Environment, Social and Governance; Vol.3, No.3; 2026
E-ISSN: 3006-3973 P-ISSN：3006-3965
DOI: https://doi.org/10.70267/ esg2026.v3n3.6472
Published by: Zeus Press

Carbon Constraints and Corporate Green Innovation: Evidence from China's National Carbon Market

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Abstract

Against the background of China's continuing pursuit of the dual-carbon goals, whether the national carbon emissions trading market can promote corporate green innovation through a market-based mechanism has become an important question for evaluating the effectiveness of environmental regulation. Using A-share listed companies from 2018 to 2023 as the research sample, this study treats the official launch of the national carbon market in 2021 as a quasi-natural experiment. Because the first compliance cycle mainly covered the power generation sector, firms in industry code D44, namely electricity and heat production and supply, are identified as the treatment group. A difference-in-differences model is then constructed to examine the impact of the national carbon market on corporate green innovation. The results show that, after the launch of the national carbon market, the total number of green patent applications by treated firms increased significantly relative to control firms. Mechanism tests indicate that the policy significantly reduced carbon emission intensity among treated firms, and carbon emission intensity is negatively associated with green innovation, suggesting that carbon constraints are an important channel through which the carbon market affects green innovation. Heterogeneity analyses further show that firms with higher pre-policy attention to green transformation respond more strongly to the policy. In this sample, firms with higher financing constraints exhibit stronger policy responses than firms with lower financing constraints. Dynamic DID estimates show no significant pre-policy differential trend between treated and control firms, while the policy effect gradually emerges after 2021. Placebo tests using the pre-policy period, an alternative post-policy window, an alternative dependent variable, and PSM-DID tests generally support the baseline conclusion. The findings suggest that China's national carbon market not only imposes emission-reduction constraints but may also influence corporate green innovation through carbon-cost pressure and expectations of low-carbon transition.

Keywords

national carbon market, green innovation, carbon emission intensity, difference-in-differences, financing constraints

1. Introduction

Climate governance is reshaping the external institutional environment and internal strategic choices of firms under China's carbon-peaking and carbon-neutrality policy framework [1]. Compared with traditional command-and-control environmental regulation, carbon emissions trading schemes transform the scarcity of emission rights into observable operating costs and asset opportunities through emission allowances, carbon price signals, and compliance obligations [2]. Firms that continue to rely on high-carbon production modes face greater compliance pressure. By contrast, firms that reduce carbon emissions per unit of output through energy-saving retrofits, process optimization, and green technology research and development may save allowance costs and even obtain additional carbon-asset returns. In this sense, a carbon market is not only an emission-reduction instrument, but also a market-based policy tool that may stimulate corporate green innovation.

China's national carbon market officially began trading on 16 July 2021. Its first compliance cycle started with the power generation industry [3,4]. Selecting the power sector as the initial coverage industry has clear policy significance. On the one hand, the sector has large-scale carbon emissions and a relatively mature emissions accounting foundation, making it suitable for piloting a unified national carbon pricing mechanism [5]. On the other hand, power enterprises are central actors in energy transition and green technology diffusion, and changes in their innovation behavior may affect the electricity structure, energy efficiency, and low-carbon transition of downstream industries.

From the perspective of corporate decision-making, the effect of a carbon market on green innovation is not merely a question of whether firms reduce emissions. It involves a comprehensive adjustment of cost constraints, technological routes, organizational cognition, and financing conditions. In response to carbon-market regulation, firms may adopt short-term compliance strategies, such as purchasing allowances or reducing output, but they may also adopt long-term transformation strategies, such as equipment upgrading, process optimization, and green R&D. Which strategy dominates depends on the intensity of carbon constraints, the firm's original emission level, managerial attention to green transformation, and financing constraints.

This paper contributes to the literature in three ways. First, it focuses on the official launch of China's national carbon market, rather than regional pilot programs, and therefore helps explain the micro-level policy effects of China's transition from regional carbon pilots to a unified national market. Second, beyond estimating the baseline DID effect, the study examines the mechanism of carbon emission intensity and explores heterogeneity by pre-policy green-transformation attention and financing constraints. Third, the paper conducts dynamic DID analysis, a pre-policy placebo test, and PSM-DID estimation to strengthen the credibility of causal identification.

