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An Empirical Analysis of the Impact of Green Investment on China's Green Development Level: Based on Mediating and Spatial Spillover Effects

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Abstract: This study, based on panel data from 30 provinces in China from 2007 to 2020, employs the Super Efficiency SBM model to measure the green total factor productivity of each province. By constructing mediating effect models and spatial econometric models, it conducts an empirical investigation into the mechanisms and spatial characteristics of how green investments promote China's green development. The results reveal that, at an overall level, green investments play a positive role in influencing China's green development. Regarding the influence pathways, innovative green technology advancements, both in terms of inventions and improvements, are important mediating channels through which green investments promote green development, with inventions having a stronger mediating effect. In terms of regional heterogeneity, green investments significantly promote green development in the eastern and central regions, while their promotion effect in the western regions is less pronounced. Concerning spatial spillover characteristics, green investments not only drive local green development levels but also stimulate the green development in surrounding areas through spatial spillover effects.

Keywords: Green Investment, Green Technology Innovation, Mediating Effect, Green Development Level

1. Introduction

Since the initiation of economic reforms and opening-up policies, China has faced a pronounced contradiction between economic growth and environmental protection. This dilemma has prompted a profound reconsideration of the rationality of our country's current mode of production. The introduction of the "dual carbon" targets has pushed China to a new level in the path of green development, emphasizing the strengthening of green investments, fostering technological innovation, and achieving a green transformation. This is expected to become a widespread consensus in current society and a predominant theme in future development. Simultaneously, the rapid development of the green economy relies on financial support. Finance is the core of modern economies and is also a crucial instrument for effectively enhancing the level of green development. While traditional

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financial development has undoubtedly made substantial contributions to economic growth, it has often failed to address issues such as environmental pollution that arise during the process of economic expansion. In contrast, green finance rectifies the deficiencies of traditional finance, making environmental protection a fundamental policy and emphasizing the harmonious development of financial activities and ecological balance. Among the various financial activities, green investment possesses inherent potential for guiding green development. Currently, in academia, research on green investment remains in its infancy, with most scholars focusing on micro-level enterprises and exploring the relationship between green investment and economic development while often overlooking the potential transmission mechanisms and spatial characteristics that may be present during the influence process. Therefore, this paper employs panel data from 30 provinces (municipalities and autonomous regions) in China as research samples to construct mediating effect models for two types of green technology innovation and spatial econometric models for empirical analysis. This not only enriches the theory of green finance but also broadens the research perspective on green finance. It also holds practical significance for expediting green economic development, ultimately achieving the "dual carbon" goals and high-quality economic development.

Based on the review of existing literature, this paper's potential marginal contributions are as follows: 1. In contrast to the prevailing focus in current academia on the status, development pathways, measurement of development levels, and the relationship between green finance and economic growth, environmental quality, and industrial structure, this paper takes a different angle. It analyzes the impact of green finance, represented by green investment, on China's green economic development, thus enriching financial support theory. 2. The paper fills a research gap concerning the impact of green investment on different types of green technology innovation. It introduces two types of green technology innovation as mediating channels and thoroughly investigates the influence pathways of green investment in promoting green development levels. 3. Grounded in spatial economics' theoretical framework and research paradigms, this paper, from the perspective of spatial spillover, delves deep into the impact effects between the two.

2. Literature Review and Research Hypotheses

2.1. The Relationship Between Green Investment and Green Economic Development

In the current stage, China's economy has transitioned from a high-speed development phase to a high-quality development phase. Green investment, as an effective financial tool, is the inevitable investment model in the face of increasingly severe environmental problems and resource constraints, serving as a result of green economic development. Currently, theoretical research on green investment in China is still in its infancy, with most scholars exploring the relationship between green investment and economic growth, environmental quality, and social well-being. Regarding the relationship between green investment and economic growth, various studies have been conducted. Pierce and Wolf studied the relationship between environmental investments and economic development, suggesting that environmental protection investments promote an increase in the national gross domestic product within a year [1]. Hiroshi Niida analyzed the impact of environmental protection investments on total output and prices, discussing the relationship between different environmental measures and price levels [2]. Gajjar used India's coal industry as an example to conclude that green investments have a positive impact on India's economic growth [3]. Huang Qingzi et al. found through the construction of a panel effects model that environmental protection investments along the Silk Road Economic Belt can promote regional economic growth, optimize economic structure, increase employment levels, improve resource utilization, and alleviate environmental pollution issues [4]. Zhang Lei et al. separated environmental protection investments from the capital variable of the production function to determine the contribution rate of

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environmental protection investments to economic growth. They concluded that environmental protection investments may hinder economic development in the short term but promote economic growth in the long term [5]. In terms of the impact of green investment on people's livelihood, green funds can be used to restore the ecological environment, improve environmental quality, and provide support for the construction of livable communities. Regarding the relationship between green investment and the ecological environment, Halkos et al. analyzed energy-saving environmental expenditure and its relationship with environmental quality in over seventy countries. The study showed that increasing the level of environmental expenditure can suppress pollutant emissions, achieving the goal of environmental protection [6]. Furthermore, empirical studies suggest that there is a strong spatial correlation and spatial transmission effect between economic and environmental activities. Cai Qiang et al. found that the development of green finance in a region can effectively promote the high-quality development of neighboring regions. Thus, regions should not only promote their own high-quality economic development but also fully utilize spatial spillover effects to mutually boost each other through regional linkage [7]. Zeng Sheng et al. used a spatial Durbin model to analyze the significant positive spatial correlation and spatial spillover effect in high-quality economic development [8]. This reveals that green investment's role in promoting green development levels to some extent exhibits spatial spillover characteristics. Based on these findings, this paper proposes the first research hypothesis:

H1: Green investment can effectively promote China's green development level.

