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How Does the "Zero Waste" Vision Promote Enterprise Innovation? Evidence from a Quasi-Natural Experiment

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ABSTRACT

Against the strategic backdrop of the "dual carbon" goal and ecological civilization construction, China's "Zero-Waste City" pilot policy represents a key institutional innovation for advancing solid waste reduction and recycling. This paper empirically examines its microeconomic effects on corporate green innovation by adopting a difference-in-differences (DID) approach, with Shanghai and Shenzhen A-share listed firms from 2015 to 2021 as the sample.The results show that the policy significantly boosts green innovation among enterprises in pilot cities, and this conclusion holds after robustness checks. Mechanism analysis reveals that R&D personnel input plays a partial mediating role, while public environmental concern has no significant mediating effect. Heterogeneity analysis indicates that the policy-driven green innovation effect is concentrated in eastern-region and large-scale enterprises, rather than central-western and small- and medium-sized enterprises.This study enriches research on the microeconomic impacts of environmental regulation and provides empirical support for the nationwide implementation and optimization of the "Zero-Waste City" policy.

KEYWORDS

Zero-Waste City; Pilot Policy; Corporate Green Innovation; Difference-in-Differences Method; Action Mechanism.

1. INTRODUCTION

With the continuous advancement of industrialization and urbanization in China, the annual generation of solid waste has been increasing year by year. The prevention and control of solid waste pollution has thus become a critical challenge in the construction of an ecological civilization. To address the dilemma of "waste siege" and promote green, low-carbon, and circular development, the General Office of the State Council issued the Work Plan for the Pilot Construction of "Zero-waste Cities" in 2018. In 2019, the first batch of pilot projects for the construction of "Zero-waste Cities" was officially launched. Taking into account factors such as geographical location and the level of economic development, the Ministry of Ecology and Environment selected 11 cities, including Shenzhen in Guangdong Province, along with five regions such as Hebei Xiong'an New Area, to carry out the pilot program. This policy aims to achieve source reduction, resource utilization, and harmless disposal of solid waste through institutional innovation, technological innovation, and model innovation. Under the constraints of the "dual carbon" goals, the construction of "Zero-waste Cities" is not only a crucial measure for improving the quality of the ecological environment but also an important institutional instrument for promoting the green transformation of enterprises and stimulating vitality in green innovation.

The relationship between environmental regulation and corporate innovation is a central topic in environmental economics[1-3] . The traditional "compliance cost theory" argues that environmental regulation increases firms' compliance costs, crowding out R&D investment and thus inhibiting innovation[4]. In contrast, the "Porter Hypothesis" posits that well-designed regulations can spur technological innovation through "innovation offsets", ultimately enhancing competitiveness. As a hybrid environmental policy combining command-and-control and market-based instruments, whether the "Zero-waste City" pilot can stimulate corporate green innovation and its underlying mechanisms remain underexplored, with limited empirical evidence[5]. Existing studies on "Zero-waste Cities" primarily focus on policy interpretation[6], international experiences, macro-environmental benefits, and implementation pathways , leaving a gap in micro-level empirical research-particularly regarding causal identification and mechanism testing of its impact on corporate green innovation . Moreover, while prior literature on environmental regulation and green innovation has largely centered on single-policy instruments like carbon emissions trading[7] or environmental tax reforms[8], systematic evidence on comprehensive urban environmental pilot policies such as "Zero-waste Cities" remains scarce.

This paper takes Shanghai and Shenzhen A-share listed companies from 2015 to 2021 as the research sample, regards the implementation of the first batch of "Zero-Waste City" pilot policies as a quasi-natural experiment, and uses the difference-in-differences (DID) model to empirically test the impact of the policy on corporate green innovation. The marginal contributions of this paper are threefold: first, it evaluates the economic effect of the policy from the perspective of micro-enterprise green innovation, making up for the shortage of existing studies that focus on macro-environmental benefits but neglect micro-subject responses; second, it tests the transmission paths of R&D personnel input and public environmental concern, and reveals the heterogeneous characteristics of the policy effect; third, it alleviates endogeneity through various robustness tests, improves the rigor and credibility of the research conclusions, and provides a methodological reference for subsequent relevant policy evaluation studies. The subsequent structure is as follows: literature review and research hypotheses, research design, empirical results and analysis, robustness tests and mechanism tests, heterogeneity analysis, and research conclusions and policy implications.