2. Literature Review and Hypothesis Development

2.1 Environmental Regulation, Carbon Markets, and Green Innovation

The relationship between environmental regulation and technological innovation has long been debated. The Porter hypothesis argues that well-designed environmental regulation may stimulate innovation and offset part of the compliance cost [6]. Empirical studies, however, have found that regulatory effects depend on the type of regulation, policy intensity, and firm characteristics [7]. In the field of energy and environmental economics, induced innovation theory suggests that changes in relative factor prices can redirect technological progress toward technologies that save the now more costly or scarcer factor [8]. Directed technical change models further show that policy incentives can affect the direction of innovation in clean and dirty technologies [9].

Carbon emissions trading is a typical market-based environmental regulatory instrument. By assigning scarcity and transaction value to carbon emission allowances, a carbon market can change firms' expected costs and returns. Evidence from the European Union Emissions Trading System shows that carbon pricing can guide directed technological change and low-carbon patenting [10]. In China, recent studies have examined the effects of carbon emissions trading schemes on green technological innovation, carbon performance, and carbon-market mechanisms [11,12,13,14]. However, compared with regional pilots, the national carbon market has broader institutional significance and requires further firm-level evidence.

2.2 Carbon Constraints and Innovation Incentives

Carbon emissions trading incorporates corporate carbon emissions into a market-based cost-accounting system through allowance constraints, carbon price signals, and compliance mechanisms. For power-sector enterprises, carbon allowances gradually become production factors with opportunity costs. The higher a firm's emission intensity, the greater the compliance pressure and potential carbon costs it faces. After the national carbon market is launched, high-carbon production modes are constrained, and the importance of green technology R&D and low-carbon transformation increases.

From the cost-constraint perspective, the carbon market changes the relative prices of production factors. When carbon emission allowances become scarce and tradable, firms maintaining high-emission production modes need to bear higher compliance costs. In contrast, firms that reduce emissions per unit of output through low-carbon combustion, energy-saving dispatch, pollution co-control, and digital energy-efficiency management can mitigate carbon-cost pressure. From the incentive perspective, carbon markets also increase the expected returns of green innovation. If green innovation lowers carbon emission intensity, firms may reduce allowance purchases and compliance expenditures, while potentially generating carbon-asset gains from saved allowances.

Therefore, compared with purely administrative regulation, emissions trading leaves firms with more autonomy to choose among emission reduction, technology investment, and allowance trading. The carbon market may promote green R&D and patenting through the dual mechanism of cost constraints and expected returns. Accordingly, this paper proposes the following hypothesis:

H1: The launch of the national carbon market significantly promotes green innovation among listed firms in the power sector.

2.3 Mechanism and Heterogeneity

Carbon emission intensity is an important mechanism linking the national carbon market and green innovation. The carbon market first affects firms' emission behavior. To reduce emissions per unit of output and lower compliance pressure, firms may increase investment in energy conservation, equipment upgrading, and process optimization. These low-carbon transformation activities often require technical support and may further appear as increases in green patent applications. Therefore, this study proposes:

H2: The national carbon market promotes green innovation by reducing corporate carbon emission intensity.

Organizational attention theory suggests that firms facing external institutional shocks differ in their response speed and intensity. Firms that already paid more attention to green transformation, environmental responsibility, and low-carbon development before the policy shock are likely to have better information foundations, managerial cognition, and resource preparation. After the launch of the national carbon market, these firms may be better able to recognize strategic opportunities embedded in carbon price signals and transform policy pressure into green R&D action. Thus:

H3: The higher a firm's pre-policy attention to green transformation, the stronger the promoting effect of the national carbon market on green innovation.

Financing constraints may also shape firms' innovation responses to carbon-market regulation. In general, firms with lower financing constraints are better able to support long-term green R&D. However, under a carbon-market regime, highly constrained firms that maintain high-carbon production may face stronger compliance costs and cash-flow pressure. They may therefore have stronger incentives to reduce future carbon costs through technological upgrading and green patent deployment. This leads to the following hypothesis:

H4: The promoting effect of the national carbon market on green innovation is stronger among firms with higher financing constraints than among firms with lower financing constraints.

3. Methodology

3.1 Sample Selection and Data Sources

This study uses A-share listed companies from 2018 to 2023 as the initial sample. The data are obtained from the CSMAR database and text-based indicators related to green transformation disclosed in listed companies' annual reports. Industry classification follows the Guidelines for the Industry Classification of Listed Companies issued by the China Securities Regulatory Commission [15]. After data cleaning, the sample contains 35,628 firm-year observations covering 5,938 listed firms. Among them, 96 firms in industry code D44, namely electricity and heat production and supply, are classified as the treatment group.