2.2. The Relationship Between Green Investment and Green Technology Innovation

Currently, both domestic and international scholars have extensively discussed the relationship between finance and technological innovation, reaching a consistent conclusion that finance positively influences technological innovation. In today's context, green development has been elevated to the level of a national strategy, largely driven by green technology innovation. The term "green technology" is defined as clean technology that reduces consumption, lowers pollution, improves the environment, and achieves a harmonious coexistence of humans and nature, as stated in the "Guidance on Building a Market-Oriented Green Technology Innovation System" [9]. Green technology is essential for promoting economic sustainability and preventing environmental degradation. In the context of the "dual carbon" goals, long-term stable financial support and strategic investments are crucial for green technology innovation. In turn, engaging in green activities attracts broad investor attention and is considered to have a long-term effective return on investment. Therefore, green investment plays a crucial role in promoting green technology innovation. In academia, most scholars agree that green investment has a certain positive impact on green technology innovation. Li Linping argues that companies can acquire green technology innovation capability by increasing research and development investment, improving production processes, and adopting green and environmental protection technologies [10]. Jiang Yufeng and others suggest that when implementing green innovation, companies can achieve higher social and ecological benefits, but economic benefits are relatively low, indicating a lack of innovation drive. Therefore, government guidance on green investment is significant [11]. Yuan Guangda points out that green capital formed by green investment will cause process reform and restructuring during operation, thereby achieving value-added and promoting green innovation in companies [12]. Shao Xingyu and others believe that introducing venture capital establishes an information exchange network for innovation, providing platform support for innovation [13]. Jaffc sees green investment as a means of government environmental regulation, effectively mitigating the negative impact of environmental externalities and accelerating the green innovation of heavily polluting enterprises [14]. Lanjouw and Mody suggest that pollution control investments have a positive impact on the green innovation output of heavily polluting enterprises [15]. Li Bin et al. empirically analyzed the impact of pollution control

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investment on technological innovation and found that the relationship is U-shaped; in the short term, pollution control investment may inhibit technological innovation, but in the long term, the lack of control efforts will motivate companies to innovate [16]. However, some scholars have proposed that green investment may have an inhibitory effect on green technology innovation [16]. Overall, green investment promotes green technology innovation in three aspects: providing financial support, triggering process innovation and restructuring, and building a network platform. Therefore, the second research hypothesis is proposed:

H2: Green investment has a positive impact on both invention-based and improvement-based green technology innovation.

2.3. The Relationship Between Green Technology Innovation and Green Development

Currently, there is a considerable amount of research on the relationship between technological innovation and green economic development. He Xingbang conducted an empirical analysis of the quality effect of technological innovation on economic growth, concluding that technological innovation significantly enhances the overall quality of economic growth in China [17]. Chen Ying studied the impact of corporate technological innovation on urban green development in the Yangtze River Economic Belt, finding significant effects, although the degree of impact varied across different regions of the Yangtze River Economic Belt [18]. Yang Yi and others found that technological innovation has a significant positive impact on promoting the green development of resource-based industries and plays a positive moderating role in the influence of resource-based industries' transformation on global value chain embedding [19]. Zhou Pengfei and others used mathematical and statistical models to verify the significant mediating effect of green technology innovation in the transmission path of industrial green development influenced by environmental regulation [20]. Zhang Ye and others found that in the Yangtze River Delta city cluster, technological innovation has a significant positive impact on green economic development in both direct and indirect aspects [21]. Zeng Gang and others found that when a city's technological innovation capability is low, improving technological innovation capability can inhibit the city's green development level. However, when the city's technological innovation capability reaches a certain level, its high innovation capability can effectively promote the city's green development level, gradually weakening the inhibitory effect [22]. Therefore, this paper believes that green technology innovation is the true enabler of environmental protection and ecological preservation. With the promotion and application of green technology and green standards, there is an increasing demand for environmentally friendly products by consumers, which encourages enterprises to make active green investments and production decisions, expand green products and services through technological innovation, and achieve green production and green living.

Analyzing the relationships between green investment, green technology innovation, and green economic development, it is clear that there is a close connection between these three factors. Combining the above discussion and hypotheses, we propose the third research hypothesis:

H3: Both invention-based and improvement-based green technology innovation play mediating roles between green investment and green development.

3. Research Design

3.1. Model Construction

This paper follows the approach of stepwise regression as suggested by Wen Zhonglin [23]. Firstly, using panel data, we examine the impact of green investment on the level of green development. Secondly, we incorporate the mediating variables into the model to test whether invention-based and improvement-based green technology innovations act as mediators in the effects between these

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variables. To do this, we construct the following baseline regression models and mediating effect models:

$$\mathrm{GTFP_{it}} = \alpha_0 + \alpha_1 \mathrm{lnINV_{it}} + \alpha_2 Controls_{\mathrm{it}} + \mu_\mathrm{i} + \varphi_\mathrm{t} + \varepsilon_\mathrm{it} \quad (1)$$

$$\mathrm{GTFP_{it}} = \alpha_0 + \alpha_1 \mathrm{lnINV_{it}} + \alpha_2 Controls_{\mathrm{it}} + \mu_\mathrm{i} + \varphi_\mathrm{t} + \varepsilon_\mathrm{it} \quad (2)$$

$$\mathrm{GTFP_{it}} = \alpha_0 + \alpha_1 \mathrm{lnINV_{it}} + \alpha_2 \mathrm{lnGREEN_{1_{it}}} + \alpha_3 Controls_{\mathrm{it}} + \mu_\mathrm{i} + \varphi_\mathrm{t} + \varepsilon_\mathrm{it} \quad (3)$$

$$\mathrm{lnGREEN_{2_{it}}} = \alpha_0 + \alpha_1 \mathrm{lnINV_{it}} + \alpha_2 Controls_{\mathrm{it}} + \mu_\mathrm{i} + \varphi_\mathrm{t} + \varepsilon_\mathrm{it} \quad (4)$$

$$\mathrm{GTFP_{it}} = \alpha_0 + \alpha_1 \mathrm{lnINV_{it}} + \alpha_2 \mathrm{lnGREEN_{2_{it}}} + \alpha_3 Controls_{\mathrm{it}} + \mu_\mathrm{i} + \varphi_\mathrm{t} + \varepsilon_\mathrm{it} \quad (5)$$

