Bidirectional Spatial Spillover Effects of Green Finance Reform and Innovation Pilot Zones

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Abstract. In 2017, the Chinese government established the first batch of Green Finance Reform and Innovation Pilot Zones (GFRIPZ), which were later expanded to "seven provinces and ten regions." Green finance is financial activity supporting environmentally sustainable projects. The policy generates both positive spillovers and negative siphon effects, potentially crowding out surrounding resources while promoting local green transformation. This paper hypothesizes that the spatial effects of green finance policy represent a coexisting relationship rather than a strict choice between "spillovers" and "siphon effects." Methodologically, this study utilises the spatial difference-in-differences method to estimate the effects of green finance policies while accounting for spatial relationships. Simultaneously, a spatial Durbin model is used to evaluate the direct and indirect spatial effects of carbon emissions from neighboring cities and explanatory variables. Furthermore, a geographically weighted regression is applied to identify the distance threshold beyond which positive effects become negative. Empirical results reveal that reform and policies related to innovation pilot zones have markedly lowered the carbon intensity of pilot cities. Moreover, the spatial spillover effects manifest a bidirectional "radiation siphon" mechanism, the magnitude of which differs by geographical distance.

Keywords: Bidirectional Spatial Spillover Effects, Green Finance Reform, Innovation Pilot Zones.

1 Introduction

Under China's "dual carbon" targets (carbon peaking and carbon neutrality), green finance functions as a market-based tool to guide capital into green sectors and promote economy transition to low-carbon. The policy began in 2017, when the State Council approved the first GFRIPZ across eight regions in five provinces: Chongqing, Guangdong, Guizhou, Jiangxi, and Xinjiang. Gansu and Zhejiang were subsequently incorporated, forming a spatial layout of "seven provinces and ten regions" [1-3]. Existing research shows that these pilot zones have promoted green innovation among enterprises and reduced regional carbon emissions [2, 3].

However, the effect of a regional policy pilot program is often not limited to its own administrative boundaries. Capital, talent, and technology move freely, carrying policy effects with them—through relocating factories, spreading know-how, and copying

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institutional models [1, 2, 4]. Studies agree that green finance pilots generate spatial spillovers, yet disagree sharply on which way they point. Some studies have found a positive spillover effect; another group of studies has found that green finance policies may have a siphon effect, competitively suppressing the energy efficiency of neighboring cities or subjecting them to negative spillovers [1, 4, 5, 6]. Furthermore, the policy effect is moderated by regional heterogeneity and is more pronounced in areas with higher levels of financial development, dense industrial agglomeration, and stronger environmental regulations [7-9]. This raises a core question: given limited green finance resources, will pilot zones act as "resource magnets," thereby inhibiting the green transformation capacity of neighboring cities [6, 10, 11]?

Based on the above review, green finance policies exhibit a dual mechanism of positive spillover and negative siphoning. Positive spillover is mainly achieved through three pathways: diffusion of green technologies and knowledge [1, 7, 9], cross-regional flow of green capital [4, 12, 13], and demonstration and synergy of environmental regulatory standards [7, 8, 14], but the marginal effect diminishes over time [6, 10]. Negative siphoning stems from unequal flows in the capital market [4, 13], the "magnet effect" of green professionals converging on policy centers [6, 12], and the "pollution refuge" trap formed by industrial transfer [1, 7, 15]. Based on this, this paper argues that these two directions are not mutually exclusive but coexist, and may undergo phased shifts with geographical distance [1, 4, 14]. Within short distances, the siphoning effect dominates; however, as distance increases, the radiation effect gradually surpasses the siphoning effect, reaching a peak of positive spillover at medium distances before gradually weakening.

To verify the above theoretical hypotheses, this paper takes the first batch of GFRIPZ established in 2017 as quasi-natural experiments to systematically evaluate the local carbon emission reduction effect of the policies and their spatial spillover characteristics. This paper proposes two core research hypotheses: First, the pilot zone policies have a significant direct effect on local carbon emission reduction, and there is a two-way spatial spillover effect with both "radiation and siphoning" [1, 2, 6]; Second, the direction of the spatial spillover effect changes with geographical distance, with siphoning suppression being the main effect at close range (≤200km) and positive radiation being the main effect at medium and long range (500-800km) [4, 6, 10].

The marginal contributions of this paper are reflected in three aspects: First, it breaks the "one-way" understanding of spatial spillover and constructs and verifies the "siphon-radiation" two-way spillover analysis framework; second, it identifies the geographical distance threshold for the conversion of spatial effect direction; third, it provides actionable policy insights for optimizing spatial layout and cross-regional collaboration mechanisms.