Because some financial control variables and carbon emission intensity variables are missing, the baseline regression, which jointly controls for firm fixed effects, year fixed effects, and firm-level controls, uses 20,425 effective observations. The mechanism test for carbon emission intensity uses 14,248 effective observations. To reduce the influence of extreme values, continuous variables are winsorized where appropriate.

3.2 Variable Definitions

Table 1: Variable Definitions

Variable type	Variable name	Definition
Green innovation	ln_green_total	ln(1 + green invention patent applications + green utility-model patent applications)
Treatment group	Treat	Equals 1 for firms in industry code D44, i.e., electricity and heat production and supply enterprises; 0 otherwise
Post-policy period	Post	Equals 1 for 2021 and subsequent years; 0 otherwise
Core DID term	DID	Treat x Post
Carbon emission intensity	carbon_intensity	Corporate carbon emission intensity; used as the mechanism variable
Green attention	attention_base	Equals 1 if the firm's pre-policy green-transformation word frequency is above the median
Low financing constraints	lowfc_base	Equals 1 if the absolute value of the pre-policy SA index is below the median
Control variables	Controls	Firm size, growth, cash-to-assets ratio, ownership concentration, ROA, and Tobin's Q

3.3 Model Specification

The baseline DID model is specified as follows:

$$GreenInnovation_{it} = \alpha + \beta DID_{it} + \gamma Controls_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (1)$$

where GreenInnovation_it denotes corporate green innovation; DID_it is the interaction between the treatment group and the post-policy period; Controls_it represents firm-level control variables; μ_i denotes firm fixed effects; λ_t denotes year fixed effects; and ε_it is the error term. Standard errors are clustered at the firm level to address within-firm serial correlation in DID estimation [16]. A significantly positive β indicates that, after the launch of the national carbon market, green innovation among treated firms increased significantly relative to control firms.

The mechanism test is conducted in two steps. First, carbon emission intensity is used as the dependent variable to test whether the DID term significantly reduces the carbon emission intensity of treated firms:

$$CarbonIntensity_{it} = \alpha + \beta DID_{it} + \gamma Controls_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (2)$$

Second, carbon emission intensity is added to the green innovation model to examine the relationship between carbon intensity and green innovation:

$$GreenInnovation_{it} = \alpha + \beta DID_{it} + \delta CarbonIntensity_{it} + \gamma Controls_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (3)$$

For heterogeneity tests, this study further includes interaction terms between DID and pre-policy green attention, and between DID and the low-financing-constraint group:

$$GreenInnovation_{it} = \alpha + \beta DID_{it} + \theta(DID_{it} \times Moderator_i) + \gamma Controls_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (4)$$

4. Empirical Results and Analysis

4.1 Descriptive Statistics

Table 2 presents the descriptive statistics. The mean value of ln(1 + total green patents) is 0.683, and the raw count of total green patents varies substantially across firms, indicating obvious heterogeneity in green innovation. The mean of the DID variable is relatively small because the treated firms account for a limited share of all A-share listed companies. The carbon emission intensity variable also shows marked dispersion, which provides empirical variation for the mechanism test.

Table 2: Descriptive Statistics

Variable	N	Mean	SD	Min.	Max.
ln(1 + total green patents)	35,628	0.683	1.079	0.000	4.466
Total green patents	35,628	5.785	36.666	0.000	1,445.000
DID	35,628	0.007	0.084	0.000	1.000
Carbon emission intensity	18,337	0.462	0.587	0.038	2.267
Firm size	21,963	22.425	1.406	19.616	26.684
Growth	26,130	0.118	0.381	-0.678	2.189
Cash-to-assets ratio	33,088	0.166	0.132	0.006	0.640
Ownership concentration	26,975	0.325	0.147	0.081	0.733
ROA	33,093	0.039	0.092	-0.411	0.265
Tobin's Q	26,607	1.904	1.240	0.813	8.310

