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An Empirical Analysis of the Impact of FDI on Environmental Quality in the Beijing-Tianjin-Hebei Region of China

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Abstract: *In the context of the coordinated development of the Beijing-Tianjin-Hebei region, scientifically assessing the impact of Foreign Direct Investment (FDI) on environmental quality holds significant practical significance for China. Based on panel data from 2003 to 2021 for 13 prefecture-level and above cities in the Beijing-Tianjin-Hebei region, this paper employs various econometric methods to examine the effects of FDI on environmental quality. The study finds that FDI exhibits a significant inverted "U" relationship with environmental quality, and this conclusion remains unchanged after a series of robustness tests and endogeneity treatments. Mechanism analysis indicates that industrial scale serves as a potential channel through which FDI influences environmental quality. Heterogeneity analysis reveals that compared to coastal areas, the inverted "U" shaped relationship between FDI and environmental quality is more pronounced in inland regions. Spatial econometric analysis demonstrates a significant negative spatial effect on environmental quality, suggesting that improvements in local environmental quality come at the expense of deteriorating environmental quality in other regions.*

Keywords: *FDI, environmental quality, instrumental variable, spatial regression*

1. Introduction

As an important channel for China to participate in the global value chain, Foreign Direct Investment (FDI) significantly contributes to bridging the funding gap in domestic economic development, enhancing the ability to connect with "two markets," and utilizing "two types of resources." FDI integrates capital, technology, marketing, and management, introducing advanced technology and management experience through spillover effects, thereby serving as one of the main engines driving China's continuous industrial restructuring and rapid economic growth in recent years. However, globally, while FDI promotes economic growth, it may also have negative effects on the environmental quality of host countries, although the impact of FDI on China's environmental quality remains to be examined. Compared to the Yangtze River Delta and Pearl River Delta regions, the Beijing-Tianjin-Hebei region is the third-largest engine of China's economic growth, with a relatively late start but rapid development in attracting foreign investment. From 2000 to 2021, the actual utilization of foreign investment in the Beijing-Tianjin-Hebei region increased from \$6.386 billion to \$56.213 billion, accounting for the proportion of the national foreign investment amount increasing from 15.68% to 31.06%.

Meanwhile, the Beijing-Tianjin-Hebei region, as a focal area for FDI, has witnessed an increasingly evident degradation of its ecology and environment in recent years. According to the "2022 China Ecological Environment Status Report" released by the Chinese Ministry of Ecology and Environment, the proportion of days with air quality exceeding standards in urban areas of the Beijing-Tianjin-Hebei region averaged 33.3%; the number of days with light pollution reached 25.1%; and the annual average concentration of PM2.5 was 44 micrograms per cubic meter, exceeding China's second-level standard of 35 micrograms per cubic meter. So, has FDI contributed to the deterioration of the environmental quality in the Beijing-Tianjin-Hebei region? If so, what are the underlying mechanisms? Answers to these questions can reveal the intrinsic connection between FDI and environmental quality, enrich existing research, and hold certain theoretical significance. By taking ecological conservation as a starting point, identifying the impact of FDI on the environmental quality of the Beijing-Tianjin-Hebei region and its mechanisms can effectively drive synergistic development in the region, carrying significant practical implications.

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2. Literature Review

Existing literature on the relationship between FDI and environmental pollution in host countries mainly consists of three viewpoints. Firstly, the "pollution haven" hypothesis suggests that FDI leads to a decline in the environmental quality of host countries. In the early stages of economic development, to attract foreign capital inflows, developing countries may relax environmental regulatory standards to some extent. This accelerates the exploitation of natural resources to produce and export pollution-intensive and resource-consuming products, catering to the demand of developed countries to lower pollution control costs. Consequently, developed countries prioritize transferring "dirty" industries and industrial chains to regions with relatively lax environmental regulations, turning these areas into "pollution haven" for developed countries [1-5].Secondly, the "pollution halo" hypothesis argues that FDI has positive effects on the environmental quality of host countries. Advanced clean production technologies brought by FDI not only reduce their own pollution emissions but also stimulate local enterprises' green production through demonstration, competition, and learning effects. This improves the pollution control efficiency of the entire industry and increases local environmental welfare [6-9].Thirdly, the relationship between FDI and the environmental quality of host countries exhibits nonlinear characteristics, influenced by the comprehensive effects of various factors, and may combine both "pollution haven" and "pollution halo" effects [10]. On the one hand, the economic scale and economic structure effects brought by FDI not only expand the production scale and output level of host countries but also exacerbate pollution emissions by favoring industries with high consumption, high energy consumption, and heavy pollution. On the other hand, the income effect and technology transfer effect brought by FDI not only increase the income level of host country residents but also improve the level of clean production and pollution control technologies. This, in turn, promotes investment in pollution control by increasing pollution control inputs and raising pollution tax rates, thereby driving enterprises towards pollution control investments. Therefore, the impact of FDI on environmental quality depends on the combined effects of these factors [11].