2 Method

This study primarily examines the impact of the GFRIPZ policy on carbon emission intensity. Based on this objective, three econometric models were constructed. Table 1 shows the variable definitions.

Difference-in-Differences (DID) Model:

$$CarbonIntensity_{it}=\alpha+\beta Treat_{it}+\gamma X_{it}+\mu_i+\lambda_t+\varepsilon_{it} \quad (1)$$

Spatial Durbin Model (SDM):

$$Y_{it}=\rho \sum_{j=1}^{n} w_{ij} Y_{jt}+\beta X_{it}+ \theta \sum_{j=1}^{n} w_{ij} X_{jt}+\mu_i+\lambda_t+\varepsilon_{it} \quad (2)$$

Geographically Weighted Regression (GWR) Model:

$$Y_i=\beta_0(u_i,v_i)+\sum_k \beta_k (u_i,v_i)X_{ik}+\varepsilon_i \quad (3)$$

Table 1. Variable definitions.

Variable Type	Variable Name	Variable Symbol	Definition
Dependent variable	Carbon emission intensity (CEI)	CarbonIntensity	The ratio of total city-level CO_2 emissions to real GDP, measuring carbon emissions per unit of economic output. The unit is tons per 10,000 yuan.
Core explanatory variable	Green finance reform and innovation pilot zone policy	Treat	Equals 1 for pilot-zone cities in the post-implementation period; 0 otherwise.
Policy group variable	Pilot city	pilot	Equals 1 if a city belongs to the Green Finance Reform and Innovation Pilot Zones; 0 otherwise.
Policy time variable	Post-policy period	post	Equals 1 for 2017 and later years; otherwise equals 0.
Control variable	Economic development level	GDP_percapita	Natural log of per capita GDP, a proxy for urban economic development.
	Urbanization level	Urbanization	The share of urban population in total population, used to measure the degree of urbanization.
	Openness	Openness	The ratio of total imports and exports to GDP, used to measure the level of external openness.
	Environmental regulation intensity	EnvironmentalRegulation	The industrial pollution control investment as a share of GDP, a proxy for local environmental governance.
Spatial lag variable	Spatial lag of policy variable	W_Treat	The spatially lagged term of Treat calculated using the spatial adjacency matrix, reflecting the effect of neighboring cities' pilot policies on the local city.
	Spatial lag of carbon emission intensity	W_CarbonIntensity	The spatially lagged term of CarbonIntensity calculated using the spatial adjacency matrix, reflecting the

			influence of neighboring cities' carbon emission intensity on the local city.
	Spatial lag of economic development level	W_GDP_percapita	The spatially lagged term of GDP_percapita calculated using the spatial adjacency matrix, used to control for the spatial influence of neighboring cities' economic development levels.
	Spatial lag of urbanization level	W_Urbanization	The spatially lagged term of Urbanization calculated using the spatial adjacency matrix, used to control for the spatial influence of neighboring cities' urbanization levels.
	Spatial lag of openness	W_Openness	The spatially lagged term of Openness calculated using the spatial adjacency matrix, used to control for the spatial influence of neighboring cities' openness levels.
	Spatial lag of environmental regulation intensity	W_EnvironmentalRegulation	The spatially lagged term of EnvironmentalRegulation calculated using the spatial adjacency matrix, used to control for the spatial influence of neighboring cities' environmental regulation intensity.
	Spatial weight	weight	A row-standardized spatial weight constructed based on geographical proximity among cities, used to measure the strength of spatial linkages.
Spatial adjacency variable	Adjacency relationship	binary_adj	Equals 1 if two cities are spatially adjacent; otherwise equals 0.
	Number of neighboring cities	neighbor_count	The number of neighboring cities connected to each city in the spatial adjacency matrix.
Geographic variable	Longitude	lon	City-level geographic longitude, used to construct the spatial adjacency matrix.
	Latitude	lat	City-level geographic latitude, used to construct the spatial adjacency matrix.
Fixed effect	City fixed effects	City FE	Controls for time-invariant unobservable heterogeneity at the city level.
	Year fixed effects	Year FE	Controls for common macro-level time shocks affecting all cities.

Model Design:

This study leverages the GFRIPZ policy as a quasi-natural experiment using city-level panel data.

A DID model is first employed to estimate the policy's local emission reduction effects. The subscripts i and t denote city and year, respectively. $CarbonIntensity_{it}$ represents city i's carbon emission intensity (CEI) in *yeart,* $Treat_{it}$ denotes the GFRIPZ policy variable, and X_{it} denotes a set of control variables including GDP per capita, urbanization, openness, and environmental regulation. The coefficient of primary interest is β; a significantly negative value indicates that the pilot zone policy effectively reduces CEI in treated cities.