Where, $\mathrm{GTFP_{it}}$ represents Green Total Factor Productivity. $\mathrm{INV_{it}}$ represents Green Investment. $\mathrm{GREEN_{1it}}$ and $\mathrm{GREEN_{2it}}$ represent Invention-based and Improvement-based Green Technology Innovation, respectively. α_0 is a constant term. α_i are coefficient terms representing the impact of Green Investment or control variables on the level of green development. $Controls_{\mathrm{it}}$ represents a series of control variables. u_i and φ_t represent individual and time-fixed effects, respectively. ε_{it} represents the random disturbance term. To maintain data stability and eliminate heteroscedasticity, this paper has applied natural logarithm transformations to Green Investment, Invention-based Green Technology Innovation, and Improvement-based Green Technology Innovation.

3.2. Variable Definitions

3.2.1. Core Dependent Variable

In this study, we employ the Data Envelopment Analysis (DEA) using the MaxDEA calculation software to assess the Green Total Factor Productivity (GTFP) of various provinces in China. Input and output indicators were constructed as per Zhang Ye's research. The specific indicators are detailed in Table 1:

Table 1: GTFP Calculation System and Indicator Explanations

Indicator Category	Indicator Name	Indicator Explanation
Inputs	Capital Investment	Capital Stock / 100 million yuan
	Labor Investment	Year-end employed population of each province or city / 10,000 people
	Energy Investment	Total energy consumption of each province / 10,000 tons
Outputs	Expected Output	Real GDP calculated at constant 2007 prices / 100 million yuan
	Non-Expected Output	Carbon dioxide emissions / million tons Industrial sulfur dioxide emissions / 10,000 tons Industrial wastewater discharge / 10,000 tons General industrial solid waste / 10,000 tons

The calculation of capital stock follows Zhang Jun's approach, using the perpetual inventory method with 2007 as the base year [24], as shown in equation (6):

$$\mathrm{K_t} = \mathrm{K_{t-1}}(1 - \delta) + \mathrm{I_t} \quad (6)$$

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Where, K_t represents the capital stock in period t; δ represents a depreciation rate of 9.6%; $I_t$represents the total amount of fixed asset formation in period t.

In this study, we employ the Super-Efficiency SBM model, following Tone's research [25], to calculate the Green Total Factor Productivity. It is assumed that the kth decision-making unit (j=1, 2, … n) has input vector $x \in R^M$, expected output vector $y^g \in R^{s1}$ and non-expected output vector $y^b \in R^{s_2}$. $X = [X_1, X_2, X_3, \dots, X_n,] \in R_{m\times n}$,$y^g=[y_1^g,\cdots y_n^g] \in R^{s_1}\times n$ 及$Y^b = [y_1^b,\cdots y_n^b] \in R^{s_2}\times n$. Thus, the following formula represents the Super-Efficiency SBM model for the kth decision-making unit, including non-expected outputs:

$$\min\rho = \frac{1+\frac{1}{m}\sum_{i=1}^{m}\frac{s_i^-}{x_{ik}}}{1-\frac{1}{s_1+s_2}(\sum_{i=1}^{s_1} s_r^g/y_{rk}^g+\sum_{t=1}^{s_2} s_t^b/y_{tk}^b)} \quad (7)$$

$$s.t. \sum_{j=1,j\neq k}^{n} x_{ij}\lambda_j - s_i^- \leq x_{ik} \quad (8)$$

$$\sum_{j=1,j\neq k}^{n} y_{rj}\lambda_j + s_r^g \geq y_{rk}^g \quad (9)$$

$$\sum_{j=1,j\neq k}^{n} y_{tj}\lambda_j - s_t^b \leq y_{tk}^b \quad (10)$$

$$\lambda \geq 0, s^g \geq 0, s^b \geq 0, s^- \geq 0 \quad (11)$$

Where, λ is the weight vector; s_i^-、s_r^g and s_t^b are slack variables; ρ is the efficiency value; $\frac{1}{m}\sum_{i=1}^{m}\frac{s_i^-}{x_{ik}}$ represents the average inefficiency level of inputs; $\frac{1}{s_1+s_2}\left(\sum_{i=1}^{s_1}\frac{s_r^g}{y_{rk}^g} + \sum_{t=1}^{s_2}\frac{s_t^b}{y_{tk}^b}\right)$ represents the average inefficiency level of outputs. The above formula allows us to calculate the economic efficiency level of each unit, but it doesn't provide a comprehensive view of the changes in Green Total Factor Productivity. Therefore, we further examine the dynamic characteristics of efficiency using the GML index, as suggested by previous studies [26]. Given that the results calculated earlier represent the rate of change in Green Total Factor Productivity, we use the approach by Zhong and Li to calculate the MI index in a year-on-year basis from the base year of 2007, resulting in GTFP values for the 30 provinces from 2008 to 2020 [27].

3.2.2. Core Explanatory Variables

The concept of green investment is relatively broad, and there is currently no unified measurement method. Based on a review of the literature, it was found that most research in China has focused on the enterprise level, primarily utilizing content analysis. At the provincial level, some scholars have proposed using green investment efficiency or industrial pollution control investment as indicators to represent green investment. However, as environmental issues caused by rapid economic development become increasingly severe, the definition of green investment has become broader. In this study, we refer to the research of He and Lidao and use the indicator of environmental protection expenditure, specifically defined as the proportion of environmental protection expenditure to local general public budget expenditure [28]. Due to the restructuring of government revenue and expenditure classifications by the Ministry of Finance, the category of environmental protection expenditure was only established in 2007. Therefore, to ensure the accuracy of environmental protection expenditure data in empirical analysis and to maintain consistency in selecting relevant data, we chose data from 2007 to 2020 for the empirical analysis.

