprises to conduct independent innovation. In the concurrent study of advanced foreign-funded enterprise technology and technology in general, domestic enterprises consciously take innovation as a strategy, increase innovation investment, undertake both imitation innovation and independent innovation, and gradually improve their own level of cleaner technology and green production technology. In this way, enterprises can improve their market position and reduce the loss of water resources, reduce the pollution of the water environment, enhance the capacity of wastewater treatment and utilization, and ultimately enhance the water environmental management efficiency.

H2: *China's two-way FDI synergistic development enhances the efficiency of water environmental management through two paths: imitation innovation and independent innovation.*

2.2. Research Design

2.2.1. Model Setup

(1) Model for Measuring the Efficiency of Water Environmental Management

Data envelopment analysis (DEA) is a method of operations research used for the study of economic production boundaries. This method is generally used to measure the efficiency of decision-making units. Traditional DEA models do not take unexpected outputs into account and cannot measure the efficiency value of indicators with such unexpected outputs. The slacks-based measure (SBM) model with the desired outputs overcomes this shortcoming of the traditional DEA model and can measure the efficiency value of indicators with undesired outputs. However, it is difficult to measure the difference when facing a situation in which the efficiency value of multiple decision-making units is 1. The superefficient SBM model with unexpected outputs overcomes the shortcomings of both of these methods and can effectively solve the slack problem in the efficiency measure and more accurately measure the superefficiency value of each decision unit [28]. The superefficient SBM model with unexpected outputs is constructed as follows [29]:

$$\begin{aligned}
 xl = \min & \frac{1 - \frac{1}{\sigma} \sum_{i=1}^{\sigma} \frac{C_i^-}{x_{i0}}}{1 + \frac{1}{(C_1 + C_2)} \left(\sum_{\theta=1}^{C_1} \frac{C_{\theta}^{\mu}}{Y_{\theta 0}^{\mu}} + \sum_{\theta=1}^{C_2} \frac{C_{\theta}^{\beta}}{Y_{\theta 0}^{\beta}} \right)} \quad (1) \\
 \text{s.t.} & \begin{cases} x_0 = X\rho + C^- \\ y_0^{\mu} = Y^{\mu}\rho - C^{\mu} \\ y_0^{\beta} = Y^{\beta}\rho + C^{\beta} \\ C^- \geq 0, C^{\mu} \geq 0, C^{\beta} \geq 0, \rho \geq 0 \end{cases}
 \end{aligned}$$

where xl is the value of the efficiency of water environmental management in China's provincial areas, σ is the input type of each decision-making unit ($x \in R^{\sigma}$), C_1 is the type of desired output ($y^{\mu} \in R^{C_1}$); C_2 is undesired output ($y^{\beta} \in R^{C_2}$); C^- is the residual of inputs; C^{β} is the residual of undesired outputs; C^{μ} is the shortfall of the desired outputs; θ represents the first θ decision unit; θ_0 represents the decision unit DMU to be solved; and ρ denotes the weight vector.

(2) Fixed effects model

The type of data collected in this paper is panel data, and the fixed effects (FE) model and the random effects (RE) model are models commonly used to address endogeneity in panel data. The individual point-in-time two-way fixed effects (TWFE) model addresses the individual effects and the time effects that do not change over time through the individual fixed effects model. Given the research purpose of this paper, the following TWFE econometric model was constructed:

$$xl_{it} = \alpha + \beta bfdi_{it} + \gamma X_{it} + \delta_i + \mu_t + \varepsilon_{it} \quad (2)$$

where xl_{it} is the dependent variable of this paper, i.e., the efficiency of water environmental management; $bfdi_{it}$ is the explanatory variable of this paper, i.e., the level of two-way FDI synergy development; X_{it} is the set of control variables affecting the innovation behavior of enterprises, including population density, water resource endowment, the degree of government intervention, industrial structure, the level of fixed asset investment and the level of industrialization; δ_i and μ_t represent individual and time fixed effects, respectively; and ε_{it} is the set of error terms.