Building on the baseline DID, this study incorporates spatial interdependence. Since carbon emissions and green finance policies may diffuse across jurisdictions, a spatial adjacency matrix is constructed based on geographic proximity and row-standardized.

In the spatial weight matrix, element w_{ij} captures the spatial linkage intensity between city i and city j, taking a positive weight if the two cities are contiguous and zero otherwise. Based on this matrix, spatial lag terms of the core and control variables are constructed to characterize the influence of neighboring cities' attributes on local CEI.

The spatially extended model is specified as follows:

$$CarbonIntensity_{it}=\alpha+\beta Treat_{it}+\rho W_CarbonIntensity_{it}+\theta W_Treat_{it}$$
$$+\gamma X_{it}+\delta W_X_{it}+\mu_i+\lambda_t+\varepsilon_{it} \quad (4)$$

Where $W_CarbonIntensity_{it}$ denotes the spatial lag term of neighboring cities' CEI, capturing the influence of surrounding emission levels on the local jurisdiction. W_Treat_{it} represents the spatial lag term of the pilot zone policy variable in neighboring cities, while $_X_{it}$ denotes the spatial lags of control variables, namely *W_GDP_percapita*, *W_Urbanization*, *W_Openness*, and *W_EnvironmentalRegulation*. In this specification, β captures the policy's direct effect on local CEI, whereas θ captures the spatial spillover effect of neighboring cities' pilot policies on the local jurisdiction. A statistically significant θ indicates that the pilot zone policy not only affects treated cities themselves but also radiates to surrounding cities through spatial linkages.

In this model, β reflects the direct impact of policies on the local city's CEI, while θ reflects the spatial impact of pilot policies in neighboring cities on the local carbon emission intensity. If θ is significant, it indicates that the policies of the GFRIPZ not only affect the pilot city itself but also influence surrounding cities through spatial connections.

3 Empirical Results

3.1 Descriptive Statistical Analysis

According to descriptive statistics, the mean CEI of the sample cities is 0.553, the standard deviation is 0.265, and the range is 0.300 to 1.675, indicating significant differences in carbon emission levels among cities. The control variables and spatial lag terms all exhibit some dispersion, suggesting differences among the sample cities,

and that CEI and policy exposure both show preliminary spatial correlation characteristics.

3.2 Correlation and Multicollinearity Analysis

Based on the correlation analysis of the original variables, W_Treat and CarbonIntensity are also negatively correlated, indicating that pilot policies in neighboring cities may have spillover effects on local carbon emission intensity. The correlation coefficient between W_CarbonIntensity and CarbonIntensity is 0.439, indicating a strong spatial synchronicity in urban carbon emission intensity. Among the control variables, per capita GDP and urbanization level are negatively correlated with CEI, suggesting that economic development and urbanization may be accompanied by an improvement in low-carbon transition capabilities.

3.3 Moran's I Spatial Autocorrelation Test

Based on the spatial autocorrelation test results of Moran's I for urban carbon emission intensity from 2012 to 2022, the values are positive for each year, indicating a stable positive spatial correlation. The data suggest that traditional non-spatial models alone may not adequately capture the spatial dependence of CEI. Therefore, introducing spatially lagged variables and spatial extension models is necessary.

3.4 Wald Joint Significance Test

Wald joint significance test results based on the DID model and spatial extension model. All policy variables passed the 1% significance level (p=0.000). In the spatial model, W_Treat was significant (p=0.004), and the core spatial terms were jointly significant (p=0.014). This indicates that green finance policies not only have local emission reduction effects and also significant spatial spillover effects.

3.5 Baseline Regression Results

Table 2. Baseline regression results based on original variables.

Variable	(1) DID	(2) Spatial Model	(3) Spatial Model + W Controls
Green finance pilot policy	-0.207*** (-6.177)	-0.220*** (-6.493)	-0.220*** (-6.480)
GDP per capita	-0.115*** (-3.751)	-0.118*** (-3.888)	-0.118*** (-3.896)
Urbanization	-0.422*** (-2.702)	-0.410*** (-2.655)	-0.410*** (-2.649)
Openness	0.025 (0.344)	0.025 (0.343)	0.024 (0.320)
Environmental regulation	-1.520** (-1.996)	-1.640** (-2.170)	-1.632** (-2.161)
Spatial lag of pilot policy		-0.295*** (-2.780)	-0.298*** (-2.786)

Spatial lag of carbon intensity		-0.019 (-0.296)	-0.021 (-0.337)
W_GDP_percapita			-0.038 (-0.528)
W_Urbanization			0.128 (0.339)
W_Openness			-0.026 (-0.129)
W_EnvironmentalRegulation			-0.172 (-0.090)

Note: t-values are reported in parentheses; * p<<0.10, ** p<0.05, *** p<0.01.