Currently, there is limited research on the impact of Foreign Direct Investment (FDI) on the environmental quality of the Beijing-Tianjin-Hebei region. Mao Mingming and Sun Jian (2015) conducted an analysis of the influence of FDI on carbon emissions in the Beijing-Tianjin-Hebei region by estimating carbon emission data from 2000 to 2012. The results indicate that the inflow of FDI has led to an increase in local carbon emissions [12]. Ren Zhixin (2015) found that FDI in the Beijing-Tianjin-Hebei region has suppressed atmospheric pollutants such as sulfur dioxide, smoke, and dust, but has increased carbon dioxide emissions [13]. Wang Xiaoling et al. (2019) analyzed the impact of FDI on the environmental performance of the Beijing-Tianjin-Hebei region using the FGLS model. They argue that FDI promotes overall environmental quality improvement and exhibits a "pollution halo" effect [14].

In summary, existing research on the environmental effects of FDI is abundant, providing a solid theoretical foundation for this study. However, there is a lack of literature specifically addressing the impact of FDI on environmental quality in the Beijing-Tianjin-Hebei region. This paper utilizes panel data from 13 prefecture-level and above cities in the Beijing-Tianjin-Hebei region from 2003 to 2021. Through the entropy method, an integrated environmental quality index is constructed, and various econometric methods are employed to examine the impact of FDI on environmental quality, its mechanisms, as well as potential spatial effects of environmental quality.

The potential contributions of this paper are as follows: First, utilizing city-level data and employing various econometric methods, this study identifies the effects of FDI on environmental quality, leading to robust research conclusions. Second, building upon existing literature, this paper proposes and empirically tests the mechanism through which FDI influences environmental quality via industrial scale, thereby deepening existing knowledge. Third, this study employs the spherical distance from various locations in the Beijing-Tianjin-Hebei region to Tianjin City as an instrumental variable for FDI and validates its rationality, thereby enriching the current research landscape

3. Theoretical analysis

Regarding the mechanisms of how FDI influences environmental quality, the impact of FDI on environmental quality involves both direct transmission mechanisms through scale, structure, and technological effects, as well as indirect transmission mechanisms through income and policy effects [15]. Foreign-invested enterprises affect sulfur dioxide emission intensity through three channels: horizontal spillover, forward spillover, and backward spillover [16]. Simultaneously, FDI inflows have improved end-of-pipe treatment technologies only through horizontal connections, but have enhanced

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clean production technologies through both horizontal and forward linkages. This helps explore the trend of pollution industry transfer caused by FDI inflows [17]. Therefore, FDI has negative scale effects, positive structural effects, and positive environmental technological effects [18]. Additionally, FDI contributes to improving regional environmental quality through significant innovation network effects, technological spillover effects, and industrial agglomeration and structural upgrading effects [19].

Building upon existing research, this paper proposes the industrial scale channel through which FDI impacts environmental quality. Regarding the relationship between FDI and industrial scale, an empirical research in the Yangtze River Delta region indicates a significant positive correlation between FDI and industrial scale[20]. However, the relationship between FDI and industrial scale is not simply linear. Under certain conditions, FDI may promote the development of domestic industries, while simultaneously impacting them to a certain extent[21].Environmental quality is primarily influenced by production and living pollution, with industrial production being the main source of pollution [22]. Industrial production inevitably generates pollutants such as emissions, wastewater, and solid waste, often leading to environmental pollution and resource depletion as industrial development progresses [23]. Based on empirical research in three major regions of Jiangsu Province, Liang et al. (2010) found that an increase in industrial scale generally leads to an overall increase in the generation of major pollutants [24]. Zhong and Wei (2011) empirically analyzed factors influencing pollution emission intensity in China's manufacturing sector from 2001 to 2008. The results indicate that the significant expansion of industrial scale notably promotes an increase in pollution emission intensity [25].