In order to serve as a comparison and reference for the results, the specific regression steps conducted in this paper were as follows. First, the model does not control for any fixed effects and control variables, and the parameters were estimated using ordinary least squares. Second, province-level control variables potentially related to the efficiency of water pollution control in China were added to the model, and the parameters were estimated using clustered least squares regression. Next, provincial control variables were added to the model and regressed by random effects model. Finally, this paper added province-level control variables to the model while controlling for year as well as individual fixed effects, and performed fixed effects model regression.

(3) Mediating effects model and threshold effects model

To further analyze the relationship between the level of two-way FDI synergistic development and the efficiency of water environmental management and to explore the channels of its influence in depth, the following mediation effect model was constructed, with reference to the study of Wen Zhonglin et al. (2004) [30]:

$$xl_{it} = \mu_0 + \mu_1 bfdi_{it} + \mu_2 X_{it} + \delta_i + \mu_t + \varepsilon_{it} \quad (3)$$

$$Z_{it} = \gamma_0 + \gamma_1 bfdi_{it} + \gamma_2 X_{it} + \delta_i + \mu_t + \varepsilon_{it} \quad (4)$$

$$xl_{it} = \delta_0 + \delta_1 bfdi_{it} + \rho Z_{it} + \delta_2 X_{it} + \delta_i + \mu_t + \varepsilon_{it} \quad (5)$$

where Z_{it} is the mediating variable indicating the heterogeneous type of technological innovation and X_{it} is the set of control variables in the baseline model. If the model simultaneously satisfying Equation (4) in γ_1 is significant and Equation (5) in δ_1 and ρ is significant, it indicates that Z_{it} has a mediating role.

Then, taking regional imitative innovation and autonomous innovation as the threshold variables, the panel threshold model was used to further analyze how technological innovation affects the utility of the two-way FDI synergistic development on water environmental governance efficiency, and the following panel threshold model was constructed:

$$xl_{it} = \alpha + \beta bfdi_{it} \times I(Z_{it} \leq \delta_1) + \beta_2 bfdi_{it} \times I(\delta_1 < Z_{it} \leq \delta_2) + \dots + \beta_n bfdi_{it} \times I(\delta_{n-1} < Z_{it} \leq \delta_n) + \beta_{n+1} bfdi_{it} \times I(Z_{it} > \delta_n) + \mu X_{it} + \delta_i + \mu_t + \varepsilon_{it} \quad (6)$$

where δ is the threshold estimate and I is the indicative function.

2.2.2. Description of Variables

(1) Explained Variables

The dependent variable in this paper was water environmental governance efficiency (xl). (Table 1) To measure the water environmental governance efficiency of Chinese provinces, this paper referred to the studies of Huang Wanhua et al. (2022) [31], Song

Min et al. (2023) [3], and Shang Zhinan et al. (2020) [32] and selected the following indexes to construct an evaluation system of water environmental governance efficiency, which was measured with the help of MATLAB R2020a software using the unguided, unexpected output superefficiency SBM model.

Table 1. Evaluation index system of China’s provincial-level water environmental management efficiency.

Level 1 Indicators	Secondary Indicators	Tertiary Indicators
Input indicators	Financial input indicators	Completed investment in wastewater treatment projects (USD million)
	Human input indicators	Employment in urban units of the water, environment and utilities management industry (10,000 persons)
	Physical input indicators	Number of urban sewage treatment plants (blocks)
Output indicators	Expected outputs	Total sewage treatment (million cubic meters)
		Municipal recycled water use (million cubic meters)
	Unexpected outputs	Chemical oxygen demand (tons) Ammonia nitrogen emissions (tons)