4.2 Baseline Results, Mechanism Tests, and Heterogeneity

Table 3: Baseline Regression, Mechanism Tests, and Heterogeneity Analyses

Variable	Baseline	Mechanism 1	Mechanism 2	Attention	Financing constraints
Dependent variable	Green innovation	Carbon emission intensity	Green innovation	Green innovation	Green innovation
DID	0.321*** (0.077)	-0.131*** (0.013)	0.326*** (0.078)	-0.129 (0.134)	0.411*** (0.099)
Carbon emission intensity			-0.082* (0.044)		
DID x High attention				0.470*** (0.155)	
DID x Low financing constraints					-0.313** (0.135)
Observations	20,425	14,248	14,248	20,425	20,425
Firm clusters	4,639	3,378	3,378	4,639	4,639
Firm/year fixed effects	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes
Within R^2	0.023	0.038	0.026	0.023	0.023

*Note: Standard errors clustered at the firm level are reported in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.*

Column (1) of Table 3 reports the baseline DID result. The coefficient of DID is 0.321 and is significant at the 1% level, indicating that, after the launch of the national carbon market, the total number of green patent applications by D44 treated firms increased significantly relative to firms in other industries. Because the dependent variable is ln(1 + x), the result has not only statistical significance but also clear economic meaning: the carbon market strengthens firms' incentives to conduct green technology R&D and patent deployment through allowance constraints and carbon price signals. H1 is therefore supported.

Columns (2) and (3) report the mechanism test based on carbon emission intensity. In the first step, the DID coefficient for carbon emission intensity is significantly negative, with a coefficient of -0.131, indicating that the national carbon market reduces the carbon emission intensity of treated firms. In the second step, the coefficient of carbon emission intensity is -0.082 and significant at the 10% level, suggesting that lower carbon emission intensity is associated with higher green innovation. This result indicates that the carbon market does not simply increase firms' compliance burden; rather, it promotes green innovation by lowering emission intensity and forcing technological upgrading and low-carbon R&D. H2 is broadly supported.

Column (4) examines the moderating role of pre-policy attention to green transformation. The coefficient of DID x High attention is 0.470 and significant at the 1% level, indicating that firms with greater pre-policy attention to green transformation show stronger green innovation responses after the launch of the national carbon market. H3 is supported. Column (5) reports the interaction result for financing constraints. The coefficient of DID x Low financing constraints is -0.313 and significant at the 5% level. Because the reference group consists of firms with higher financing constraints, this finding means that the policy effect is weaker for firms with lower financing constraints, or conversely, that firms with higher financing constraints experience a stronger forced-innovation effect. H4 is supported.

5. Robustness Checks

5.1 PSM-DID Matching Balance Test

Table 4: Balance Test after PSM-DID Matching

Variable	Treatment mean	Control mean	SMD before matching	SMD after matching
Green innovation	1.569	1.568	0.514	0.001
Firm size	23.581	23.509	0.875	0.050
Growth	0.081	0.088	-0.022	-0.036
Cash-to-assets ratio	0.083	0.087	-0.693	-0.075
Ownership concentration	0.387	0.394	0.395	-0.042
ROA	0.024	0.021	-0.006	0.081
Tobin's Q	1.156	1.168	-0.784	-0.040
SA financing constraints	3.937	3.920	0.149	0.052
Green attention	0.971	0.971	0.587	0.000

Table 4 reports the balance test after PSM-DID matching. The matching variables include pre-policy green innovation, firm size, growth, cash-to-assets ratio, ownership concentration, ROA, Tobin's Q, the SA financing-constraint index, and green attention. Nearest-neighbor matching is conducted within the common support region following the propensity-score matching literature [17,18]. After matching, the absolute values of standardized mean differences for all covariates are below 0.1, indicating that the treated and control firms are relatively comparable in observable characteristics and that the matched sample provides a reasonable basis for subsequent PSM-DID estimation.

5.2 Dynamic DID and Additional Robustness Tests

Table 5: Dynamic DID and Robustness Tests

Variable	Dynamic DID	After 2022	Invention patents	Placebo	PSM-DID
Treat x 2018	-0.116 (0.121)				
Treat x 2019	-0.096 (0.100)				
Treat x 2021	0.176* (0.106)				
Treat x 2022	0.325*** (0.102)				
Treat x 2023	0.277** (0.117)				
DID (2022 and after)		0.301*** (0.083)			
DID (green invention patents)			0.075 (0.062)		
DID (2019 placebo; pre-policy sample)				0.050 (0.083)	
DID (PSM matched sample)					0.245** (0.107)
Observations	20,425	20,425	20,425	8,894	795
Firm clusters	4,639	4,639	4,639	3,365	136
Firm/year fixed effects	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes

*Note: Standard errors clustered at the firm level are reported in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.*

Table 5 first reports the dynamic DID results. Taking 2020 as the base year, the coefficients of Treat x 2018 and Treat x 2019 are not significant, suggesting that the treatment and control groups did not exhibit significant differential trends before the policy. The coefficient of Treat x 2021 is positive and significant at the 10% level, while the coefficients of Treat x 2022 and Treat x 2023 are significantly positive. These findings support the parallel-trends assumption and indicate that the green innovation response emerged gradually after the national carbon market began operating.

Several robustness checks are then conducted. First, when the post-policy period is redefined as 2022 and after, the DID coefficient remains significantly positive. This indicates that the baseline conclusion does not depend entirely on whether the policy took effect in 2021, the initial year of trading. Second, when the dependent variable is replaced with green invention patents, the coefficient remains positive but is not statistically significant. This finding does not reject the baseline result; instead, it suggests structural differences in the policy effect. After the launch of the national carbon market, firms may first respond through the quantity of green innovation, while green invention patents, which represent higher-quality innovation, require longer R&D cycles and greater technical difficulty and may not become statistically significant in the short run.

Third, a placebo test is performed using only the pre-policy sample from 2018 to 2020 and setting 2019 as a pseudo-policy year. The placebo DID coefficient is insignificant, indicating that the baseline result is not mechanically driven by pre-existing trends. Fourth, after PSM matching, the matched sample contains 68 treated firms and 68 control firms, and the DID coefficient remains significantly positive. Therefore, after accounting for possible sample-selection bias, the core conclusion remains robust.

6. Conclusion and Policy Implications

Using panel data on A-share listed companies from 2018 to 2023, this paper treats the 2021 launch of China's national carbon market as a quasi-natural experiment and applies a difference-in-differences model to examine its effect on corporate green innovation. The results show that the national carbon market significantly increases the total number of green patent applications by D44 treated firms. The reduction of carbon emission intensity is an important mechanism. Firms with higher pre-policy attention to green transformation respond more strongly, and firms with higher financing constraints show stronger policy effects than those with lower financing constraints. Dynamic DID estimates, a pre-policy placebo test, and PSM-DID analysis further support the robustness of the findings.

The findings have several policy implications. First, China should continue improving the price-discovery and compliance mechanisms of the national carbon market, thereby strengthening the stability of carbon price signals and helping firms form long-term expectations for green R&D. Second, regulators should enhance the quality management of corporate carbon emissions data and assessment of carbon emission intensity, guiding firms to shift from passive compliance to active technological upgrading. Third, firms should be encouraged to systematically disclose green transformation targets in annual reports, social responsibility reports, and strategic plans, so as to strengthen organizational attention and implementation capacity for low-carbon transition. Fourth, the green innovation needs of firms facing financing constraints should receive more policy support. Green credit, transition finance, and carbon-asset pledge financing may help reduce the financing cost of technological transformation [19,20].

This study also has limitations. First, the sample period covers only the first three years after the national carbon market was launched, and high-quality innovations such as green invention patents may have longer time lags. Second, the treatment group is identified mainly by industry code, and the analysis does not further distinguish the actual compliance status of listed companies and their subsidiaries. Future studies may use firm-level allowance, compliance, and carbon-trading data to identify more precisely the causal mechanisms linking carbon prices, allowance constraints, and green innovation.

References

[1] State Council of the People's Republic of China. (2021, October 27). Action plan for carbon dioxide peaking before 2030.

https://english.www.gov.cn/policies/latestreleases/202110/27/content_WS6178a47ec6d0df57f98e3dfb.html

[2] Ministry of Ecology and Environment. (2020, December 31). Measures for the administration of carbon emissions trading (Trial). [In Chinese]. https://www.mee.gov.cn/xxgk2018/xxgk/xxgk02/202101/t20210105_816131.html

[3] Ministry of Ecology and Environment. (2021, December 31). The first compliance cycle of the national carbon market was successfully completed. [In Chinese]. https://www.mee.gov.cn/ywgz/ydqhbh/wsqtkz/202112/t20211231_965906.shtml

