world

MDPI

Article

Green Innovation and Environmental Performance: The Moderating Roles of Governance and Policy

Fatima Batool [1], Muhammad Mohsin [2,*] and Belal Mahmoud Alwadi [3]

[1] School of Finance, Central University of Finance and Economics, 39 South College Road, Haidian District, Beijing 100081, China; 2020630005@email.cufe.edu.cn
[2] Department of Informatics, Bioengineering, Robotics and Systems Engineering (DIBRIS), University of Genoa, 16146 Genoa, Italy
[3] Department of Basic Sciences, Al-Zaytoonah University of Jordan, Queen Alia Airport Street, Amman 11733, Jordan; b.alwadi@zuj.edu.jo
* Correspondence: muhammad.mohsin@edu.unige.it

Abstract: This study investigates the impact of green innovation (GI) on corporate environmental performance (CEP), while examining the moderating roles of corporate governance practices (CGPs) and environmental policy pressure (EPP). This study uses advanced statistical methods to ensure the reliability of the results. These include techniques such as propensity score matching (PSM), difference-in-differences (DID) analysis with China's National Green Development Fund (2020) as the policy intervention, and the generalized method of moments (GMM), and this study examines how internal governance mechanisms and external regulatory pressures influence the GI-CEP relationship. The results show that GI significantly increases CEP, and that this effect is amplified by robust CGPs and EPP. By analyzing data from 4026 firm-year observations of A-share listed Chinese companies (2017–2022), the findings highlight the importance of innovation, governance, and policy in achieving sustainable environmental outcomes. This study provides valuable insights for firms and policymakers to foster green innovation and align corporate strategies with global sustainability goals.

Keywords: green innovation; corporate environmental performance; governance practices; environmental policy pressure; sustainable development

JEL Classification: O33; Q56; G38; Q58; Q01

check for updates

Academic Editor: Mahmoud Elmarzouky

Received: 24 November 2024
Revised: 16 January 2025
Accepted: 24 January 2025
Published: 17 February 2025

Citation: Batool, F.; Mohsin, M.; Alwadi, B.M. Green Innovation and Environmental Performance: The Moderating Roles of Governance and Policy. *World* **2025**, *6*, 29. https://doi.org/10.3390/world6010029

Correction Statement: This article has been republished with a minor change. The change does not affect the scientific content of the article and further details are available within the backmatter of the website version of this article.

Copyright: © 2025 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

The adoption of "going green" has become a critical approach for companies as they strive to address urgent environmental challenges [1]. Today, green innovation is widely embraced in response to the escalating need to reduce greenhouse gas (GHG) emissions and mitigate climate change [2]. Green innovation involves developing environmentally friendly products, processes, and management practices, allowing firms to reduce their environmental footprint while enhancing their competitive positioning [3]. However, the effects of environmental degradation continue to grow, with emissions, waste, and global warming presenting critical challenges to societies worldwide [4]. With recovery costs projected to reach USD 380 billion in 2023 and fossil fuel usage expected to increase by 45%, corporate environmental action has never been more urgent [5,6].

Green innovation has emerged as a strategic response, enabling companies to manage environmental risks through energy conservation and pollution control [7,8]. Aligned with

the 2030 sustainable development goals (SDGs), understanding the effects of green innovation on corporate environmental performance (CEP) has become a focal point, especially in economies like China, where balancing rapid economic growth with environmental sustainability is imperative [9]. Rising attention to environmental, social, and governance (ESG) criteria among investors and regulators underscores the essential role of corporate governance practices (CGPs) in achieving sustainability objectives [10]. Theoretical frameworks like stakeholder theory and the resource-based view (RBV) provide valuable insights into how companies integrate environmental practices into their strategies, highlighting that both internal governance and external regulatory pressures shape environmental outcomes [11,12].