(2) Core explanatory variables

The core explanatory variable of this paper was the two-way FDI synergy development level (bfdi). Referring to the capacity coupled system model in physics, the two-way coupling level was calculated as follows:

$$C_{it} = \frac{OFDI_{it} \times IFDI_{it}}{(\rho OFDI_{it} + \sigma IFDI_{it})^\theta} \quad (7)$$

where $IFDI_{it}$ and $OFDI_{it}$ are China’s outward direct investment and foreign direct investment flows converted at the annual average RMB exchange rate, respectively; and C_{it} is the degree of coupling between the two. Because “bringing in” and “going out” are equally important to the Chinese government, this paper adopted $\rho = 0.5$ and $\sigma = 0.5$, respectively, and θ denotes the adjustment coefficient, which equals 2, referring to the study of Huang Lingyun et al. [33]. To reflect the coupling degree of OFDI and IFDI as well as their degree of coordination, the coordinated development index was further introduced:

$$D_{it} = \left(C_{it} \times \frac{OFDI_{it} + IFDI_{it}}{2} \right)^{\frac{1}{2}} \quad (8)$$

Combining the two equations yields the level of two-way FDI synergy development:

$$bfdi_{it} = \left[\frac{OFDI_{it} \times IFDI_{it}}{(OFDI_{it} + IFDI_{it})/2} \right]^{\frac{1}{2}} \quad (9)$$

The larger the value of $bfdi_{it}$, the higher the level of synergistic development of China’s FDI and direct FDI in both directions in the corresponding region in the corresponding year.

(3) Mediating variables

Studies have measured regional technological innovation from the perspective of input and output, in which the output indicators are mostly measured by the number of patents, which can visualize the level of technological innovation [27,34]. According to the previous theoretical analysis, this paper selected heterogeneous technological innovation as the mediating variable and subdivided technological innovation into autonomous technological innovation and imitation technological innovation.

① Autonomous technological innovation: The number of invention patent authorizations was used to measure autonomous innovation.

② Imitation technological innovation: The sum of utility model patent and design patent authorizations was used to characterize imitation technological innovation.

(4) Control variables

To reduce the bias of the regression results caused by the omitted variables, the following control variables were selected, with reference to previous studies [27,34,35].

① Population density: expressed as the ratio of the regional population to the area of administrative division.

② Water resource endowment: expressed as per capita water resources.

③ Degree of government intervention: expressed as the proportion of government fiscal expenditure to GNP.

④ Industrial structure: expressed as the ratio of the output value of tertiary industry to the output value of the secondary industry.

⑤ Level of fixed asset investment: expressed as the proportion of fixed asset investment to GNP.

⑥ Level of industrialization: expressed as the proportion of industrial value-added products to GNP.

2.2.3. Data Sources

In view of data availability and the purpose of this paper, the research period of this paper was 2004–2021, and the sample of this paper was 30 provinces, municipalities and autonomous regions in China (due to missing data, the sample of this paper did not cover Hong Kong, Macao Special Administrative Region of China, Taiwan and Tibet Autonomous Region of China). The data for the variables in this paper came from the statistical yearbook of each province, China Statistical Yearbook, China Environmental Statistical Yearbook, China Environmental Yearbook, China Outward Foreign Direct Investment Statistical Bulletin and the EPS data platform, and the data were analyzed and processed using Stata 16. Some missing data were filled in by linear interpolation.

Specific variable meanings and the descriptive statistics of the variables are shown in Table 2.

Table 2. Meaning of the variables and descriptive statistics of the variables.

Variable Type	Variable Symbol	Variable Meaning	Observed Value	Average Value	(Statistics) Standard Deviation	Minimum Value	Maximum Value	Observed Value
Dependent variable	xl	Efficiency of water environmental management	540	0.4	0.4	0	0.2	1.8
Explanatory variable	bfdi	Level of two-way FDI synergy development	540	5.2	5.2	0	3.8	28.3
Intermediary variable	zz	Autonomous and innovative	540	9.3	1.7	3.9	9.4	13.6
	mf	Imitate and innovate	540	7.5	1.7	3	7.6	11.5
Control variable	people	Population density	540	0.5	0.7	0	0.3	3.9
	water	Water resources per capita	540	2.1	2.6	.1	1.6	17.1
	gov	Government fiscal expenditure as a share of GDP	540	0.2	0.1	0.1	0.2	0.6
	jg	Tertiary output vs. ratio of secondary sector output	540	1.1	0.6	0.5	0.9	5.3

Table 2. Cont.