4. Methodology

Constrained by data availability, this paper selects the period from 2003 to 2021 as the research timeframe, with 13 prefecture-level and above cities in Beijing, Tianjin, and Hebei provinces (cities) as the research samples. For outliers and partially missing values in the data, corrections and supplements are made by consulting statistical yearbooks and statistical bulletins on national economic and social development from various regions in China (hereinafter referred to as statistical bulletins). The remaining small number of missing values are supplemented through linear interpolation.

4.1. Model specification

Drawing from the study by Gu et al. (2020) [26], this paper specifies the following econometric model:

$$\mathrm{environment}_{it} = \alpha + \beta_1 \mathrm{fdi}_{it} + \beta_2 \mathrm{fdi}_{it}^2 + \theta X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (1)$$

$\mathrm{Environment}_{it}$ represents the environmental quality of city i in year t, while fdi_{it} denotes the level of FDI in city i in year t. To examine the potential non-linear relationship between FDI and environmental quality, this study incorporates the quadratic term of FDI level in city i in year t, denoted as fdi_{it}^2. X_{it} represents a series of control variables under scrutiny in this study. Due to the multitude of factors influencing environmental quality, beyond the focal concern of FDI levels and the included control variables, there exist additional unobservable factors. Hence, this study employs a two-way fixed effects model for estimation, where μ_i and λ_t respectively represent city fixed effects and year fixed effects. ε_{it} denotes the error term.

4.2. Variable and Data

4.2.1. Dependent Variable

Building upon the foundation laid by Liao and Qin (2022) , this study employs the entropy method to select three indicators—per capita emissions of sulfur dioxide, per capita emissions of industrial smoke (dust), and per capita emissions of industrial wastewater—to construct a composite environmental quality index for assessing the environmental quality of each city, denoted by "environment" [27].

4.2.2. Core Independent Variables

The core independent variables of this study are the FDI level of each city and its quadratic term, denoted as fdi and fdi^2 respectively. Following the study by Zhao et al. (2022), the proportion of actual utilization of foreign direct investment to the regional GDP in each locality in the respective year is used as a measure [28].

4.2.3. Covariates

The covariates selected in this study include: Economic Development Level, denoted as "development," measured by the real per capita regional GDP, adjusted using the regional GDP index to reflect the real regional GDP based on the 2002 benchmark year; Industrial Structure, represented by "industry," measured by the proportion of the sum of the output values of the secondary and tertiary industries to the regional GDP; Population Size, denoted as "population," assessed using the year-end resident population; Wage Level, represented by "wage," measured by the real per capita wage, adjusted using the regional GDP index to reflect the real per capita wage based on the 2002 benchmark year; Government Control Scale, denoted as "government," indicated by the proportion of general government budgetary expenditures to the regional GDP; Environmental Regulation Level, represented by "regulation," evaluated by the proportion of completed investment in industrial pollution control to the regional GDP; Infrastructure Level, denoted as "infrastructure," assessed by the number of hospital beds per ten thousand people.

4.2.4. Data Source

The data on sulfur dioxide emissions, industrial smoke (dust) emissions, industrial wastewater discharge, regional GDP, output values by industry, per capita wage, and government general budgetary expenditures are sourced from the "China City Statistical Yearbook." Data on actual utilization of foreign direct investment and year-end resident population are sourced from the statistical yearbooks of Beijing, Tianjin and Hebei. Data on completed investment in industrial pollution control are sourced from the China National Bureau of Statistics. Table 1 presents the summary statistics for the main variables.

Table 1: Summary statistics for the main variables.

Variables	Obs	Mean	Std.	Min.	Median	Max.
environment	247	75.14	20.54	13.52	79.46	99.68
fdi	247	2.09	1.66	0.12	1.63	8.19
fdi^2	247	7.14	12.98	0.02	2.67	67.10
development	247	3.29	2.07	0.62	2.81	11.90
industry	247	88.75	5.38	77.96	87.57	99.72
population	247	805.28	462.21	188.28	729.44	2195.00
wage	247	3.98	2.50	0.91	3.31	13.59
government	247	15.44	6.65	5.57	14.95	40.19
regulation	247	0.0262	0.0559	0.0004	0.0099	0.5039
infrastructure	247	36.90	10.56	16.25	37.14	96.00

5. Empirical Evidence

Building upon the baseline regression, this paper conducts a comprehensive robustness check using multiple methods, and delves into the issues of endogeneity, the mechanism through which FDI affects environmental quality, heterogeneity characteristics, and spatial effects of environmental quality.