Table 2 reports baseline regression results. In column (1), the pilot zone policy coefficient is −0.207 (significant at 1%), indicating significant local emission reduction after controlling for city and year fixed effects and covariates. In columns (2) and (3), the Treat coefficient remains significantly negative with spatial lags included, confirming robustness. W_Treat coefficients are −0.295 and −0.298 (both significant at 1%), implying that neighboring pilot policies reduce local carbon intensity (Fig.1). Among controls, GDP per capita, urbanization, and environmental regulation are all significantly negative, suggesting these factors facilitate the low-carbon transition.

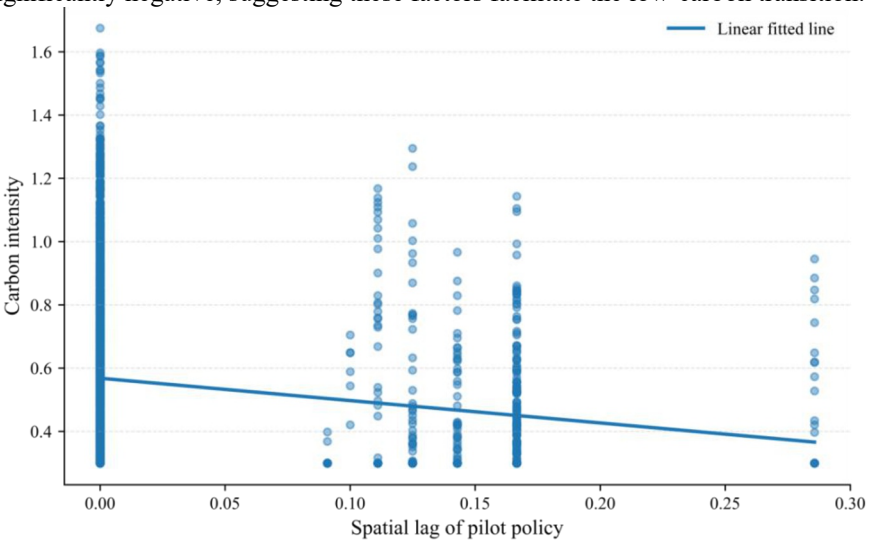


Fig. 1. Relationship between Spatial Policy Exposure and Carbon Emission Intensity (Picture credit: Original).

Figure 1 is plotted based on the original W_Treat and original CarbonIntensity variables. The fitted line shows a downward trend, indicating that the higher the policy exposure in neighboring cities, the lower the local carbon emission intensity. This is the same with the conclusions in the baseline spatial regression, suggesting that the policy impact is not limited to the pilot cities. Therefore, this figure provides intuitive support for the spatial spillover conclusions at the raw data level.

3.6 Further Analysis: Robustness, Distance Heterogeneity, and d-GWR Evidence

Table 3 reports robustness test results. In column (1), the Treat coefficient remains significantly negative after winsorizing the dependent variable, ruling out extreme-value bias. In column (2), both Treat and W_Treat stay significantly negative with spatial controls, confirming stable local and spillover effects. In column (3), adding d-GWR local coefficients does not materially alter the original policy variables' sign or significance. These findings demonstrate that the pilot zone policy's emission-reduction effect is robust across specifications.

Table 3. Robustness checks based on original variables.

Variable	(1) Winsorized Y	(2) W Controls	(3) With d-GWR Coefficient
Green finance pilot policy	-0.217*** (-6.616)	-0.220*** (-6.480)	-0.220*** (-6.493)
Spatial lag of pilot policy	-0.262** (-2.549)	-0.298*** (-2.786)	-0.295*** (-2.780)
Spatial lag of carbon intensity	-0.038 (-0.619)	-0.021 (-0.337)	-0.019 (-0.296)
GDP per capita	-0.111*** (-3.728)	-0.118*** (-3.896)	-0.118*** (-3.888)
Urbanization	-0.335** (-2.251)	-0.410*** (-2.649)	-0.410*** (-2.655)
Openness	0.043 (0.591)	0.024 (0.320)	0.025 (0.343)
Environmental regulation	-1.483** (-1.996)	-1.632** (-2.161)	-1.640** (-2.170)
W_GDP_percapita		-0.038 (-0.528)	
W_Urbanization		0.128 (0.339)	
W_Openness		-0.026 (-0.129)	
W_EnvironmentalRegulation		-0.172 (-0.090)	
d-GWR local coefficient			0.000 (.)

Note: t-values are reported in parentheses; * p<0.10, ** p<0.05, *** p<0.01.