2. THEORETICAL ANALYSIS AND RESEARCH HYPOTHESES

2.1. Research on the "Zero-waste City" Policy

Guided by the new development philosophy of innovation, coordination, greenness, openness, and sharing, the "Zero-waste City" is an urban development model that promotes green development and lifestyles. It aims to continuously advance the source reduction and resource utilization of solid waste, minimize landfill volume, and reduce the environmental impact of solid waste to the lowest possible level. Existing studies on Zero-waste Cities primarily focus on three areas: first, research on policy connotation and international experience, which clarifies the core concepts, construction frameworks, and advanced international practices, providing a theoretical basis for the implementation of China's pilot policies; second, macro-level environmental and economic benefit assessments, with most studies analyzing the positive effects of Zero-waste City construction on solid waste reduction, carbon emission reduction, and the development of a circular economy at the urban level; third, analysis of implementation pathways and challenges, which examines issues such as incomplete institutional systems, insufficient technical support, and underdeveloped market mechanisms in the construction of Zero-waste Cities in China, and proposes corresponding optimization suggestions. Overall, most existing research focuses on macro-level qualitative analysis and policy interpretation, with a relative lack of quantitative empirical research at the micro-level of enterprises, leaving the causal impact of the Zero-waste City policy on corporate behavior insufficiently identified[6,9-11].

2.2. The Baseline Effect of the "Zero-waste City" Pilot Policy on Corporate Green Innovation

As a composite environmental regulation policy, the "Zero-Waste City" pilot policy incentivizes corporate green innovation through a dual mechanism of command-and-control measures and market-based incentives, operating via three core channels[10,12]. First, compliance pressure compels innovation: the policy sets rigid targets for solid waste reduction and resource utilization, coupled with stringent supervision and assessment, forcing firms to invest in green technology and process upgrades to avoid penalties and reputational damage. Second, the "Porter Hypothesis" is validated through innovation compensation: supportive policies such as fiscal subsidies, tax incentives, and green credit reduce innovation costs, while the expanded market for waste resources creates opportunities for firms to offset compliance costs and gain competitive advantages. Third, the enabling role of an optimized institutional environment. The "Zero-waste City" pilot policy enhances the institutional framework for green innovation in pilot areas-such as intellectual property protection-creating a supportive external environment for enterprises. It also channels social capital toward green and low-carbon sectors, easing financing constraints and boosting corporate motivation for green innovation. Based on this, the paper proposes its core research hypothesis.:

H1: The implementation of the "Zero-Waste City" pilot policy significantly enhances the level of green innovation among enterprises in pilot areas.

2.3. Mechanisms of the "Zero-waste City" Pilot Policy Affecting Corporate Green Innovation

The "Zero-waste City" pilot policy affects corporate green innovation mainly through two paths[12-14]: R&D personnel input and public environmental concern. In terms of R&D personnel input, the compliance pressure and innovation incentives brought by the policy, coupled with talent preferential policies in pilot areas, encourage enterprises to expand green R&D teams and introduce professional talents, thereby improving R&D capabilities and innovation efficiency and promoting green innovation. In terms of public environmental concern, the policy enhances public environmental attention through publicity and education, forming public opinion supervision, green market demand and reputation incentives, which force and guide enterprises to carry out green innovation. Accordingly, hypotheses are proposed:

H2: R&D personnel input plays a significant mediating role in this relationship;

H3: public environmental concern plays a significant mediating role.

2.4. Heterogeneous Characteristics of the Impact of the "Zero-waste City" Pilot Policy on Corporate Green Innovation

The impact of the "Zero-waste City" pilot policy on corporate green innovation varies depending on regional characteristics[15,16] and firm size[17,18]. At the regional level, the eastern region, with its strong economic foundation, well-established innovation resources, and environmental regulation systems, can more effectively translate policy pressure into green innovation momentum. In contrast, the central and western regions, characterized by heavy industrial structures and a lack of innovation resources, face higher transformation costs, resulting in relatively limited policy incentive effects. At the firm size level, large enterprises, leveraging their advantages in capital, talent, and technological accumulation, possess greater risk-bearing capacity and innovation transformation ability, enabling them to actively respond to policy requirements and reap market rewards. Small and medium-sized enterprises, constrained by financing limitations and insufficient innovation capacity, tend to opt for passive compliance rather than active innovation. Based on this, the following research hypotheses are proposed:

H4: The promotional effect of the pilot policy on corporate green innovation is primarily concentrated in the eastern region;

H5: The promotional effect of the pilot policy on corporate green innovation is primarily concentrated in large-scale enterprises.

3. RESEARCH DESIGN

3.1. Sample Selection and Data Sources

This study takes A-share listed companies on the Shanghai and Shenzhen Stock Exchanges from 2015 to 2021 as the initial research sample. Following the common practices of existing studies, the initial sample is screened as follows: ① Excluding ST (Special Treatment) and *ST companies to avoid the interference of financially abnormal samples on the empirical results; ② Excluding listed companies in the financial and insurance industries, as their accounting standards and business models differ significantly from other industries; ③ Excluding samples with severely missing data for core variables; ④ Excluding companies delisted during the study period. Ultimately, an unbalanced panel dataset of 14,514 firm-year observations is obtained. To mitigate the impact of extreme values on the empirical results, all continuous variables are winsorized at the 1% and 99% levels.