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3.2.3. Mediating Variables

Currently, research on green technology innovation in China is in its early stages, and there is a lack of standardized measurement methods, leading to uncertainty. Some scholars have used regression residuals of technology performance obtained from decomposed productivity or Solow residuals to represent technological input or R&D investment. These indicators do not distinguish well between green technology innovation and general technology innovation, which affects the accuracy of research results. Some researchers suggest that patents can reflect the degree of technological innovation and advancement. Green patents, which are related to environmental changes, more accurately represent the output of green technology innovation. Green patents are divided into green invention patents and green utility model patents. The former are based on energy saving and emission reduction as primary innovations, while the latter represents secondary innovations without significantly changing the technical principles of existing products. Therefore, in this study, we select green invention technology innovation (GREEN1) and green utility model technology innovation (GREEN2) as mediating variables [29]. The number of applications and authorizations for green invention patents and green utility model patents will be used as indicators to measure green technology innovation.

3.2.4. Control Variables

Since there are numerous factors influencing Green Total Factor Productivity, this study selects the following variables as control variables: ① Per Capita GDP: Defined as the ratio of total provincial GDP to the local population; ② New Infrastructure (INF): The study uses the combined fixed asset investments of two industries: "Information Transmission, Software and Information Technology Services" and "Scientific Research and Technical Services" as a proxy variable for new infrastructure investment. Based on 2007 as the base year, various provinces' fixed asset price index values were adjusted, and the perpetual inventory method was used to further convert them into the stock of new infrastructure; ③ Public Education Level (EDU): The natural logarithm of the education expenditure portion of financial expenditures in each province is used as an indicator to measure the level of public education; ④ Industrial Structure (IS): Borrowing from the research by Fu Linghui, this study uses the overall industrial structure upgrading index [30] as a variable to measure the level of industrial structure. This index covers changes and upgrades in the output structure of China's three industries and the level of coordinated development between industries.

3.3. Sample Selection and Data Sources

This study employs panel data from 30 Chinese provinces for the years 2007-2020 as the research sample, with data from the Tibet Autonomous Region, as well as Hong Kong, Macau, and Taiwan Special Administrative Regions, excluded due to missing data. The majority of the research data is sourced from the CSMAR database, "China Statistical Yearbook," "China Environmental Yearbook," and the statistical yearbooks of various provinces. Data on green invention and green utility model technology innovation are obtained from the China National Intellectual Property Database, matched using WIPO's International Patent Classification Green List to identify the number of green patent applications in each province. This study employs linear interpolation to fill in missing data and performs 1% trimming to mitigate the influence of outliers.

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4. Empirical Results and Analysis

4.1. Descriptive Statistics

In this study, a descriptive statistical analysis of all variables was conducted to provide insights into the overall trends, central tendencies, and dispersion characteristics of the data. The results are presented in Table 2.

Table 2: Descriptive Statistics

Variable	Obs	Mean	Median	Standard Deviation	Min	Max
GTFP	420	1.111	1.04	0.221	0.322	2.459
lnINV	420	0.028	0.028	0.012	0.001	0.068
$lnGREEN_1$	420	7.018	7.127	1.700	3.496	9.720
$lnGREEN_2$	420	7.473	7.805	1.699	3.997	9.945
IS	420	2.341	2.322	0.137	2.020	2.836
lnGDP	420	10.58	10.596	0.566	8.959	12.013
lnINF	420	6.472	6.513	1.038	2.897	8.778
lnEDU	420	6.250	6.334	0.807	3.551	8.164

4.2. Baseline Regression Analysis

This study employed a stepwise inclusion of control variables to conduct a regression analysis on the baseline model. The aim was to investigate the actual impact of green investment on the level of green development. The specific test results are presented in Table 3.

Table 3: Baseline Model Estimation

Variables	(1) GTFP	(2) GTFP	(3) GTFP	(4) GTFP	(5) GTFP
lnINV	7.587***	7.683***	7.104***	7.125***	7.134***
	(8.03)	(8.14)	(7.21)	(7.21)	(7.21)
IS		0.322*	0.281	0.287	0.501***
		(1.75)	(1.53)	(1.55)	(3.20)
lnGDP			-0.161**	-0.160*	-0.141
			(-1.97)	(-1.95)	(-1.44)
lnINF				-0.009	0.042*
				(-0.34)	(1.72)
lnEDU					-0.026
					(-0.36)
Constant	0.789***	0.070	1.762*	1.789*	1.734*
	(22.42)	(0.17)	(1.85)	(1.87)	(1.79)
Observations	420	420	420	420	420
R-squared	0.451	0.455	0.461	0.461	0.461
Time	Y	Y	Y	Y	Y
Individual	Y	Y	Y	Y	Y

Note: ***p<0.01, **p<0.05, *p<0.1. Values in parentheses are t-values.

As shown in column (1) of Table 3, when control variables are not included, green investment has a positive impact on green development. Subsequently, with the gradual inclusion of control variables,

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the core explanatory variable remains significantly positive at the 1% level. An increase of one percentage point in green investment leads to a 7.134 percentage point improvement in green development, indicating that green investment effectively promotes environmentally friendly economic growth. Additionally, when examining the control variables, industrial structure and new infrastructure have a significant positive impact, while per capita GDP and public education levels exhibit negative effects, aligning with existing research findings. In conclusion, as green investment continues to increase, the degree of green development significantly improves, confirming research hypothesis H1.

4.3. Mediation Analysis

To further explore the pathway through which green investment influences the level of green development and verify the mediating effects of invention-oriented and improvement-oriented green technology innovations, this study included them in the regression analysis to test the mediation effects. The results are presented in Table 4.