Table 4 reports extra test results for d-GWR distance differences. In the full model, the d-siphon coefficient within 200km is 0.806 (p<0.01), meaning CEI of nearby cities rises. The d-radiation coefficient within 500-800km is -0.364 (p<0.01), meaning cities at medium and long distances benefit. Results for split samples also show the same pattern, directly supporting the core hypothesis of "short-distance siphoning and medium-to-long-distance radiation" (Fig.2-4).

Table 4. Supplementary evidence for d-GWR distance heterogeneity.

Variable	(1) Full d Model	(2) Near 200km	(3) 500-800km	(4) Full d + GWR
d siphon effect within 200km	0.806*** (8.952)	0.817** (2.800)		0.799*** (8.904)
d radiation effect within 500-800km	-0.364*** (-11.353)		-0.457*** (-3.177)	-0.372*** (-11.551)
GDP per capita	-0.198*** (-3.749)	-0.167 (-0.869)	-0.179** (-2.124)	-0.193*** (-3.627)
Environmental regulation	-4.433*** (-3.246)	2.692 (0.569)	-4.053* (-1.774)	-4.405*** (-3.202)

Note: t-values are reported in parentheses; * p<0.10, ** p<0.05, *** p<0.01.

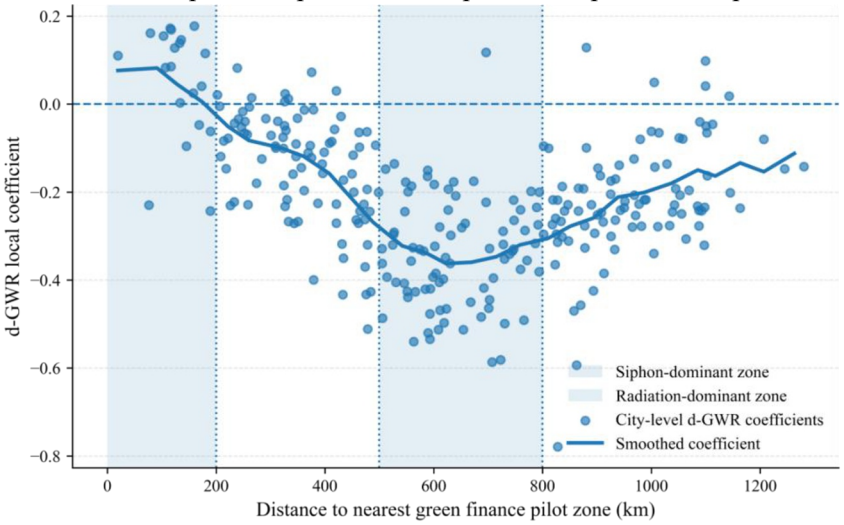


Fig. 2. Distance-dependent spatial spillover effects (d-GWR)(Picture credit: Original).

Figure 2 shows how d-GWR local coefficients shift with distance. Within 200 km, the curve sits mostly above zero, suggesting that nearby areas face marked siphon pressure. As distance grows, the curve steadily drops and becomes clearly negative in the 500–800 km range, indicating that radiation effects take over at medium-to-long distances. This figure records the gradual shift of spatial effects from positive to negative, implying that an average spillover coefficient cannot fully capture the intricate spatial effects of green finance policy.

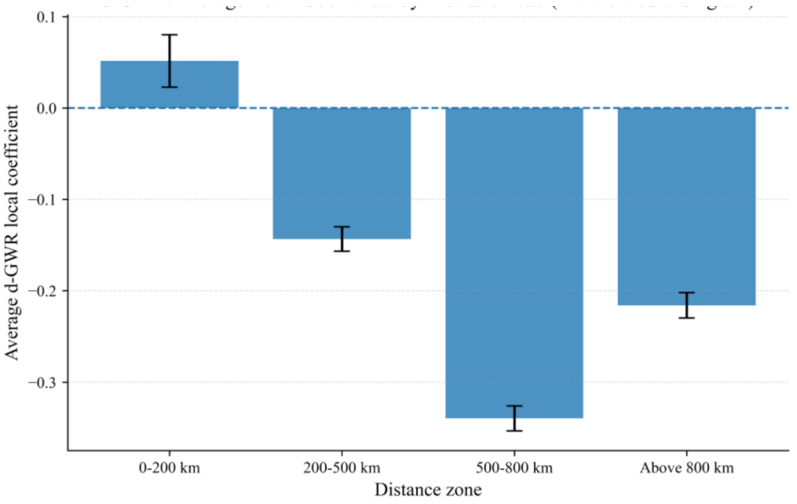


Fig. 3. Average d-GWR local coefficients across distance bands (Picture credit: Original).