The data sources for this paper mainly include: ① Corporate financial data, corporate governance data, and green innovation data are sourced from the CSMAR database and the Wind database; ② The list of “Zero-waste City” pilot cities is obtained from official documents issued by the Ministry of Ecology and Environment and other relevant departments; ③ Regional economic development data are derived from provincial and municipal statistical yearbooks and the National Bureau of Statistics; ④ Public environmental concern data are collected from the Baidu Index platform.

3.2. Variable Definition

The dependent variable, corporate green innovation (LnGreen), is measured as the natural logarithm of one plus the number of green patent applications. The core explanatory variable is the difference-in-differences term (did), defined as the interaction between a treatment group dummy indicating whether a firm is located in a pilot city and a post-policy dummy for years from 2019 onward. Two mediating variables are employed: R&D personnel input, measured by the natural logarithm of the proportion of R&D employees; and public environmental concern, captured by the natural logarithm of the annual average Baidu Index search volume for “environmental pollution” in the firm's city. To isolate the policy's net effect, firm-level control variables include leverage, fixed asset ratio, growth, duality, ROA, top shareholder ownership, size, and operating cash flow; region-level controls include GDP per capita and FDI. Firm and year fixed effects are also incorporated.

Table 1. Variable definitions

Variable Type	Variable Symbol	Variable Name	Definition and Measurement
Dependent Variable	LnGreen	Corporate Green Innovation Level	Natural logarithm of one plus the number of green patent applications
Core Explanatory Variable	did	Difference-in-Differences Term	treat × post; equals 1 for pilot areas after policy implementation, and 0 otherwise
Mediating Variables	RDPersonRatio	R&D Personnel Input	Natural logarithm of the proportion of R&D personnel in total employees
Control Variables	search_index	Public Environmental Concern	Natural logarithm of the annual average Baidu Index search volume for “environmental pollution” in the firm's registered city
	Lev	Leverage Ratio	Total liabilities / Total assets
	Fixed	Fixed Assets Ratio	Net fixed assets / Total assets
	Growth	Firm Growth	Year-on-year growth rate of operating revenue
	Dua	Duality	Equals 1 if the chairman and general manager are the same person, and 0 otherwise
	Roa	Return on Assets	Net profit / Average total assets
	Top1	Largest Shareholder Ratio	Shares held by the largest shareholder / Total shares
	Size	Firm Size	Natural logarithm of total assets
	Cflow	Operating Cash Flow	Net cash flow from operating activities / Total assets
	Gdp	Regional Economic Development Level	GDP of the city where the firm is registered
	Fdi	Regional Foreign Direct Investment	Actual utilized foreign direct investment in the city where the firm is registered
Fixed Effects	CodeFE	Firm Fixed Effects	Firm dummy variables
	YearFE	Year Fixed Effects	Year dummy variables

3.3. Model Specification

3.3.1. Baseline Regression Model

To examine the baseline effect of the “Zero-waste City” pilot policy on corporate green innovation, this paper constructs a two-way fixed effects difference-in-differences model:

$$LnGreen_{it} = \alpha_0 + \alpha_1 did_{it} + \sum\alpha_k Control_{it} + \mu_i + \lambda_t + \varepsilon_{it} \tag{1}$$

Where *i* represents the firm and *t* represents the year. The dependent variable $LnGreen_{it}$ is the level of green innovation of firm i in year t. The core explanatory variable did_{it} is the difference-in-differences term. $Control_{it}$ denotes all control variables. μ_i represents firm fixed effects, λ_t represents year fixed effects, and ε_{it} is the random error term. The coefficient α_1 is of primary interest. If α_1 is significantly positive, it indicates that the "Zero-waste City" pilot policy significantly promotes corporate green innovation, thereby validating hypothesis H1.

3.3.2. Mediation Effect Model

To test the mediating roles of R&D personnel input and public environmental concern, this paper follows the three-step mediation effect testing procedure proposed by Hayes (2013)[19] and constructs the following models based on Model (1):

$$M_{it} = \beta_0 + \beta_1 did_{it} + \sum\beta_k Control_{it} + \mu_i + \lambda_t + \varepsilon_{it} \tag{2}$$

$$LnGreen_{it} = \gamma_0 + \gamma_1 did_{it} + \gamma_2 M_{it} + \sum\gamma_k Control_{it} + \mu_i + \lambda_t + \varepsilon_{it} \tag{3}$$

Where M_{it} epresents the mediating variables, namely R&D personnel input (RDPersonRatio) and public environmental concern (search_index).Other variables and coefficients are the same as those in Model (1).