Table 4: Mediation Analysis

Variables	(1) $lnGREEN_1$	(2) GTFP	(3) $lnGREEN_2$	(4) GTFP
lnINV	9.327***	6.840***	12.163***	6.792***
	(2.94)	(6.86)	(3.98)	(6.74)
$lnGREEN_1$		0.031*		
		(1.95)		
$lnGREEN_2$				0.028*
				(1.68)
IS	1.643**	-0.233	1.615**	-0.129
	(2.59)	(-1.35)	(2.09)	(-0.71)
lnGDP	1.503***	0.177*	2.876***	0.233**
	(4.48)	(1.91)	(7.06)	(2.32)
lnINF	-0.018	0.002	0.050	-0.001
	(-0.19)	(0.07)	(0.44)	(-0.05)
lnEDU	0.706***	-0.224***	0.355	-0.170**
	(2.81)	(-3.29)	(1.16)	(-2.40)
Constant	-3.337	1.839*	-2.590	1.807*
	(-1.07)	(1.90)	(-0.87)	(1.87)
Observations	420	420	420	420
R-squared	0.791	0.466	0.801	0.465
Time	Y	Y	Y	Y
Individual	Y	Y	Y	Y

Note: ***p<0.01, **p<0.05, *p<0.1.

Table 4 reports the results of the mediation analysis. Columns (1) and (3) regress the relationship between green investment and invention-oriented and improvement-oriented green technology innovations using fixed effects models, respectively. The results indicate that green investment has a significant positive impact on both invention-oriented and improvement-oriented green technology innovations at the 1% level, thus confirming H2.

Upon observing columns (2) and (4), it is evident that the regression coefficients of invention-oriented and improvement-oriented green technology innovations are significantly positive at the 10%

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level, with the former showing a more pronounced mediating effect. Meanwhile, the regression coefficients of the core explanatory variable remain significantly positive, albeit slightly reduced. Taking these results into account, it can be inferred that both invention-oriented and improvement-oriented green technology innovations partially mediate the relationship between green investment and the level of green development, with invention-oriented green technology innovation playing a stronger mediating role. In conclusion, both pathways contribute to the growth of China's green total factor productivity, validating hypothesis H3.

4.4. Robustness Tests

To further validate the robustness of the regression results, this study primarily employed two methods: replacing the explanatory variables and addressing endogeneity issues. The results of these tests are presented in Table 5.

Table 5: Robustness Test Regression Results

Variables	(1) GTFP	(2) GTFP	(3) GTFP	(4) l.GTFP
lnINV	7.134***			6.554***
	(7.21)			(7.81)
GP		3.429***		
		(2.60)		
l.lnINV			4.055***	
			(3.83)	
IS	0.501***	-0.133	0.086	0.117
	(3.20)	(-0.73)	(0.39)	(0.72)
lnGDP	-0.141	0.212**	0.286***	0.262***
	(-1.44)	(2.29)	(2.67)	(2.87)
lnINF	0.042*	0.007	-0.002	0.003
	(1.72)	(0.28)	(-0.05)	(0.11)
lnEDU	-0.026	-0.166**	0.011	-0.107*
	(-0.36)	(-2.30)	(0.13)	(-1.75)
Constant	1.734*	-0.014	2.929**	2.100**
	(1.79)	(-0.02)	(2.47)	(2.42)
Observations	420	420	390	390
R-squared	0.461	0.464	0.402	0.527
Time	Y	Y	Y	Y
Individual	Y	Y	Y	Y

Note: ***p<0.01, **p<0.05, *p<0.1.

First, the replacement of explanatory variables. Following the research of Liu Zhixiong and others, this study employed "green pollution control investment" (GP) as an alternative variable for green investment and re-estimated the model [31]. Green pollution control investment is defined as the ratio of environmental pollution control investment to GDP in each province. The results in column (2) of Table 5 demonstrate a significant impact on green development at the 1% level, compared to the baseline regression results in column (1). This preliminary finding indicates that even after replacing the core explanatory variable, the conclusion remains valid.

Second, addressing endogeneity. This study addressed endogeneity issues by considering first-order lag terms of the core explanatory variable and the dependent variable, significantly reducing

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the potential errors in the econometric setup. The results in columns (3) and (4) of Table 5 show that the coefficient of the first-order lag term of the independent variable is 4.055, and that of the first-order lag term of the dependent variable is 6.554, indicating a significant positive correlation between them. Considering the results from columns (1) to (4) in Table 5, it verifies the significant promotional effect of green investment on green development, consistent with the previous regression results, and ensures the robustness of the research findings.

4.5. Regional Heterogeneity Analysis

Due to variations in the economic development foundation across different regions in China, the effectiveness of green investment may differ. Therefore, this study divided China into three major regions: East, Central, and West, based on geographical and economic development factors, and further examined the regional heterogeneity. The regression results are presented in Table 6.

Table 6: Results of Regional Heterogeneity Testing

VARIABLES	GTFP (Eastern Region)	GTFP (Central Region)	GTFP (Western Region)
lnINV	8.510***	5.739***	0.465
	(4.04)	(2.63)	(0.35)
IS	-0.452	-0.378	0.662***
	(-0.88)	(-1.32)	(4.70)
lnGDP	-0.667**	0.005	0.285***
	(-2.45)	(0.03)	(2.82)
lnINF	-0.047	0.316***	-0.049**
	(-0.79)	(5.57)	(-2.04)
lneEDU	0.122	-0.127	-0.059
	(0.80)	(-1.09)	(-0.84)
Constant	8.416***	0.443	-2.631***
	(2.75)	(0.40)	(-2.73)
Observations	154	112	154
Number of province	11	8	11
R-squared	0.508	0.640	0.480
Time	Y	Y	Y
Individual	Y	Y	Y

Note: ***p<0.01, **p<0.05, *p<0.1.