Figure 3 shows the mean d-GWR local coefficients by distance band. The mean coefficient for the 0–200 km band is positive, showing that cities nearest the policy center face stronger siphon effects; the mean coefficient for the 500–800 km band is the lowest and negative, showing that policy radiation peaks at medium to long distances. The grouped results further confirm distance threshold features of spatial spillover effects.

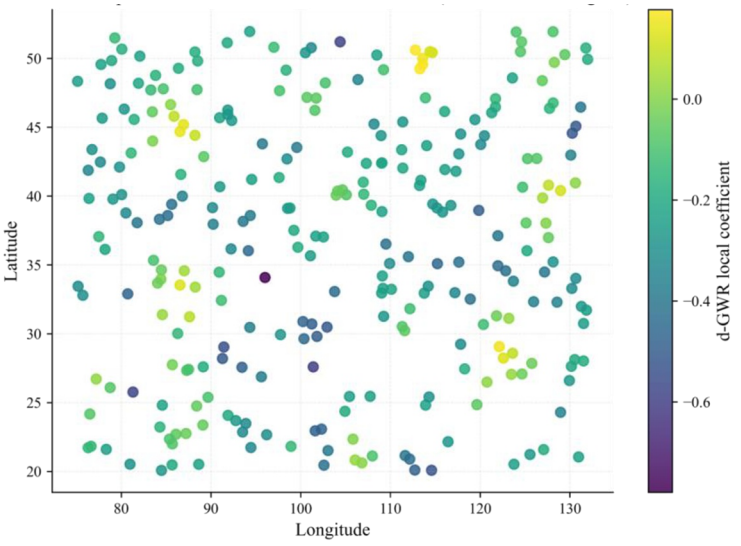


Fig. 4. Spatial distribution of d-GWR Local coefficients (Picture credit: Original).

Figure 4 plots d-GWR local coefficients across cities. Coefficients differ markedly by location, showing clear spatial heterogeneity in policy effects. Higher values signal stronger siphon pressure, while lower or negative ones signal stronger radiation effects.

This pattern matches the distance curve and bar chart results, showing that siphon–radiation coexistence is not random but follows a clear spatial structure.

3.7 Further Analysis: Mechanisms, Moderating Effects, and Heterogeneity

Table 5. Mechanism tests.

Variable	(1) Green Innovation	(2) Y + Green Innovation	(3) Industrial Upgrade	(4) Y + Industrial Upgrade	(5) Financing Constraint	(6) Y + Financing Constraint
Green finance pilot policy	0.246*** (6.895)	-0.246*** (-3.476)	0.166*** (8.354)	-0.241*** (-3.434)	-0.207*** (-7.506)	-0.243*** (-3.455)
GDP per capita	0.130*** (2.848)	-0.218*** (-3.839)	0.047 (1.078)	-0.217*** (-3.831)	-0.027 (-0.701)	-0.219*** (-3.863)
Urbanization	-0.418* (-1.670)	-0.159 (-0.468)	0.636*** (2.758)	-0.117 (-0.346)	0.284 (1.225)	-0.162 (-0.479)
Openness	-0.064 (-0.567)	0.078 (0.453)	0.020 (0.169)	0.080 (0.466)	0.119 (1.039)	0.075 (0.436)
Environmental regulation	0.322 (0.268)	-5.485*** (-3.722)	1.417 (1.258)	-5.413*** (-3.695)	1.681 (1.423)	-5.548*** (-3.757)
Green innovation		-0.017 (-0.605)				
Industrial upgrading				-0.055** (-1.999)		
Financing constraint						0.034 (1.397)
F statistic	13.440	32.228	17.173	34.804	7.676	32.904

Note: t-values are reported in parentheses; * p<0.10, ** p<0.05, *** p<0.01.

Table 5 reports mechanism results. The policy significantly promotes green innovation, industrial upgrading, and eases financing constraints. With these mediators in the carbon intensity equation, the policy coefficient remains significantly negative, suggesting both direct and indirect emission reduction effects.

Table 6 reports moderation results. The environmental regulation–policy interaction is significantly positive, meaning regulatory intensity shapes the policy's marginal effect. The proximity–regulation interaction is significantly negative, meaning stronger rules dampen the siphon effect. This suggests environmental governance capacity helps buffer spillover risks and improves spatial policy performance.

Table 6. Moderating effect tests.