4. EMPIRICAL RESULTS AND ANALYSIS

4.1. Descriptive Statistics

Table 2. Descriptive Statistics

VarName	Mean	SD	Min	Max
LnGreen	0.992	1.217	0.000	5.242
Lev	0.379	0.188	0.054	0.965
Fixes	0.213	0.130	0.002	0.685
Groeth	0.186	0.393	-0.633	2.910
Dua	0.347	0.476	0.000	1.000
Roa	0.057	0.072	-0.336	0.254
Top1	32.872	13.852	8.420	74.820
Size	22.034	1.167	19.087	26.207
Cflow	0.053	0.066	-0.187	0.255
Gdp	1.250	1.080	2.060	4.328
Fdi	546.184	748.250	1.000	3063.000

Table 2 presents the descriptive statistics of the core variables. The dependent variable, corporate green innovation (LnGreen), has a mean of 0.992 and a standard deviation of 1.217, indicating considerable variation in green innovation levels among sample firms. Among firm-level control variables, the mean values of leverage (Lev) and firm size (Size) are 0.379 and 22.034, respectively, reflecting a relatively reasonable capital structure and size distribution of the sample. At the regional level, the mean values of GDP per capita (Gdp) and foreign direct investment (Fdi) are 1.250 and 546.184, respectively, suggesting disparities in economic development and the foreign investment environment across firms' locations.

4.2. Baseline Regression Results

Table 3. Estimation findings of DID method

	(1)	(2)	(3)
	LnGreen	LnGreen	LnGreen
did	0.3866***	0.1331***	0.0965***
	(12.2846)	(4.2194)	(3.0068)
Lev		-0.1692**	-0.1828**
		(-2.2522)	(-2.4460)
Fixed		-0.0201	0.0537
		(-0.1986)	(0.5318)
Growth		-0.0533***	-0.0322**
		(-3.3495)	(-2.0009)
Dua		0.0052	0.0137
		(0.2469)	(0.6524)
Roa		-0.2685**	-0.1778
		(-2.3223)	(-1.5435)
Top1		-0.0023*	0.0006
		(-1.7375)	(0.4213)
Size		0.5568***	0.4447***
		(29.6413)	(21.4067)
Cflow		0.2196**	0.0789
		(1.9759)	(0.7032)
Gdp		0.0000***	-0.0000
		(4.6074)	(-1.4135)
Fdi		-0.0001	0.0001**
		(-1.2071)	(2.0603)
YearFE	NO	NO	YES
CodeFE	YES	YES	YES
_cons	0.9676***	-11.2126***	-9.0101***
	(172.1103)	(-27.1237)	(-20.0293)
N	14514	14514	14514
R^2	0.013	0.122	0.136
adj. R^2	-0.251	-0.114	-0.096

Notes:t statistics in parentheses

* p < 0.1, ** p < 0.05, *** p < 0.01

Table 3 reports the firm fixed effects regression results with the logarithm of corporate green innovation level (LnGreen) as the dependent variable. In Column 1, which only controls for firm fixed effects in the baseline regression, the coefficient of the core explanatory variable did is 0.3866, significantly positive at the 1% statistical level. After adding firm-level and region-level control variables in Column 2, the coefficient of did decreases to 0.1331, remaining significantly positive at the 1% level, indicating that the positive impact of the policy remains robust after controlling for factors such as corporate leverage, growth, size, cash flow, and regional economic development level. In Column 3, after further controlling for time fixed effects, the coefficient of did is 0.0965, significantly positive at the 1% level. This result suggests that, after excluding common time-related shocks such as macroeconomic fluctuations and industry trends, the net effect of the policy on corporate green innovation remains present and robust. Overall, the policy shock has a significant and robust positive promoting effect on corporate green innovation. The explanatory power of the models gradually increases with the inclusion of control variables and time effects, confirming the reliability of the core conclusion.

4.3. Robustness Test

4.3.1. Event Study

Figure 1 reports the parallel trends test results for the difference-in-differences model. Before the policy implementation, the coefficients for each period are not significant, and the confidence intervals contain zero, indicating no significant difference in green innovation levels between the treatment group and control group firms prior to the policy, thus satisfying the parallel trends assumption. After the policy implementation, the coefficients become significantly positive, suggesting that the policy shock has a significant positive promoting effect on corporate green innovation, and this effect persists in the post-policy period.