Variable Type	Variable Symbol	Variable Meaning	Observed Value	Average Value	(Statistics) Standard Deviation	Minimum Value	Maximum Value	Observed Value
	fix	Investment in fixed assets as a share of GDP	540	0.7	0.3	0.1	0.7	1.5
	industry	Industrial value-added products as a share of GDP	540	3.4	0.9	1	3.5	5.6

3. Results

3.1. Basic Econometric Regression Results

The benchmark regression results of this paper are shown in Table 3. The dependent variables were all China's provincial water environment governance efficiency, *xl*. The Hausman test yielded a *p*-value of 0.00, thus rejecting the original hypothesis that the individual effects are not related to the explanatory variables and supporting the choice of the panel data fixed effects model for empirical analysis. The fixed effects model regression results are shown in Table 3, model (4). As shown in the results of the benchmark regressions, the estimated coefficients on the core explanatory variable of all models, i.e., the two-way FDI synergy development level, are statistically, significantly positive at the 10% level, regardless of the controls. From the regression results of the fixed effects model, it can be seen that, at a statistical level of 1%, for every 1% increase in the level of two-way FDI synergistic development, the efficiency of water environmental governance improves by 0.015%.

Table 3. Benchmark test of the impact of two-way FDI synergy on the efficiency of water environmental management.

Variable	Model (1) <i>xl</i>	Model (2) <i>xl</i>	Model (3) <i>xl</i>	Model (4) <i>xl</i>
bfdi	0.0400 *** (0.00286)	0.0229 * (0.0112)	0.0229 *** (0.00468)	0.0150 *** (0.00549)
people		−0.428 (0.287)	−0.428 ** (0.216)	0.0276 (0.231)
water		0.0263 (0.0217)	0.0263 (0.0194)	0.0198 (0.0196)
gov		−0.607 (0.465)	−0.607 (0.385)	−0.665 (0.469)
jg		0.190 * (0.106)	0.190 *** (0.0587)	−0.0401 (0.0733)
fix		0.133 (0.168)	0.133 (0.0853)	0.0525 (0.0969)
industry		0.0427 (0.0759)	0.0427 (0.0394)	0.104 ** (0.0409)
Constant	0.158 *** (0.0220)	1.101 * (0.568)	1.101 *** (0.309)	−0.0239 (0.204)
Individual fixed effect	No	No	No	Yes
Time fixed effect	No	No	No	Yes
Observations	540	540	540	540
R2	0.228	0.595		0.205

Note: Values in parentheses are T statistics; *, ** and *** represent significance levels of 10%, 5% and 1%, respectively.

3.2. Split-Sample Regression

To examine the regional heterogeneity of the influence of the two-way FDI synergistic development level on the efficiency of water environmental management, a subregional

regression analysis was conducted. First, based on the differences in economic resource endowment and openness to the outside world between China's coastal and noncoastal regions, the research sample was divided into coastal and noncoastal regions for the regression, and the results are shown in Table 4, models (1)–(2). Then, it was further discussed whether the level of two-way FDI synergistic development affects its role in the efficiency of water environmental management. Taking the average value of the two-way FDI synergistic development level as the division, the sample was divided into a group with high two-way FDI synergistic development and a group with low two-way FDI synergistic development, and the regression results are shown in Table 4, models (3)–(4).

Table 4. Regional heterogeneity analysis of the impact of two-way FDI synergy on the efficiency of water environmental management.