Analysis of Table 6 reveals that green investment significantly promotes green development in the Eastern and Central regions, while its impact is not as prominent in the Western region. Specifically, green investment has a significant positive influence on green total factor productivity (GTFP) in the Eastern and Central regions at the 1% significance level, with the most substantial impact on GTFP observed in the Eastern region. This can be attributed to the advantageous geographical locations, higher economic development levels, well-established environmental infrastructure, and strong technological innovation capabilities in the Eastern and Central regions. In contrast, the Western region is geographically remote and has a lower level of economic development. Excessive investment in environmental protection in the Western region may not only reduce investments in other sectors but also have adverse effects on local economic development.

In conclusion, regional heterogeneity factors lead to variations in the impact of green investment on the green development levels in the Eastern, Central, and Western regions.

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5. Further Discussion Based on Spatial Effects

As demonstrated in the previous analysis, green investment effectively promotes China's green development levels through both inventive and innovative green technologies. In practice, each province formulates and implements green investment policies that are tailored to its specific circumstances. These policies not only demonstrate consistency but also adapt to local conditions, resulting in region-specific green investment models that serve as examples for other regions to learn from and replicate. Based on this, the study asserts that the driving force of green investment on green development levels exhibits spatial spillover characteristics. Therefore, this paper further constructs a spatial econometric model to validate these effects.

5.1. Construction of Spatial Econometric Models

In the baseline regression model, it was assumed that variables are independent of one another. However, in reality, they inevitably differ due to factors such as inter-provincial distances and proximity. These factors result in the presence of spatial relationships among economic indicators. Therefore, spatial information can be incorporated into panel data, and spatial econometric models can be constructed to examine the spatial impact of green investment on green development. Different spatial econometric models often reveal different spatial characteristics. To ensure the empirical fit, this study simultaneously constructs three types of spatial econometric models: spatial error model, spatial lag model, and spatial Durbin model. The optimal spatial econometric model is selected based on a series of subsequent statistical tests. The specific model formulations are as follows:

$$\lambda \geq 0, s^{g} \geq 0, s^{b} \geq 0, s^{-} \geq 0 \quad (12)$$
$$\varepsilon_{it} = \lambda W \varepsilon_{it} + \tau_{it}$$

In Equation (12), w represents the spatial weight matrix; ρ、θ_1、θ_2、λ are spatial item coefficients; α_1 represents the impact coefficient of green investment on green development levels; α_2 represents the impact coefficients of a series of control variables on green development; $Controls_{it}$ represents a series of control variables. When $\lambda = 0$, it is the spatial Durbin model; when $\lambda = \theta_1 = \theta_2 = 0$, it is the spatial lag model; when $\rho = \theta_1 = \theta_2 = 0$, it is the spatial error model.

Regarding the specification of w, this paper draws from the research of Zhang Yu and others and combines spatial geographic distance with economic attributes to construct a spatial economic distance nested weight matrix [32]. The specific expression is as follows:

$$C_{ij} = \left(\frac{1}{|PGDP_j - PGDP_i + 1|}\right) \times e^{-d_{ij}} \quad (13)$$

Where C_{ij} is the spatial economic distance nested matrix, $PGDP_j$ and $PGDP_i$ represent the per capita GDP of city j and city i, and d_{ij} represents the geographical distance.

5.2. Spatial Correlation Testing and Model Selection

To better assess the level of spatial correlation among variables, a spatial correlation test is required before establishing the spatial econometric model. The Moran's I index is used to examine the spatial autocorrelation of economic activities. The specific calculation formula is as follows:

$$I = \frac{n \sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij} (Y_i - \bar{Y})(Y_j - \bar{Y})}{\sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij} \sum_{i=1}^{n} (Y_i - \bar{Y})^2} \quad (14)$$

Here, n represents the number of provinces, and W_{ij} represents the spatial weight matrix. Only the global Moran's I index test results for green total factor productivity are presented in Table 7. The results show that the autocorrelation for most years passed the significance test, with positive coefficients. While there is a slight fluctuation in the I values, overall, they exhibit an increasing trend. This suggests that green development demonstrates significant and strengthening positive spatial agglomeration effects in the distribution of spatial economic distance weights. Therefore, when analyzing green development levels, its spatial characteristics should be thoroughly considered.

Table 7: Global Autocorrelation Test Results

Year	I-Value	z-Value	P-Value
2007	0.013	1.505	0.132
2008	0.027	1.890	0.059
2009	0.028	1.925	0.054
2010	0.040	2.075	0.038
2011	0.042	2.118	0.034
2012	0.054	2.471	0.013
2013	0.064	2.829	0.005
2014	0.072	3.094	0.002
2015	0.075	3.202	0.001
2016	0.081	3.444	0.001
2017	0.083	3.613	0.000
2018	0.084	3.696	0.000
2019	0.069	3.269	0.001
2020	0.090	3.980	0.000

Note: Using spatial economic distance nested weight matrix.

Based on the Moran's I test, further selection of the spatial effect econometric model is required through the LM test, Wald test, and LR test to determine the optimal spatial model. As shown in Table 8, the Durbin model with two-way fixed effects is the best-fitting model.