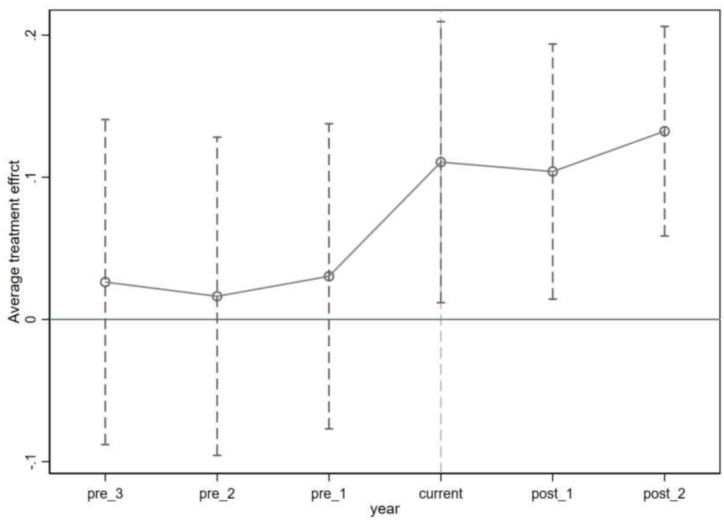

Figure 1. Parallel trend test results

4.3.2. Placebo Test

A sample of enterprises with the same number as the original treatment group was drawn from the sample to serve as the "pseudo-treatment group". A "pseudo-policy" implementation variable was generated for regression, and this procedure was repeated 500 times. The test results, as shown in Figure 2, are robust and reliable.

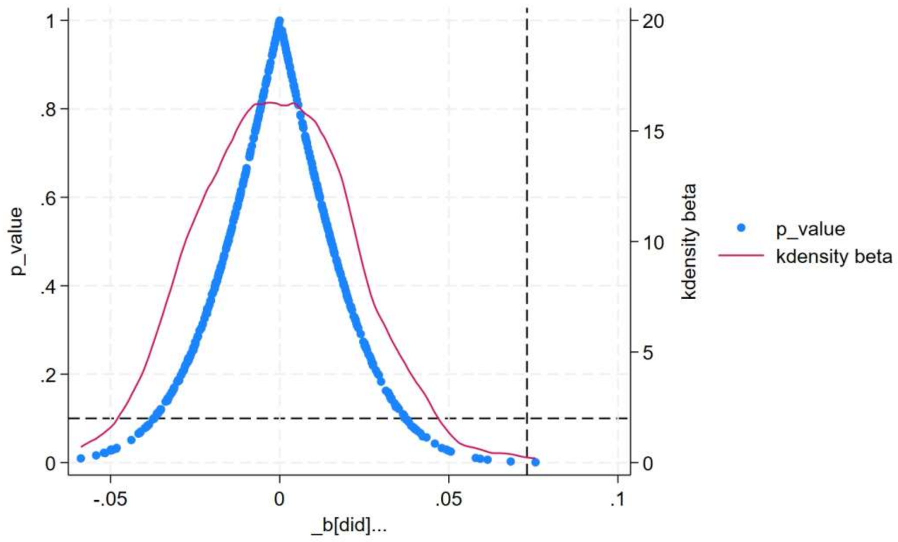

Figure 2. Placebo Test

4.3.3. PSM-DID

To mitigate the endogeneity issue arising from sample selection bias, this paper employs the Propensity Score Matching (PSM) method to match the treatment group with the control group, and then conducts a difference-in-differences regression using the matched sample. Specifically, the one-to-one nearest neighbor matching method is adopted, with covariates including firm size, leverage ratio, firm growth, return on assets, and fixed assets ratio for propensity score matching. The balance test results show that after matching, the standardized biases of all covariates are significantly reduced and are all controlled within 10%, indicating that the matching method is appropriately chosen and effectively balances the sample characteristics between the treatment and control groups. The regression results after matching are presented in Column 1 of Table 4. The coefficient of the core explanatory variable did is 0.3749, significantly positive at the 10% statistical level, which is consistent with the baseline regression conclusion. This indicates that after mitigating sample selection bias, the promoting effect of the "Zero-waste City" pilot policy on corporate green innovation remains significant, and the core conclusion is robust.