[4] Ministry of Ecology and Environment. (2022). Report on the first compliance cycle of the national carbon emissions trading market. [In Chinese]. https://www.mee.gov.cn/ywgz/ydqhbh/wsqtkz/202212/P020221230799532329594.pdf

[5] Ministry of Ecology and Environment. (2022, December 19). Guidelines for accounting and reporting greenhouse gas emissions from power generation facilities. [In Chinese]. https://www.mee.gov.cn/xxgk2018/xxgk/xxgk06/202212/t20221221_1008430.html

[6] Porter, M. E., & van der Linde, C. (1995). Toward a new conception of the environment-competitiveness relationship. *Journal of Economic Perspectives*, *9*(4), 97–118. https://doi.org/10.1257/jep.9.4.97

[7] Jaffe, A. B., & Palmer, K. (1997). Environmental regulation and innovation: A panel data study. *Review of Economics and Statistics*, *79*(4), 610–619. https://doi.org/10.1162/003465397557196

[8] Popp, D. (2002). Induced innovation and energy prices. *American Economic Review*, *92*(1), 160–180. https://doi.org/10.1257/000282802760015658

[9] Acemoglu, D., Aghion, P., Bursztyn, L., & Hémous, D. (2012). The environment and directed technical change. *American Economic Review*, *102*(1), 131–166. https://doi.org/10.1257/aer.102.1.131

[10] Calel, R., & Dechezleprêtre, A. (2016). Environmental policy and directed technological change: Evidence from the European carbon market. *Review of Economics and Statistics*, *98*(1), 173–191. https://doi.org/10.1162/REST_a_00470

[11] Liu, J. Y., & Liu, X. (2023). Effects of carbon emission trading schemes on green technological innovation by industrial enterprises: Evidence from a quasi-natural experiment in China. *Journal of Innovation & Knowledge*, *8*(3), Article 100410. https://doi.org/10.1016/j.jik.2023.100410

[12] Wang, P., Huang, S., Wang, Y., & Li, W. (2023). Research on the impact of carbon emission rights trading on carbon performance of enterprises [In Chinese]. *Science Research Management, 44*(12), 158–169. https://doi.org/10.19571/j.cnki.1000-2995.2023.12.016

[13] Jia, L. J., Zhang, X., Wang, X. N., Chen, X. L., Xu, X. F., & Song, M. L. (2024). Impact of carbon emission trading system on green technology innovation of energy enterprises in China. *Journal of Environmental Management*, *360*, Article 121229. https://doi.org/10.1016/j.jenvman.2024.121229

[14] Cao, H., Yi, Y., & Jiang, J. (2024). The driving mechanism of green innovation in carbon markets: Property-right definition or market trading? [In Chinese]. *Journal of Finance and Economics, 50*(7), 80–94. https://doi.org/10.16538/j.cnki.jfe.20240511.301

[15] China Securities Regulatory Commission. (2012). Guidelines for the industry classification of listed companies. [In Chinese]. https://www.csrc.gov.cn/csrc_en/c102030/c1370756/content.shtml

[16] Bertrand, M., Duflo, E., & Mullainathan, S. (2004). How much should we trust differences-in-differences estimates? *The Quarterly Journal of Economics*, *119*(1), 249–275. https://doi.org/10.1162/003355304772839588

[17] Rosenbaum, P. R., & Rubin, D. B. (1983). The central role of the propensity score in observational studies for causal effects. *Biometrika*, *70*(1), 41–55. https://doi.org/10.1093/biomet/70.1.41

[18] Heckman, J. J., Ichimura, H., & Todd, P. E. (1997). Matching as an econometric evaluation estimator: Evidence from evaluating a job training programme. *Review of Economic Studies*, *64*(4), 605–654. https://doi.org/10.2307/2971733

[19] People's Bank of China et al. (2016, August 31). Guidelines for establishing the green financial system. https://www.pbc.gov.cn/english/130721/3133045/index.html

[20] Wang, X., & Wang, Y. (2021). Research on green credit policy to enhance green innovation [In Chinese]. *Management World, 37*(6), 173–188, 11. https://doi.org/10.19744/j.cnki.11-1235/f.2021.0085

Funding

This research received no external funding.

Conflicts of Interest

The authors declare no conflict of interest.

Data Availability

The data used in this study are available from the CSMAR database and publicly disclosed annual reports of listed companies, subject to the database provider's terms of use.

Acknowledgment

This paper is an independent research output by the author.

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