Table 8: Suitability Test Results for Spatial Econometric Models

Test Method	LM-error	R-LM (error)	LM-lag	R-LM (lag)	Wald-lag	Wald-error	LR-lag	LR-error
Spatial Economic Distance Weight Matrix	3.627 **	9.998***	3.986 **	7.620 ***	80.52 ***	42.31 ***	68.99 ***	37.37 ***

Note: *** p<0.01, ** p<0.05, * p<0.1

5.3. Regression Analysis of Spatial Econometric Model

As indicated by the regression results of the Durbin model in Table 9, under the spatial economic distance nested weight matrix, the coefficient of green investment is significant at the 1% level, with a value of 7.358. This value is notably higher than the coefficient of 7.134 in the standard baseline regression model. This suggests that the standard baseline model significantly underestimated the impact of green investment on China's green development. The spatial correlation significantly enhances the advantage of green investment. The spatial correlation coefficient (ρ) for the level of green development is significantly positive at the 1% level, indicating a positive spatial spillover effect. Additionally, the coefficient of W×lnINV is 22.189 and significant at the 1% level, signifying that under the spatial spillover effect, green investment has a significant spatial transmission effect on China's green development. This implies that local green investment can significantly promote the improvement of green development in neighboring provinces. This may be attributed to the liquidity of green investment in China, but with uneven development. With the continuous improvement of the green financial system, the green development level in various provinces will rise accordingly.

To more accurately measure the spatial spillover characteristics of green investment on the green development level, this paper reports the decomposition effect results in Table 9. Among these, the direct effect of the green investment coefficient is 6.773 and significantly positive at the 1% level. The indirect effect, also known as the spatial spillover effect, reflects the impact of green investment on the green development level of surrounding areas. The coefficient of green investment in this context significantly increases and is positive at the 5% level. The total effect mainly reflects the average comprehensive effect of green investment on green development, with a coefficient of 12.449, significantly positive at the 1% level. The regression analysis and decomposition results above indicate that green investment not only promotes green development in the local region but also has a positive leading effect on the green development level in neighboring regions, displaying a "local-to-neighboring" spatial effect. This further validates the robustness and reliability of the baseline regression results.

Table 9: Results of Two-Way Fixed Effects Spatial Durbin Model

Variable	GTFP	Direct Effect	Indirect Effect	Total Effect
lnINV	7.358***	6.773***	5.676**	12.449***
	(8.59)	(7.01)	(2.25)	(5.87)
IS	0.562***	0.444***	0.989	1.433**
	(3.50)	(3.11)	(1.63)	(2.46)
lnGDP	0.128	0.142	-0.077	0.064
	(1.38)	(1.21)	(-0.28)	(0.30)
lnINF	-0.010	-0.012	0.041	0.029
	(-0.40)	(-0.44)	(0.53)	(0.36)
lneEDU	-0.053	0.004	-0.671***	-0.667***
	(-0.81)	(0.05)	(-3.50)	(-3.90)
ρ	0.604***			
	(6.93)			
W×lnINV	22.189***			
	(4.44)			
W×IS	2.843**			
	(2.25)			
W×lnGDP	0.047			
	(0.08)			
W×lnINF	0.076			
	(0.43)			
W×lnEDU	-1.571***			
	(-4.08)			
Observations	420	420	420	420
R-squared	0.175	0.175	0.175	0.175
Time	Y	Y	Y	Y
Individual	Y	Y	Y	Y

Note: *** p<0.01, ** p<0.05, * p<0.1.

6. Conclusion and Recommendations

Connecting green investment with the level of green development not only broadens the research scope of green finance but also holds practical significance for China in achieving its "dual carbon" goals and promoting high-quality economic development. This paper, based on provincial panel data from 2007 to 2020 in China, employs the super-efficiency SBM model to measure the green total factor productivity of each province. It empirically tests the impact of green investment on green development and its mechanisms using fixed-effects models. The following conclusions are drawn: ① From an overall perspective, green investment has a positive promoting effect on China's level of green development; ② In terms of the impact pathway, both inventive green technology innovation and improvement-oriented green technology innovation serve as crucial intermediaries in the impact of green investment on the level of green development. The intermediary effect of inventive green technology innovation is more pronounced; ③ Concerning regional heterogeneity, green investment significantly promotes green development in the eastern and central regions, but its promoting effect on the western region is not significant; ④ Regarding spatial spillover characteristics, green investment not only drives local green development but also has a positive spillover effect on surrounding areas. Based on these conclusions, the following policy recommendations are proposed:

1. Enhance the Green Financial System to Support "Dual Carbon" Goals: Firstly, improve the green financial standards to align with carbon neutrality objectives. Secondly, develop green financial information disclosure standards. Thirdly, establish and enhance the system for monitoring and assessing green finance statistics. Fourthly, encourage financial institutions to allocate more assets to green investments and reduce the cost of green development. Fifthly, provide financial support for the green investment field through measures like fiscal subsidies and tax exemptions. Lastly, enhance risk management capabilities by utilizing financial technology and establish an effective green financial statistical monitoring system to accurately and timely identify risk information.

2. Promote Inventive and Improvement-Oriented Green Technology Innovation: Firstly, strengthen the position of enterprises in green technology innovation. Secondly, deepen green value concepts and production methods while raising awareness of high-quality green products and ecological services. Thirdly, continually improve the research and development capabilities of enterprises in green technology. Fourthly, emphasize the selection, digestion, and absorption of foreign technological resources. Fifthly, utilize technological talent advantages. Lastly, accelerate the updating of production technologies to ensure the efficient application of the outcomes of green technology innovation by enterprises.

3. Tailored Management Based on Regional Characteristics to Narrow Economic Disparities: Differential management is necessary due to varying economic development levels and resource endowments in different regions. In the eastern and central regions, utilizing their advantages in population size, economic scale, and technological innovation capabilities is critical. The enhancement of environmental infrastructure and the vigorous promotion of green technology innovation are key. Concurrently, the sustainable development of the environment and economy must be pursued in harmony. In the western region, adjusting the industrial structure, eliminating outdated and high-energy-consuming enterprises, and restricting the development of highly polluting and high-emission industries are essential. Leveraging national policies, absorbing mature technologies, learning, imitating, and assimilating, are necessary to boost technological innovation and narrow the economic gap.