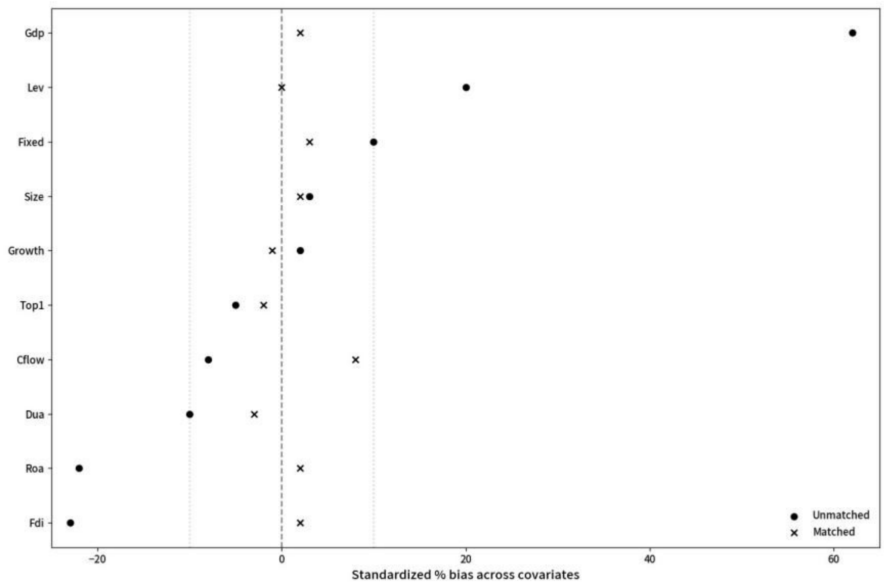

Figure 3. Covariate Balance Results Based on Nearest Neighbor Matching

4.3.4. High-Dimensional Fixed Effects Regression

To further mitigate the interference of omitted variable bias on the estimation results, this paper employs a high-dimensional fixed effects regression approach for robustness testing. By incorporating more stringent multi-dimensional fixed effects, this method more comprehensively controls for the influence of unobservable factors. The regression results are presented in Column 2 of Table 4. The coefficient of did is 0.0965, statistically significant at the 1% level, which is fully consistent with the baseline regression in terms of magnitude, direction, and significance. This indicates that the baseline findings are not driven by model specification errors or omitted variables, demonstrating strong robustness.

4.3.5. Excluding the Policy Implementation Year Sample

To avoid the potential influence of observations from the policy implementation year on the research conclusions, this paper excludes firm samples from 2019-the year when the "Zero-waste City" pilot policy was implemented-and re-conducts the regression. The results are shown in Column 3 of Table 4. The coefficient of the core explanatory variable did is 0.1129, significantly positive at the 1% level, which is highly consistent with the baseline regression findings. This suggests that the core conclusion is not driven by specific events in 2019 but rather reflects the causal effect of the policy itself, further enhancing the credibility of the findings.

Table 4. Robustness Test Results

	(1)	(2)	(3)
	PSM-DID	High-dimensional regression	Drop 2019
did	0.3749*	0.0965***	0.1129***
	(1.8618)	(2.8774)	(3.0503)
Controls	YES	YES	YES
YearFE	YES	YES	YES
CodeFE	YES	YES	YES
_cons	-15.6274***	-8.7976***	-9.2104***
	(-5.5086)	(-16.0147)	(-19.1852)
N	1641	14064	12343
R2	0.218	0.809	0.152
adj. R2	-2.483	0.766	-0.130

Notes:t statistics in parentheses

* p < 0.1, ** p < 0.05, *** p < 0.01

5. MECHANISM TEST

5.1. Mediation Effect Test of R&D Personnel Input

R&D personnel input is a core element for enterprises to carry out green innovation activities, and its intensity directly determines a firm's capability for green technology research, development, and transformation. This paper measures the level of R&D personnel input using the natural logarithm of the ratio of R&D personnel to total employees (RDPersonRatio) and constructs a mediation effect model to test its mechanism. The test results are shown in Table 5. Column 1 presents the baseline regression results, where the coefficient of the core explanatory variable did is 0.0898, significantly positive at the 5% statistical level, once again validating the policy's promoting effect on corporate green innovation. Column 2 uses R&D personnel input as the dependent variable for regression; the coefficient of did is 0.7209, highly significant at the 1% level, indicating that the implementation of the “Zero-waste City” pilot policy significantly promoted firms in pilot areas to increase their R&D personnel input. In Column 3, after incorporating R&D personnel input into the baseline regression model, the coefficient of the core explanatory variable did remains significantly positive at the 5% level, but its value slightly decreases from 0.0898 to 0.0882. Meanwhile, the coefficient for R&D personnel input is 0.0095, significantly positive at the 1% level.

The above results fully meet the testing criteria of the three-step mediation effect procedure, confirming that R&D personnel input plays a significant partial mediating role between the “Zero-waste City” pilot policy and corporate green innovation. Thus, research hypothesis H2 of this paper is validated. This finding indicates that the “Zero-waste City” pilot policy, by guiding enterprises to increase their R&D personnel input, achieves continuous empowerment of intellectual capital, provides core human capital support for corporate green innovation, and consequently promotes the improvement of firms' green innovation levels.

5.2. Mediation Effect Test of Public Environmental Concern

Table 5. Mechanism Test

	(1)	(2)	(3)
	LnGreen	search_index	LnGreen
did	0.0898**	3.8620***	0.0900**
	(2.4613)	(12.0550)	(2.4654)
search_index			-0.0003
			(-0.2298)
Controls	YES	YES	YES
YearFE	YES	YES	YES
CodeFE	YES	YES	YES
_cons	-9.6408***	59.1657***	-9.6274***
	(-19.9374)	(14.6644)	(-19.7671)
N	12435	13732	12435
R2	0.147	0.532	0.147
adj. R2	-0.084	0.410	-0.084

Notes:t statistics in parentheses

* p < 0.1, ** p < 0.05, *** p < 0.01

To further explore the mechanism through which the “Zero-waste City” pilot policy influences corporate green innovation, this paper examines the mediating role of public environmental concern. As public environmental concern increases, this “bottom-up” force gradually exerts a significant impact on corporate innovation activities. This paper measures public environmental concern using the natural logarithm of the annual average Baidu Index search volume for “environmental pollution,” as shown in Table 6. Column 1 presents the baseline regression results, once again validating the policy's significant promoting effect. Column 2 uses public environmental concern as the dependent variable for regression; the coefficient of did is 3.8620, highly significant at the 1% statistical level, indicating that the implementation of the “Zero-waste City” pilot policy effectively stimulated public concern for environmental issues in pilot areas. In Column 3, after incorporating public environmental concern into the baseline regression model, the coefficient of the core explanatory variable did remains significantly positive at the 5% level, while the coefficient for public environmental concern is -0.0003 and statistically insignificant.