Variable	Model (1) xl	Model (2) xl	Model (3) xl	Model (4) xl
bfdi	0.036 *** (0.009)	−0.024 * (0.014)	0.031 *** (0.009)	−0.037 (0.024)
people	−0.086 (0.293)	1.933 ** (0.980)	−1.039 (0.797)	0.902 (0.705)
water	0.070 (0.051)	0.010 (0.022)	0.016 (0.046)	0.031 (0.027)
gov	−3.322 * (1.694)	−0.734 * (0.423)	−1.351 (1.065)	−1.325 ** (0.581)
jg	−0.130 (0.215)	−0.061 (0.128)	−0.092 (0.130)	−0.044 (0.198)
fix	−0.186 (0.186)	0.219 ** (0.091)	0.056 (0.150)	0.029 (0.128)
industry	0.397 ** (0.166)	0.080 (0.049)	0.307 ** (0.123)	0.121 * (0.066)
Constant	−0.393 (0.746)	−0.322 (0.327)	0.339 (0.757)	−0.067 (0.457)
Individual effect	Yes	Yes	Yes	Yes
Time effect	Yes	Yes	Yes	Yes
Observations	198	342	183	350
R2	0.565	0.688	0.797	0.558

Note: Values in parentheses are T statistics; *, ** and *** represent significance levels of 10%, 5% and 1%, respectively.

3.3. Intermediation Mechanism Test

Based on the above theoretical analysis, this paper explored whether a mediating role of imitation innovation and independent innovation exists. The results are shown in Table 5. As it can be seen in the table, first, the impact coefficient of the level of two-way FDI synergy development in China on imitation innovation is 0.014, which is significant at the 1% significance level; the impact coefficient of the imitation innovation capacity on the efficiency of water environment management is 0.025, which is significant at the 10% significance level. Second, the coefficient of the impact of the level of two-way FDI synergy development in China on the independent innovation capacity is 0.19, which is significant at the 1% significance level; and the coefficient of the impact of independent innovation capacity on the efficiency of water environment management is 0.048, which is significant at the 1% significance level.

Table 5. Mediation mechanism test for the impact of two-way FDI synergy on the efficiency of water environmental management.

Variable	Imitate and Innovate			Autonomous and Innovative		
	(1) xl	(2) mf	(3) xl	(4) xl	(5) zz	(6) xl
mf			0.025 * (0.014)			

Table 5. Cont.

Variable	Imitate and Innovate			Autonomous and Innovative		
	(1) xl	(2) mf	(3) xl	(4) xl	(5) zz	(6) xl
zz						0.048 *** (0.015)
bfdil	0.135 *** (0.003)	0.014 ***	0.009 * (0.004)	0.135 *** (0.003)	0.190 *** (0.010)	0.004 (0.004)
people	0.163 *** (0.027)	0.005 (0.082)	0.163 *** (0.027)	0.163 *** (0.027)	0.108 (0.077)	0.158 *** (0.027)
water	0.009 (0.007)	−0.026 (0.216)	0.009 (0.007)	0.009 (0.007)	−0.065 (0.020)	0.012 * (0.007)
gov	−0.316 (0.223)	−5.808 *** (0.678)	−0.168 (0.237)	−0.316 (0.223)	−5.225 (0.635)	−0.067 (0.234)
jg	0.322 *** (0.037)	0.955 *** (0.112)	0.298 *** (0.039)	0.322 *** (0.037)	1.049 (0.105)	0.272 *** (0.040)
fix	0.005 (0.074)	2.586 *** (0.224)	−0.061 (0.082)	0.005 (0.074)	2.537 (0.210)	−0.116 (0.082)
industry	0.029 (0.024)	0.726 *** (0.073)	0.011 (0.026)	0.029 (0.024)	0.483 (0.069)	0.006 (0.025)
Constant	−0.182 (0.131)	4.348 (0.399)	−0.293 ** (0.144)	−0.182 (0.131)	3.197 (0.373)	−0.334 ** (0.138)
Observations	540	540	540	540	540	540
R2	0.459	0.688	0.462	0.459	0.724	0.469

Note: Values in parentheses are T statistics; *, ** and *** represent significance levels of 10%, 5% and 1%, respectively.