5.1. Baseline Regression

The baseline regression result of the model is presented in Table 2. In column (1), only the first-order term of FDI levels is included for regression, yielding a coefficient that is positive but not significant. In column (2), the regression includes both the first and second-order terms of FDI levels. The results indicate a significant positive coefficient for the first-order term and a significant negative coefficient for the second-order term, suggesting a inverted "U" shaped relationship between FDI and environmental quality. This implies that environmental quality initially improves with increasing FDI levels, followed by a decline. In column (3), after controlling for other variables, the signs and significance of the first and second-order terms of FDI levels remain unchanged, with only minor changes in coefficient values. This preliminary validation suggests the presence of an inverted "U" shaped relationship between FDI and environmental quality. The possible explanation for this phenomenon is that when the level of FDI inflow is low, the host country is typically in a phase of low industrialization and technological backwardness. The influx of FDI brings advanced production and governance technologies, with the primary effect being technological. This aids in the improvement of the host country's environmental quality. As FDI reaches a certain threshold, known as the "turning point," the "technology dividend" gradually diminishes. However, local governments, driven by economic benefits, continue to increase

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the scale of FDI and introduce various policies to attract FDI inflows. Consequently, some high-pollution FDI, without technological updates, enter the market. At this stage, the scale of secondary industry FDI continues to grow, with structural and scale effects becoming predominant, leading to environmental degradation.

Table 2: Baseline regression.

Variable	(1)	(2)	(3)
fdi	1.371	9.591*	7.979**
	(1.713)	(4.714)	(2.969)
fdi2		-1.007*	-0.774**
		(0.477)	(0.351)
Constant	72.275***	62.263***	227.473***
	(3.587)	(6.510)	(45.859)
Covariates	NO	NO	YES
City fixed effects	YES	YES	YES
Year fixed effects	YES	YES	YES
Obs	247	247	247
R^2	0.839	0.852	0.907

Note: *, **, *** denote significance at the 10%, 5%, 1% levels, respectively, with clustered robust standard errors in parentheses. The same applies throughout.

5.2. Robustness Check

To ensure the robustness and reliability of the baseline regression result, this study conducts robustness tests using two methods: replacing the dependent variable and conducting sub-sample regression.

5.2.1. Replacing the Dependent Variable

To provide a more intuitive understanding of the impact of FDI on environmental quality, this study selects sulfur dioxide emissions, denoted as SO_2; per capita sulfur dioxide emissions, denoted as SO_2_1; and sulfur dioxide emissions per unit of administrative area, denoted as SO_2_2, as proxy variables for environmental quality to conduct robustness test. The rationale behind this choice lies in the fact that sulfur dioxide is a common pollutant, being one of the major gases emitted in industrial, transportation, and energy production activities. Sulfur dioxide emissions serve as a key indicator of environmental quality for a region or country, given its association with various environmental issues such as acid rain, atmospheric pollution, and health concerns.

Columns (1) through (3) of Table 3 report the regression results. The coefficients of the first-order term of FDI are consistently negative and statistically significant, while those of the second-order term are positive and statistically significant. As the level of FDI increases, the three indicators of sulfur dioxide emissions initially show a decreasing trend, indicating an improvement in environmental quality. However, with further expansion of FDI levels, the three indicators of sulfur dioxide emissions exhibit an upward trend, suggesting a gradual deterioration in environmental quality. Thus, the inverted "U" shaped relationship between FDI and environmental quality remains valid.

5.2.2. Sub-sample Regression

Table 3: Robustness test.

Variable	(1)	(2)	(3)	(4)
	SO_2	SO_2_1	SO_2_2	environment
fdi	-3.513***	-41.752**	-2.038**	8.654**
	(1.088)	(15.313)	(0.680)	(2.985)
fdi^2	0.444***	4.150**	0.263***	-0.756**
	(0.124)	(1.824)	(0.075)	(0.333)
Constant	5.734	-646.565**	5.908	229.249***
	(24.896)	(233.277)	(13.513)	(56.764)
Covariates	YES	YES	YES	YES
City fixed effects	YES	YES	YES	YES
Year fixed effects	YES	YES	YES	YES
Obs	247	247	247	228
R^2	0.908	0.903	0.921	0.917

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Compared to other cities, Beijing, as the capital of China with a high political status, enjoys a series of advantages in resource allocation. The city's economic and social development often proceeds at a faster pace, and its importance within a region gradually increases over time [29]. Including Beijing in the empirical sample could introduce bias, thus this study excludes it from the overall sample for robustness testing. The regression results, presented in column (4) of Table 3, indicate that the coefficient of the first-order term of FDI is significantly positive, while the coefficient of the second-order term is significantly negative. The inverted "U" shaped relationship between FDI and environmental quality remains robust.