The above results indicate that although the “Zero-waste City” pilot policy significantly increased public environmental concern, public environmental concern does not exhibit a significant mediating effect between the policy and corporate green innovation. Therefore, research hypothesis H3 of this paper is not validated. The reason for this result may be that, at the current stage, the primary drivers of green innovation among Chinese enterprises remain top-down policy regulations and market pressures. As a form of “bottom-up” informal environmental regulation, the transmission mechanism of public environmental concern to corporate innovation decisions has not yet been fully established. On the one hand, feedback channels and supervision mechanisms for public environmental appeals remain underdeveloped, making it difficult to effectively translate public environmental pressure into corporate innovation momentum. On the other hand, corporate responses to public environmental concern tend to remain at the compliance level, such as environmental information disclosure and public welfare campaigns, rather than translating into substantive green R&D investment and technological innovation.

6. FURTHER ANALYSIS

To gain a deeper understanding of the boundary conditions under which the “Zero-waste City” pilot policy affects corporate green innovation, this paper conducts an analysis from two core dimensions: regional heterogeneity and firm size heterogeneity. On the one hand, China's vast territory exhibits significant regional disparities in economic development levels, industrial structures, environmental regulation enforcement intensity, and innovation resource endowments. The eastern region, with its strong economic foundation, concentration of innovation factors, and higher degree of marketization in environmental governance, is more responsive to policy signals. In contrast, the central and western regions lag in economic transformation and technological accumulation, leading to potential regional variations in the implementation effectiveness of the pilot policy. Therefore, dividing the sample into eastern, central, and western regions can effectively reveal the differentiated policy effects across different development gradients. On the other hand, firm size is a key determinant of resource acquisition capabilities and risk-bearing willingness. Large-scale enterprises, with their ample funds, more established R&D systems, and stronger policy compliance capabilities, are better positioned to transform environmental regulation pressure into green innovation momentum. Small and medium-sized enterprises, however, commonly face financing constraints, technological bottlenecks, and talent shortages, leaving them with limited capacity to respond to policy shocks. By distinguishing between large-scale and small and medium-sized enterprises, the differential distribution of policy benefits among various market entities can be clearly identified.

The regression results reveal that, in terms of regional heterogeneity, the coefficient of did in the subsample of the eastern region is 0.0773, significantly positive at the 10% statistical level. In contrast, the coefficients of did in the central and western regions are not significant, indicating that the green innovation incentive effect of the policy is primarily concentrated in the eastern region, which possesses superior economic and innovation foundations. Regarding firm size heterogeneity, the coefficient of did in the subsample of large-scale enterprises is 0.0936, significantly positive at the 10% statistical level, while the coefficient of did in the subsample of small and medium-sized enterprises is not significant. This suggests that the policy's promoting effect is mainly driven by large-scale enterprises, whereas small and medium-sized enterprises still exhibit insufficient capacity to respond to the policy.

Table 6. Heterogeneity Analysis

	(1)	(2)	(3)	(4)	(5)
	Eastern	Western	Central	Large	Small&medium
did	0.0773*	-0.1102	0.1331	0.0936*	0.0357
	(1.9059)	(-0.7531)	(0.8803)	(1.8464)	(0.6455)
Controls	YES	YES	YES	YES	YES
YearFE	YES	YES	YES	YES	YES
CodeFE	YES	YES	YES	YES	YES
_cons	-10.0716***	-9.4153***	-8.9144***	-7.9985***	-11.8342***
	(-17.0359)	(-6.9592)	(-7.6108)	(-9.5917)	(-12.6615)
N	8740	1435	2260	6429	6006
R2	0.146	0.161	0.154	0.065	0.179
adj. R2	-0.090	-0.068	-0.083	-0.317	-0.063

Notes:t statistics in parentheses

* p < 0.1, ** p < 0.05, *** p < 0.01

7. RESEARCH CONCLUSION AND POLICY IMPLICATIONS

7.1. Research Conclusion

Using A-share listed companies on the Shanghai and Shenzhen Stock Exchanges from 2015 to 2021 as the research sample, this paper treats the implementation of the first batch of “Zero-waste City” pilot policies as a quasi-natural experiment. Employing a difference-in-differences model, it empirically examines the impact, mechanisms, and heterogeneous characteristics of this policy on corporate green innovation. The main research conclusions are as follows:

First, the implementation of the “Zero-waste City” pilot policy has significantly enhanced the green innovation level of enterprises in pilot areas. This conclusion remains robust after a series of tests, including parallel trend tests, placebo tests, PSM-DID analysis, high-dimensional fixed effects regression, and excluding the policy implementation year sample. This indicates that the innovation incentive effect of the “Zero-waste City” pilot policy possesses robust causality.