3.4. Panel Threshold Analysis Based on Heterogeneous Types of Technological Innovation

Does regional two-way FDI synergistic development have different impacts on water environmental governance efficiency under different heterogeneous technological innovation thresholds? This paper adopted the bootstrap self-sampling method to obtain the F value and the corresponding *p*-value of the threshold effect test and selected 400 as the number of sampling times. The results of the threshold effect test are shown in Table 6. Regional independent innovation passed the single-threshold test, and the threshold value was 8.4814. Regional imitation innovation did not pass the threshold test. The regression results of the panel threshold model are shown in Table 7.

Table 6. Panel threshold effect tests.

Threshold Variables	Original Hypothesis	F Value	<i>p</i> -Value	Confidence Interval (Math.)			Threshold Value
				1%	5%	10%	
autonomous and innovative	single threshold	35.02	0.0200	41.9746	26.4869	21.3651	8.4814
imitate and innovate	single threshold	13.07	0.3350	43.2571	28.4529	22.0503	/

Table 7. Estimation results of the panel threshold model.

Variable	Autonomous Technological Innovation
	xl
bfdi-1	−0.0164 (0.0115)
bfdi-2	0.0222 ** (0.0102)
control variable	be
constant term (math.)	0.0779 (0.323)
N	540
R2	0.188

Note: Values in parentheses are T statistics; ** represent significance levels of 5%.

3.5. Robustness Tests

To further increase the reliability, robustness and reasonableness of the regression analysis, this paper conducted robustness tests in the following aspects: ① Winsorization. The main variables were subjected to winsorization at the 1st and 99th percentiles to eliminate the influence of extreme values and re-examine the effect of the two-way FDI synergies on the efficiency of water environmental management, and the results are shown in model (1) in Table 8. ② Replacement of the explanatory variables. The output-oriented superefficient SBM model was used to remeasure the efficiency value of water environmental management, a fixed effects model regression analysis was conducted, and the results are shown in Table 8, model (2). ③ Restricted dependent-variable model panel Tobit model analysis. Given the explanatory variables, the distribution of water pollution management efficiency is $[0, \infty)$, that is, there is a truncation. This paper further considered the restricted dependent-variable model panel Tobit for the robustness test, and the results are shown in Table 8, model (3).

Table 8. Robustness test.

Variable	Winsorization Model (1)	Substitution of Explanatory Variables Model (2)	Panel Tobit Model Test Model (3)
bfdil	0.022 *** (0.007)	0.014 ** (0.006)	0.015 *** (0.005)
people	−0.073 (0.288)	−0.028 (0.241)	0.028 (0.219)
water	0.012 (0.028)	0.003 (0.018)	0.020 (0.019)
gov	−1.317 ** (0.628)	−0.561 (0.386)	−0.665 (0.445)
jg	0.171 (0.179)	−0.079 (0.108)	−0.040 (0.070)
fix	0.049 (0.097)	0.038 (0.080)	0.053 (0.092)
industry	0.105 * (0.054)	0.068 (0.046)	0.104 *** (0.039)
Constant	−0.053 (0.316)	0.352 (0.246)	1.326 *** (0.297)
individual effect	Yes	Yes	Yes
time effect	Yes	Yes	Yes
Observations	472	540	540
R2	0.602	0.633	

Note: Values in parentheses are T statistics; ** and *** represent significance levels of 5% and 1%, respectively.