5.3. Endogeneity

This study identifies two main potential sources of endogeneity issues in the model used. First is omitted variables, despite the comprehensive consideration of various factors influencing environmental quality and the utilization of a double fixed-effects model to control for both time-varying and non-time-varying unobservable factors, there remains the possibility of certain factors that are difficult to characterize and measure, leading to bias in the estimated results. Second, there is the possibility of reverse causality, where regions with lower environmental quality may attract more foreign direct investment and become pollution havens [30].To address potential endogeneity bias in the model, instrumental variable (IV) estimation is employed.

Regarding the selection of instrumental variables, this study chooses the spherical distance from cities to Tianjin as the instrumental variable. The signing of the Beijing Treaty in the tenth year of Xianfeng (1860) opened Tianjin as a commercial port. Following Tianjin's opening, Western advanced civilizations landed there. With the significant influence and traction of foreign production methods, supported by abundant resources, goods, and markets in the vast hinterland, Tianjin rapidly developed into the most economically modernized port city in the northern region, becoming the largest foreign trade center in the north [31]. Hence, it can be anticipated that cities closer geographically to Tianjin would have higher levels of FDI.As geographic distance does not change over time, to impart dynamic characteristics, this study follows the approach of Liu et al. (2017) by multiplying the distance by the reciprocal of the exchange rate to construct an interaction term for two-stage least squares (2SLS) regression[32]. The results of the estimation are presented in the first column of Table 4.

Examination of the effectiveness of instrumental variable reveals that the p-values of the Kleibergen-Paap rk LM statistic in the underidentification test are all 0, significantly rejecting the null hypothesis of underidentification. Furthermore, the Kleibergen-Paap rk Wald F statistic in the weak instrument test exceeds the critical value at the 10% level under the Stock-Yogo weak instrument test, thus rejecting the hypothesis of weak instrumental variable. Overall, these tests demonstrate the validity of the instrumental variable selected in this study. The coefficient of the first-order term of FDI is significantly positive, while the coefficient of the second-order term is significantly negative, indicating that after effectively addressing the endogeneity issue within the model, the inverted "U" shaped relationship between FDI and environmental quality remains robust.

Table 4: Instrumental variable regression.

Variable	(1)
fdi	13.029***
	(4.320)
fdi^2	-1.789***
	(0.544)
Kleibergen-Paap rk LM	14.597
	[0.000]
Kleibergen-Paap rk Wald F	14.467
	{7.03}
Covariates	YES
City fixed effects	YES
Year fixed effects	YES
Obs	247
R^2	0.335

Note: *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively. Standard errors in parentheses, p-values in brackets, and critical values for the Stock-Yogo test in curly brackets.

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5.4. Mechanism

Building on the discovery of an inverted "U" shaped relationship between FDI and environmental quality, this study further examines the mechanism through which FDI influences environmental quality. Jiang (2022) pointed out flaws in the current stepwise regression mediation analysis method used in economics, suggesting a more feasible approach is to examine only the relationship between the core explanatory variable and the mediating variable under the condition of an intuitive causal relationship between the mediating variable and the explained variable [33]. Previous sections have provided an intuitive explanation for the impact of industrial scale on environmental quality. Therefore, this section conducts a mechanism test by examining the effect of FDI on industrial scale.

The proportion of employees in the secondary industry is used to measure industrial scale, with data sourced from the "China City Statistics Yearbook." Table 5, column (1), reports the regression results. The coefficient of the FDI level's linear term is negative, while the quadratic term coefficient is positive, indicating an "U" shaped relationship between FDI and industrial scale, with industrial scale first decreasing and then expanding as FDI levels increase. One possible explanation is that the inflow of FDI initially has a certain substitutive effect on local industries, leading to a decrease in industrial scale. As FDI continues to flow in and local industries transform, the downward trend in industrial scale will reverse, gradually expanding. The size of the industrial scale directly affects local environmental quality, with industrial scale generally having a negative impact on environmental quality, thus resulting in the inverted "U" shaped relationship between FDI and environmental quality. It is important to note that while there are some shortcomings in the significance level of the coefficients, this study believes that industrial scale is a crucial potential channel through which FDI affects environmental quality and should not be overlooked.