Second, the mechanism tests reveal that R&D personnel input plays a significant partial mediating role between the “Zero-waste City” pilot policy and corporate green innovation. That is, the policy guides enterprises to increase R&D personnel input, thereby providing intellectual support for green innovation and subsequently enhancing corporate green innovation levels. However, the mediating effect of public environmental concern is not observed. Although the policy has significantly increased public environmental concern, this “bottom-up” supervisory force has not yet been effectively transformed into an internal driver for corporate green innovation.

Third, the heterogeneity analysis demonstrates significant boundary conditions for the green innovation incentive effect of the “Zero-waste City” pilot policy. From the perspective of regional heterogeneity, the policy's promoting effect is primarily concentrated among enterprises in the eastern region and is not significant for enterprises in the central and western regions. From the perspective of firm size heterogeneity, the policy's promoting effect is mainly concentrated among large-scale enterprises and is not significant for small and medium-sized enterprises.

Future research can be expanded in the following directions: First, explore the synergistic effects of the “Zero-waste City” policy with other environmental regulation policies, such as carbon emissions trading and environmental protection taxes, to provide empirical evidence for constructing a systematic and comprehensive environmental regulation system. Second, analyze the impact of the "Zero-waste City" policy on other micro-level economic variables, such as corporate total factor productivity, export trade, financial performance, and employment structure, to comprehensively assess the economic and social effects of the policy. Third, analyze the transmission effects of the "Zero-waste City" policy from an industrial chain perspective, investigating the spillover effects of the policy on the green innovation of upstream and downstream enterprises, thereby deepening the understanding of the policy's micro-level effects.

7.2. Policy Implications

Based on the above research conclusions, this paper proposes targeted policy implications from three dimensions: government, enterprise, and regional coordination.

First, at the government level: (1) Continue to deepen the national promotion and optimization of the "Zero-waste City" pilot policy. While expanding the scope of the pilot program, further improve the top-level design of the policy and provide more precise supporting incentives such as fiscal subsidies, tax incentives, and green credit to reduce the costs and risks of corporate green innovation, thereby fully unleashing the innovation incentive effect of the policy. (2) Establish a differentiated policy support system. For the central and western regions, increase central fiscal transfer payments and the allocation of innovation resources, improve environmental infrastructure construction, and enhance the capacity for environmental regulation enforcement. Simultaneously, formulate policy objectives tailored to regional industrial characteristics to avoid a "one-size-fits-all" approach. For small and medium-sized enterprises, establish special support funds for green innovation, broaden green financing channels to alleviate financing constraints, and provide green technology guidance and support through public R&D platforms to lower the threshold for innovation for SMEs. (3) Smooth the transmission channels for public environmental appeals. Improve the mandatory disclosure system for corporate environmental information, strengthen the legal effectiveness of public environmental supervision, and establish a response and feedback mechanism for public environmental demands. Promote synergy between "bottom-up" public supervision and "top-down" policy regulation to jointly stimulate corporate green innovation momentum.

Second, at the enterprise level: (1) Actively respond to the requirements of the "Zero-waste City" policy by integrating the concept of green and low-carbon development into long-term corporate strategies. Increase investment in innovation factors such as R&D personnel, and focus on green technology R&D in core areas like solid waste reduction and resource utilization, achieving a win-win situation of environmental compliance and innovative development. (2) Large-scale enterprises should fully leverage their leading role by driving upstream and downstream SMEs to engage in green technology innovation through industrial chain collaboration, technology sharing, and joint R&D, thereby building a green and low-carbon industrial and supply chain system. (3) Small and medium-sized enterprises should actively seize policy opportunities, proactively connect with government green support policies, strengthen industry-university-research cooperation with universities and research institutions, focus on green technology innovation in niche areas, and explore low-cost green transformation paths suitable for their own development.

Third, at the regional coordination level: Strengthen inter-regional green development collaboration by establishing green technology transfer and innovation cooperation mechanisms between the eastern region and the central and western regions, promoting the diffusion of advanced green technologies and management experiences from the east to the central and western regions. Establish a cross-regional collaborative development system for solid waste treatment and the circular economy, break down regional administrative barriers, achieve optimal regional allocation of solid waste resource utilization, narrow the green development gap between regions, and promote the coordinated national advancement of "Zero-waste City" construction.

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