4. Discussion

The basic econometric regression results show that the increase in the level of the two-way FDI synergistic development significantly promotes the improvement in the efficiency of water pollution management in Chinese provinces. Hypothesis H1 of this paper is verified. From the results of the robustness test, it can be seen that, whether winsorizing, replacing the explanatory variables or replacing the model, China's two-way FDI synergistic development has a significant positive utility on the efficiency of water pollution management, and the results of this paper are highly robust. According to the regression results of the control variables, at a statistical level of 5%, for every 1% increase in the level of industrialization, the efficiency of water environmental management increases by 0.104%. The discussion on industrialization and environmental quality begins with the theory of the environmental Kuznets curve (EKC), according to which environmental pollution gradually increases with the development of the industrialization process, but when industrialization develops to a certain level, environmental quality begins to improve. In other words, environmental factors can slowly self-regulate in the development process

of industrialization, and this self-regulation process depends on national economic restructuring and technological restructuring. When industrialization develops to a certain stage, it begins to have a positive effect on the efficiency of water environmental management. Population density, water resource endowment, the degree of government intervention, industrial structure and the level of investment in fixed assets have not yet had a statistically significant impact on the efficiency of water environmental management, indicating that these factors have not, to date, become key elements for improving the efficiency of water pollution management in China.

The impact coefficient of the two-way FDI synergistic development level on water environmental governance efficiency in coastal areas is 0.036, which is significantly positive at the 1% statistical level, indicating that the improvement in the two-way FDI synergistic development level in coastal areas contributes to the enhancement in water environmental governance efficiency. However, the impact coefficient of the two-way FDI synergistic development in noncoastal areas on the efficiency of water environmental governance is -0.024 , which is significantly negative at the 10% statistical level, indicating that the level of the two-way FDI synergistic development plays an inhibitory role. Possible reasons for this are as follows: (1) Coastal cities opened up earlier, and with their advantages in terms of geography, foreign trade policy, industrial base, infrastructure level, and people's environmental education, environmental regulations are more appropriate, and the water environmental technology spillover effect associated with two-way FDI synergistic agglomeration can be better understood. Noncoastal areas are underdeveloped in terms of the level of industrialization, science, and technology, but their land, labor, and other factors of production cost less, enabling them to attract IFDI seeking cost-effective factors of production. Moreover, their foreign investment motivation and ability are insufficient, and their two-way FDI synergistic development is not high, such that it cannot improve the quality of the water environment very well. (2) Two-way FDI synergistic development is accompanied by the expansion of the domestic production scale, and the scale effect of foreign trade development in inland areas causes the aggravation of water environmental pollution. This causes two-way FDI synergistic development in inland areas to inhibit improvement in the efficiency of water environmental management. The further observation of the regression results of the group with a high two-way FDI synergistic development and of the group with a low two-way FDI synergistic development shows that, in the regions of China with a high two-way FDI synergistic development level, the coefficient of the two-way FDI development level is 0.031, which significantly promotes the improvement in the efficiency of water environmental governance at the 1% statistical level. In the regions of China with a low two-way FDI synergistic development level, the coefficient of two-way FDI development on water environmental governance efficiency is -0.037 , which is not significant at a statistical level. The utility of two-way FDI synergistic development for the efficiency of water environmental governance is closely related to the level of two-way FDI synergistic development, and the positive externality on the efficiency of water environmental governance can be realized only when the two-way FDI synergistic development reaches a certain level.

The regression results of the mediating mechanism show the following: ① For the mechanism of imitation innovation, the level of two-way FDI synergistic development in Chinese provinces and regions significantly promotes regional imitation innovation, and the enhancement in regional imitation innovation capacity significantly improves the efficiency of water environmental governance. From the perspective of autonomous innovation mechanisms, the level of two-way FDI synergistic development in China's provinces and regions significantly promotes regional autonomous innovation capacity, and the improvement in regional autonomous innovation capacity contributes to the improvement in water environmental governance efficiency. H2 of this paper is verified, i.e., the level of regional two-way FDI synergistic development generates a significant positive effect on the efficiency of water environmental governance through two paths, namely, imitation innovation and independent innovation. When the level of regional