Table 5: Mechanism test result.

Variable	(1)
fdi	-3.220
	(2.047)
fdi^2	0.418*
	(0.221)
Constant	47.205
	(30.557)
Covariates	YES
City fixed effects	YES
Year fixed effects	YES
Obs	247
R^2	0.853

5.5. Heterogeneity

From the perspective of average treatment effects, there does appear to be an inverted "U" relationship between FDI and environmental quality. However, there exist differences in resource endowments among various cities within the Beijing-Tianjin-Hebei region, which may lead to heterogeneity in the impact of FDI on environmental quality, warranting further discussion. This study divides the sample of 13 prefecture-level and above cities into coastal and inland regions, and employs a grouping regression method for analysis, as shown in Table 6. In column (1), the coefficient of the FDI linear term is positive, while the quadratic term coefficient is negative, but neither passes the significance test. In column (2), the linear term coefficient of FDI level is significantly positive, while the quadratic term coefficient is significantly negative, and the p-values based on Fisher's combined test with 1000 bootstrap samples are all significant. The results indicate that the inverted "U" relationship between FDI and environmental quality is significant in inland regions, while this impact is not significant in coastal regions. Possible reasons for this could be that the coastal region, as the earliest area opened up in China, benefits from superior geographical conditions and policy advantages, creating a favorable business environment that attracts successive waves of cutting-edge foreign capital. The newly-entered enterprises possess cleaner production technologies and more advanced governance methods, resulting in limited negative impacts on local environmental quality. While continuously introducing these FDI with high-end technologies in coastal areas, the FDI in the region's original relatively backward areas are continuously being transferred to inland regions[34]. The technological differences in the FDI undertaken by coastal and inland regions largely contribute to the heterogeneity in the impact of FDI on environmental quality.

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Table 6: Heterogeneity test result.

Variable	(1)	(2)
	Coastal region	Inland region
fdi	6.504	13.492**
	(6.329)	(4.178)
	[0.096]	
fdi^2	-0.133	-2.200**
	(0.715)	(0.807)
	[0.017]	
Constant	238.108**	205.531***
	(54.594)	(30.109)
Covariates	YES	YES
City fixed effects	YES	YES
Year fixed effects	YES	YES
Obs	76	171
R^2	0.967	0.912

Note: *, **, *** indicate significance at the 10%, 5%, 1% levels, respectively. Clustered robust standard errors are presented in parentheses, and p-values of Fisher's combined test are presented in brackets.

5.6. Spatial Regression

The environmental quality issues in different regions do not exist independently; the environmental quality of one region may also be influenced by the environmental quality of other regions, exhibiting a certain degree of spatial correlation. In such cases, employing conventional panel data regression methods for analysis may lead to biased estimation results. To address this issue, this study utilizes spatial econometric methods to further examine the relationship between FDI and environmental quality.

5.6.1. Spatial Regression Model

First, an explanation of the spatial weight matrix used in this paper is provided. Following the approach of Zhu et al. (2023), the spatial distance weight matrix (W) is constructed as shown in equation (2), where d_{ij} represents the spherical distance between city i and city j [35].

$$W_{it} = \begin{cases} 1/d_{ij} \ , \ i \neq j \\ 0 \ , \ i = j \end{cases} \tag{2}$$

The commonly used spatial econometric models mainly include the Spatial Autoregressive Model (SAR), Spatial Error Model (SEM), and Spatial Durbin Model (SDM). To select an appropriate spatial model, this paper conducted LM tests, and the results are presented in Table 7. It can be observed that the LM-error statistic did not pass the significance test, while the LM-lag statistic was significant at the 1% level. According to the research of Tao and Yang (2014), the SAR model is preferred [36].

Table 7: LM test result.

Test	Statistic	P-value
LM-error	0.051	0.821
Robust-LM-error	7.140	0.008
LM-lag	31.318	0.000
Robust-LM-lag	38.407	0.000

Construct a SAR model as shown in equation (3):

$$environment_{it} = \alpha + \rho W \times environment_{it} + \beta_1 fdi_{it} + \beta_2 fdi_{it}^2 + \theta X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \tag{3}$$

W is the spatial distance weight matrix, $W \times environment_{it}$ is the spatial lag term of environmental quality, and the meaning of other variables is consistent with model (1).