Variable	(1) Env. Regulation	(2) Economic Development	(3) Urbanization	(4) Distance x Env. Regulation
Green finance pilot policy	-0.243*** (-3.713)	-0.315** (-2.560)	-0.251*** (-3.198)	-0.200*** (-3.824)
Centered environmental regulation	-5.730*** (-3.903)			
Treat x environmental regulation	12.912*** (3.036)			
GDP per capita	-0.223*** (-3.928)		-0.220*** (-3.872)	-0.204*** (-3.819)
Urbanization	-0.156 (-0.459)	-0.146 (-0.430)		-0.236 (-0.764)
Openness	0.074 (0.431)	0.081 (0.473)	0.079 (0.462)	0.084 (0.539)
Centered GDP per capita		-0.220*** (-3.878)		
Treat x GDP per capita		-0.122 (-0.973)		
Environmental regulation		-5.529*** (-3.761)	-5.493*** (-3.727)	-4.083*** (-2.780)
Centered urbanization			-0.153 (-0.449)	
Treat x urbanization			0.032 (0.075)	
d siphon effect within 200km				0.935*** (13.490)
d radiation effect within 500-800km				-0.310*** (-10.843)
Near effect x environmental regulation				-16.420*** (-4.198)
Mid effect x environmental regulation				0.029 (0.015)

Note: t-values are reported in parentheses; * p<0.10, ** p<0.05, *** p<0.01.

Table 7 reports the results of the group heterogeneity test. Policy variables were significantly negative in the low GDP group, while the coefficients were not significant in the high GDP group, indicating that emission reduction effects were more pronounced in cities with relatively low development levels. The d-siphon effect within 200km was significantly positive, while the d-radiation effect within 500-800km was

significantly negative, indicating that the distance conversion mechanism has strong stability and exhibits a two-way spatial spillover pattern.

Table 7. Heterogeneity tests.

Variable	(1) High GDP	(2) Low GDP	(3) High Regulation	(4) Low Regulation
Green finance pilot policy	-0.268 (-1.316)	-0.132*** (-2.964)	-0.128** (-2.204)	-0.229*** (-3.517)
d siphon effect within 200km	1.102*** (15.509)	0.506*** (7.362)	0.618*** (6.280)	1.036*** (12.762)
d radiation effect within 500-800km	-0.310*** (-6.881)	-0.389*** (-8.127)	-0.372*** (-8.127)	-0.343*** (-7.231)
d far-distance effect	-0.015 (-0.373)	-0.145*** (-3.179)	-0.058 (-1.328)	-0.103** (-2.313)
Spatial lag of carbon intensity	0.064 (0.523)	0.042 (0.283)	-0.050 (-0.360)	0.124 (0.841)
GDP per capita	-0.226*** (-2.987)	-0.189** (-2.529)	-0.117 (-1.449)	-0.297*** (-3.781)
Urbanization	-0.436 (-1.059)	-0.065 (-0.134)	-0.004 (-0.008)	-0.334 (-0.758)
Openness	-0.094 (-0.445)	0.240 (1.016)	0.082 (0.343)	0.133 (0.601)
Environmental regulation	-6.145*** (-3.713)	-2.230 (-1.048)	-3.668* (-1.661)	-4.363* (-1.846)

Note: t-values are reported in parentheses; * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

3.8 Placebo Test

To verify the robustness of the baseline DID estimates, a placebo test was conducted by randomly reassigning pilot city status. The results are presented in Fig. 5.

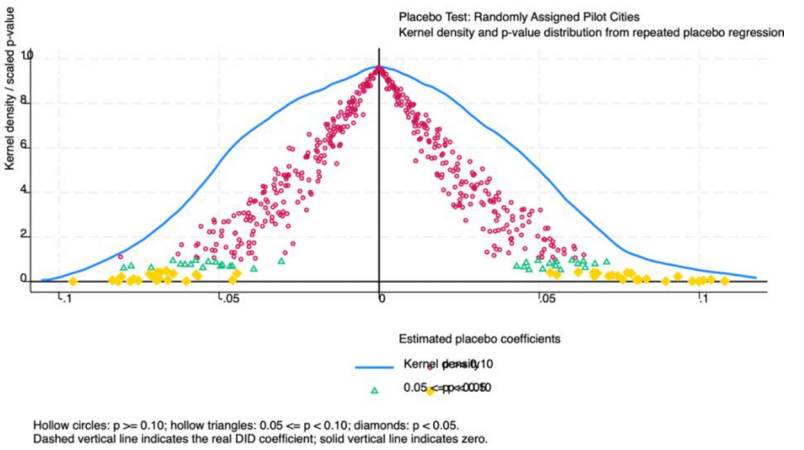


Fig. 5. Placebo Test (Picture credit: Original).

Figure 5 presents placebo test results with pilot cities randomly reassigned. The true DID estimate sits at the far left of the distribution, well away from the center. This gap suggests the negative policy effect is real—not just a product of random or model setup. The placebo test thus backs up the DID conclusion.