independent innovation is not higher than 8.4814, the effect of the two-way FDI synergistic development level on water environmental governance efficiency is not significant; when the level of regional independent innovation is higher than 8.4814, the two-way FDI synergistic development level increases by 1%, and the water environmental governance efficiency improves by 0.022%. This indicates that independent R&D is a long-cycle and high-return process, and in the early stage of independent R&D, the technological spillover effect of the two-way FDI synergistic development on water environmental governance cannot be well exerted. Only when the accumulation of independent R&D reaches a certain level does quantitative change cause qualitative change, and independent innovation has a significant marginal promotion effect on the spillover of the two-way FDI synergistic development of the environmental effect. Therefore, to achieve a sustainable, positive effect of two-way FDI synergistic development on water environmental management, the core lies in learning and imitating the excellent technology of advanced countries to lay a solid foundation for further independent innovation and then play the “late-comer advantage” to actively conduct independent technology research and development and persist in independent technology innovation for a long period to overcome technological difficulties and firmly grasp the advantages of technologies.

5. Conclusions and Recommendations

This paper applied the superefficient SBM model to measure the water environmental governance efficiency of 30 provinces, municipalities and autonomous regions in China, and based on panel data of 30 provinces, municipalities and autonomous regions in China from 2004 to 2021, it explored the impact of bidirectional FDI synergistic development on water environmental governance efficiency by using a fixed-effects model. It also analyzed the intermediary mechanism role played by heterogeneous technological innovations and the threshold effect. The following conclusions can be drawn.

Firstly, the two research hypotheses of this paper were verified. Overall, two-way FDI synergistic development helps to improve the efficiency of water environment governance in China. The level of two-way FDI synergistic development positively affects the efficiency of water environment governance through the two mediating mechanisms of imitation innovation and independent innovation.

Then, there was regional heterogeneity in the impact of two-way FDI synergistic development on China's water environment governance efficiency, and two-way FDI synergistic development had a significant positive effect in the coastal region and an inhibitory effect in the inland region. Noncoastal areas had obvious deficiencies in two-way FDI synergistic development and water environment governance. The promotion effect of two-way FDI synergistic development on the efficiency of water environment governance was more significant in places with high levels of FDI synergistic development.

In addition, independent innovation is characterized by a long cycle and high returns. According to the panel threshold regression results of heterogeneous technological innovation, when the level of independent innovation is lower than the 8.4814 threshold, the impact of two-way FDI synergistic development on water environmental governance efficiency is not significant. When the level of independent innovation exceeds the 8.4814 threshold, two-way FDI synergistic development has a promoting effect on the efficiency of water environment governance.

Based on the findings of this paper, the following policy recommendations are proposed:

First, we should emphasize the synergistic development of two-way FDI and consider the processes of “bringing in” and “going out” as equally important. Relevant departments should provide legal and policy support for the synergistic development and quality upgrading of two-way FDI, introduce high-quality IFDI in a purposeful and selective way, and guide the flow of foreign capital to water environmentally friendly and high-tech industries. Moreover, OFDI should be utilized to integrate domestic and foreign resources and transfer out sunset industries that do not meet the requirements of China's water environment quality.

Second, a regional environmental synergistic management strategy should be implemented to promote the regional linkage effect of water environmental management. Coastal areas should play a good role as a model, expanding the degree of openness while adhering to green coordinated development and providing inland areas with sufficient talent and technical support. Inland areas should rely on the national strategy of “Western Development”; create a good business environment; improve the attractiveness of high-quality IFDI; increase investment in R&D of clean water technology; promote the combination of industry, academia and research; and prevent the risk of the tragedy of the commons.

Third, we should rely on imitation innovation, strengthen independent innovation and give full play to the technology spillover effect of two-way FDI synergistic development on water environmental management. China should rely on “dry learning” to absorb, imitate and transform the water environmental management technology of advanced countries and give full play to the “late-comer advantage” to actively conduct independent innovation to develop in parallel or even surpass the technology level of advanced countries. The government should flexibly use innovation subsidies, tax relief and other tools to encourage enterprises to strengthen independent innovation and strengthen the application of cleaner production technology for the water environment to accelerate the penetration of technological innovation into water environmental management.

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