5.6.2. Spatial Regression Result

Table 8 presents the regression result of Model (3) in columns (1) and (2). It can be observed that regardless of the inclusion of control variables, the coefficient of the FDI level's linear term is significantly positive, while the quadratic term coefficient is significantly negative, with values close to the baseline regression result, indicating the robustness of the research findings. The coefficients of the spatial lagged terms of environmental quality are all significantly negative, indicating significant negative spatial effects of environmental quality, whereby improvements in environmental quality in other regions adversely affect local environmental quality. This may be attributed to the enhancement of environmental quality in one region occurring at the expense of deteriorating environmental quality in neighboring regions due to the transfer of polluting industries.

Table 8: Spatial regression result.

Variable	(1)	(2)
W×environment	-0.697***	-0.605***
	(0.158)	(0.135)
fdi	8.800**	7.418***
	(4.196)	(2.634)
fdi^2	-0.902**	-0.709**
	(0.427)	(0.309)
$sigma^2$	56.876***	36.737***
	(14.305)	(7.078)
Covariates	NO	YES
City fixed effects	YES	YES
Year fixed effects	YES	YES
Obs	247	247
R^2	0.035	0.071

6. Conclusion

This study utilizes panel data from 13 prefecture-level and above cities in the Beijing-Tianjin-Hebei region spanning from 2003 to 2021. It constructs an integrated environmental quality index using the entropy method and employs various econometric methods to examine the effects of FDI on environmental quality. The study finds: Firstly, FDI exhibits a significant inverted "U" shaped relationship with environmental quality, a conclusion that remains robust after a series of robustness tests and endogeneity treatments. Secondly, mechanism test results suggest that the inverted "U" shaped effect of FDI on environmental quality may be realized through the industrial scale channel. Thirdly, heterogeneity analysis indicates that compared to coastal regions, the inverted "U" shaped relationship between FDI and environmental quality is more significant in inland regions, possibly due to technological differences in FDI absorption between coastal and inland regions. Fourthly, spatial econometric analysis reveals significant negative spatial effects of environmental quality, where improvements in environmental quality in other regions adversely impact local environmental quality.

Based on the conclusions of the above research, this paper proposes the following recommendations. Firstly, cities in the Beijing-Tianjin-Hebei region should adhere to the dual goals of attracting foreign investment and preventing pollution. This entails considering the environmental effects of foreign investment during the attraction process, using environmental regulations as a threshold for foreign investment entry, and actively attracting high-quality foreign investment that is green and technologically advanced. Simultaneously, establishing incentives for green investment and actively guiding already attracted foreign investment, while appropriately penalizing heavily polluting foreign investment, and providing corresponding policy preferences for high-quality, efficient, and technologically advanced foreign investment, thus promoting fair competition among foreign investment. Secondly, enhancing the intensity of environmental regulations is crucial. In the coordinated development of the Beijing-Tianjin-Hebei region, the sustainable development of both the economy and the environment is paramount. While environmental regulations may increase business costs, they can also enhance production technology innovation and efficiency. Correspondingly, endogenous enterprise innovation can reduce production costs, partially or wholly offsetting the cost increases caused by exogenous environmental regulation. Therefore, it is imperative to establish stringent environmental standards, implement a system of pollution discharge permits, rigorously control and actively guide the sources and flow of foreign investment, in order to better leverage the positive role of environmental governance and accelerate the "green transformation and upgrade" of FDI in the Beijing-Tianjin-Hebei region. Thirdly, a scientific and normalized mechanism for regional environmental cooperation should be constructed. Joint and coordinated efforts to control environmental pollution must harness the synergistic effects between provinces and municipalities and pay attention to the spatial effects of environmental quality. It is essential to break regional administrative monopolies, establish truly cross-regional environmental protection agencies, hold regular joint meetings, actively implement environmental cooperation projects

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such as pollution discharge rights, carbon emission rights, energy use rights, and water use rights trading, and establish incentive-based horizontal and basin ecological compensation mechanisms. Moreover, it is crucial to implement a vertical management mechanism for environmental supervision, improve the cross-regional environmental law enforcement system, and coordinate responses to cross-regional environmental pollution emergencies.

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