References

[1] *Pearce D W, Warford J J. World without end: economics, environment, and sustainable development[M]. Oxford University Press, 1993.*

[2] Hiroshi Niida. (1990). Introduction to Input-Output Analysis. China Statistics Press.
[3] Gajjar Y. Exploring the scope of green investment in the coal sector of India and its efficacy on Indian economy[J]. Environmental Claims Journal, 2021, 33(4): 279-303.
[4] Huang, Q., Zhang, L., & Wang, Z. (2016). Research on the Environmental Protection Investment Effect of the Silk Road Economic Belt. China Population, Resources and Environment, 26(3), 89-99.
[5] Zhang, L., & Li, X. (2009). Empirical Analysis of the Contribution Rate of China's Environmental Protection Investment to Economic Growth. Special Zone Economy, 2009(3), 265-266.
[6] Halkos G E, Paizanos E A. The effect of government expenditure on the environment: An empirical investigation[J]. Ecological Economics, 2013, 91: 48-56.
[7] Cai, Q., & Wang, X. (2022). The Impact of Green Finance on High-Quality Economic Development from a Spatial Perspective. Jianghan Forum, (528)(6), 21-28.
[8] Zeng, S., & Zhang, M. (2021). Green Investment, Carbon Emission Intensity, and High-Quality Economic Development: A Nonlinear Relationship Test Using Spatial Econometric Model. Western Forum, 31(5), 69-84.
[9] Han, P. (2019). Guidance on Building a Market-Oriented Green Technology Innovation System. Petroleum and Petrochemical Green and Low Carbon, 4(4), 70.
[10] Li, L. (2006). Analysis of the Current Situation and Countermeasures of China's Green Investment. Ecological Economy, 2006(7), 75-77.
[11] Jiang, Y., & Tian, H. (2014). Can External Pressure Promote Corporate Environmental Responsibility? An Empirical Study Based on China's Transitional Economy. Journal of Shanghai University of Finance and Economics, 16(6), 40-49.
[12] Yuan, G. (2009). Green Investment, Green Capital, and Its Value. Modern Economic Research, 2009(11), 13-16.
[13] Shao, X., & Fan, D. (2022). Does Green Venture Capital Suppress Carbon Emissions? An Empirical Study from the Perspective of Green Technology Innovation. Journal of Chongqing University of Technology (Social Science), 36(4), 55-68.
[14] Jaffe A B,Newell R G,Stavins R N. A tale of two market failures: Technology and environmental policy[J]. Ecological Economics,2005,54(2):164-174.
[15] Lanjouw A,Olson J,Mody,A. Stimulating Innovation and The International,Diffusion of Environmentally Responsive Technology: The Role of Expenditures and institutions[J].1995,25(4):549-571.
[16] Li, B., Peng, X., & Chen, Z. (2011). Environmental Regulation, FDI, and Technical Innovation for Pollution Control in China: An Analysis Based on Provincial Dynamic Panel Data. Economic Research, 37(10), 92-102.
[17] He, X. (2019). Technical Innovation and Quality of Economic Growth: An Empirical Analysis Based on Provincial Panel Data. China Science and Technology Forum, 2019(10), 24-32+58.
[18] Chen, Y. (2022). Research on Scientific Research Investment, Technical Innovation, and Urban Green Development: An Empirical Analysis Based on the Yangtze River Economic Belt. Development Research, 2022(3), 23-35.
[19] Yang, Y., Tan, N., & Hu, J. (2022). Global Value Chain Embedding, Technical Innovation, and Green Development of Resource-Based Industries. Statistics and Decision, 38(15), 71-76.
[20] Zhou, P., & Shen, Y. (2022). Environmental Regulation, Green Technology Innovation, and Industrial Green Development. Journal of Hebei University (Philosophy and Social Science), 47(4), 100-113.
[21] Zhang, Y., & Shen, H. (2022). The Influence of Technical Innovation on Green Development: A Case Study of the Yangtze River Delta City Cluster. Science and Technology and Industry, 22(2), 22-28.
[22] Zeng, G., & Hu, S. (2021). Research on the Impact of Technical Innovation on Green Development of Urban Agglomerations in the Yellow River Basin. Geographical Science, 41(8), 1314-1323.
[23] Wen, Z., & Ye, B. (2014). Mediation Analysis: Method and Model Development. Advances in Psychological Science, 22(5), 731-745.
[24] Zhang, J., Wu, G., & Zhang, J. (2004). Estimation of Provincial Material Capital Stock in China: 1952-2000. Economic Research, (10), 35-44.
[25] Tone,K. Dealing with Undesirable Outputs in DEA: A Slacks-based Measure(SBM) Approach. GRIPS Research Report Series,2003.
[26] Oh,D. A Global Malmquist-Luenberger Productivity Index. Journal of Productivity Analysis,2010,34(3) : 183-197.
[27] Li J, Wu Y, Xiao J J. The impact of digital finance on household consumption: Evidence from China[J]. Economic Modelling, 2020, 86: 317-326.
[28] He, L., Wang, Y., & Zhang, X. (2018). Fiscal Decentralization, Energy Conservation and Environmental Protection Expenditure, and Green Development. Economic and Management Review, 34(6), 25-35.
[29] Xu, J., Tong, B., & Wang, M. (2022). Research on the Impact of Green Technology Innovation on CO2 Emissions from a Spatial Perspective. Studies in Science of Science, 40(11), 2102-2112.
[30] Fu, L. (2010). Empirical Study on the Relationship between Advanced Industrial Structure and Economic Growth in China. Statistical Research, 27(8), 79-81.

DOI: 10.54254/2754-1169/73/20231306

[31] Liu, Z. (2011). Empirical Study on the Role of Green Investment in China's Economic Growth. Business Research, (10), 146-150.

[32] Zhang, Y., & Hu, Y. (2020). The Influence of Innovative Human Capital on Green Total Factor Productivity in the Yangtze River Delta Region: An Empirical Analysis Based on Spatial Durbin Model. China Population, Resources and Environment, 30(9), 106-120.