4 Conclusion

This paper uses the GFRIPZ established in 2017 as a quasi-natural experiment, employing a difference-in-differences method to systematically evaluate the carbon emission reduction effect and spatial spillover characteristics of the policy. The study finds that: First, the pilot zone policy significantly reduced the CEI of the pilot cities, internalized environmental externalities into corporate decision-making costs, guided capital from high-energy-consuming industries to energy-saving and environmental protection sectors, achieved local low-carbon transformation, and verified the effectiveness of green finance. Second, the spatial spillover of the policy exhibits a two-way pattern of "radiation-siphoning," with the dominant direction shifting in stages with geographical distance: within a short distance (≤200km), it manifests as "siphoning inhibition"; while within a medium-to-long distance of 500-800km, it forms "radiation-driven," providing new evidence for understanding the complexity and spatial heterogeneity of policy spillovers.

Based on the conclusions, this paper draws the following policy implications and future prospects: At the spatial layout level, specific compensation and talent attraction policies should be implemented for areas within 200km to alleviate the development gap caused by the siphon effect; a cross-regional collaborative emission reduction mechanism should be established within a range of 500-800km to amplify the positive radiation effect. At the policy design level, the coverage of green credit and green bonds should be further broadened, environmental information should be incorporated into

the routine supervision of financial institutions, and emphasis should be placed on the multi-path linkage between green technology innovation, industrial structure upgrading, and the alleviation of financing constraints. In the future, with the continuous innovation of green finance instruments and the advancement of regional coordinated development strategies, green finance is expected to promote regional green collaborative development on a larger scale, providing replicable and scalable market-based experience for achieving "dual carbon" goals.

References

1. Li, H., Tong, M., Zhang, G.: The carbon reduction effect of green finance reform and innovation pilot zones: a perspective based on spatial spillover effects and urban heterogeneity. Statistical Research 41(9), 44-58 (2024)
2. Lyu, C., Wang, C., Zhang, K.: The carbon reduction effect of green finance policy: evidence from green finance reform and innovation pilot zones. Chinese Journal of Management Science 33(5), 360-368 (2025)
3. Shi, X., Chen, Y.: Can green finance promote agricultural carbon reduction under the "dual carbon" background? From the perspectives of pilot policy, technology spillover and external competition. Technology and Innovation Management 46(5), 547-557 (2025)
4. Sun, Y., Li, Y., Hao, Y., et al.: Impact of green finance on carbon emissions and spatial spillover effects: empirical evidence from China. Journal of Cleaner Production 457, 142362 (2024)
5. Huang, Y., Mariadas, P.A.: Does China's regional green finance reform drive low-carbon transition? A spatial spillovers perspective. Applied Economics Letters, 1-10 (2025)
6. Liu, R., Wang, D., Zhang, L., et al.: Spatial impact of green finance reform pilot zones on environmental efficiency: a pathway to mitigating China's energy trilemma. Energy 312, 133602 (2024)
7. Zhang, Z., Wang, T., Chen, X.: The impact of green finance reform and innovation pilot zone policy on carbon emissions. China Population, Resources and Environment 34(2), 32-45 (2024)
8. Liu, X., Yang, M.: Can green finance empower the development of new quality productive forces? Empirical evidence from green finance reform and innovation pilot zone policy. Modern Finance (3), 42-49 (2025)

9. Ma, Y., He, W., Cui, X., et al.: Research on the impact of green finance on carbon emissions from the perspectives of nonlinearity and spatial spillover. Frontiers in Environmental Science 13, 1647224 (2025)
10. Li, Z., Song, Z.: Green finance reform and innovation pilot zones: a catalyst for green development efficiency in Chinese cities. Journal of Cleaner Production 525, 146576 (2025)
11. Chen, X., Wang, G.: Beyond traditional pathways: how green finance drives dual carbon-pollution reduction by heterogeneous innovation and spatial spillovers in Chinese cities. Journal of Cleaner Production 530, 146812 (2025)
12. Wang, X., Li, Y., Chen, J., et al.: The effect of green credit policy on carbon emissions based on China's provincial panel data. Scientific Reports 14, 24142 (2024)
13. Wang, X., Baležentis, T., Chi, Y.: Disentangling the effects of green finance in reducing CO2 emission from energy systems: evidence from a novel factor decomposition mechanism. Economic Analysis and Policy 85, 1721-1738 (2025)
14. Shao, W., Sun, W.: The impact of sci-tech finance on urban carbon emission efficiency: evidence from 281 cities in China. Journal of Cleaner Production (2025)
15. Nie, R., Sun, H.: Green finance policy and pollution and carbon reduction: impact mechanisms and spatial spillover effects. Technology Economics and Management Research (10), 78-86 (2025)

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