Recognizing the impact of resource consumption on future generations, researchers and policymakers increasingly prioritize green innovations that support sustainable growth and low-carbon economies without compromising profitability in field [13,14]. Studies suggest that green innovation could drive a low-carbon, inclusive, and sustainable future [15]. As stakeholders demand greater environmental accountability, green innovation becomes essential for companies to remain competitive while reducing their environmental impacts [16]. Importantly, environmental policy pressure (EPP) also plays a critical role in influencing the relationship between green innovation and CEP, as regulatory pressures shape firms' approaches to sustainability [17–19]. Prior studies often rely on traditional financial metrics, which do not fully capture a company's environmental efforts or potential for sustainable growth [20–22]. Although green innovation is linked to improved environmental performance, the relationship between eco-friendly technological advancements and long-term environmental outcomes is still underexplored [23]. Furthermore, conventional accounting metrics often fail to provide an accurate representation of a firm's environmental strengths, creating a need for comprehensive methods that assess corporate environmental performance [24]. This study examines the relationship between green innovation and corporate environmental performance, focusing on the moderating roles of corporate governance practices and environmental policy pressure. Drawing on stakeholder theory, which emphasizes the importance of balancing internal resources with external demands, this study addresses gaps in the literature regarding how these factors interact in emerging markets. Previous research has largely focused on Western economies, leaving a need to explore these dynamics in contexts like China, where regulatory frameworks and governance structures differ significantly.

To address these gaps, this study investigates the moderating roles of corporate governance practices (CGPs) and environmental policy pressure (EPP) in the relationship between green innovation and CEP. Building on Michael Porter's perspective that corporations, rather than countries, drive global competitiveness, this research explores how both internal governance mechanisms and external regulatory pressures influence the effectiveness of green innovation on environmental outcomes within the context of China's economic and environmental landscape. In order to rigorously estimate these relationships and address potential biases, we employ a combination of propensity score matching (PSM), difference-in-differences (DID) estimation, and the generalized method of moments (GMM): PSM is used to mitigate selection bias by matching firms that adopt green innovation (treated) with comparable firms that do not (control), ensuring that baseline characteristics are balanced across groups. The difference-in-differences (DID) analysis in this study was influenced by China's National Green Development Fund (2020) as the policy intervention. This policy was established to promote green innovation and sustainable development by providing financial and regulatory support to firms investing in environmentally friendly practices. The fund represents a significant effort by the Chinese government to address environmental challenges, encourage cleaner production processes, and align corporate practices

with national sustainability goals. The policy creates a clear pre- and post-intervention context, allowing the DID framework to measure the causal effect of green innovation adoption on corporate environmental performance (CEP) while considering moderating factors such as corporate governance practices (CGPs) and environmental policy pressure (EPP). DID estimation then allows us to examine the causal effect of green innovation on CEP by comparing changes in environmental performance over time between treated and control firms, particularly in response to policy or regulatory shifts. GMM is applied to address potential endogeneity issues, providing robust estimates of the dynamic effects of green innovation on CEP and incorporating both time-varying and firm-specific effects. These methodologies collectively provide a comprehensive approach to assess the impact of green innovation on CEP while accounting for confounding variables and selection effects, offering a clearer understanding of the role of governance and policy pressure in shaping environmental outcomes.

This study seeks to address the following research questions: How does green innovation influence corporate environmental performance in Chinese A-share listed firms? Why does the impact of green innovation vary across firms, particularly in heavily polluting industries? What governance practices (e.g., board independence, executive compensation) moderate the relationship between green innovation and corporate environmental performance? How does environmental policy pressure shape the effectiveness of green innovation in driving corporate environmental performance?

The focus on China is particularly relevant given its position as a global leader in green innovation and its significant contribution to global carbon emissions. China's regulatory environment, including the implementation of strict environmental policies such as the China national development policy, offers a unique context to study the interplay between green innovation, governance practices, and corporate environmental performance. This setting provides valuable insights for other emerging economies facing similar sustainability challenges. This study has five primary objectives: (1) to assess the impact of green innovation on CEP; (2) to evaluate how green innovation influences corporate environmental practices in China's unique regulatory environment; (3) to investigate the role of CGPs in enhancing CEP; (4) to analyze how EPP shapes environmental outcomes; and (5) to explore the combined moderating effects of CGPs and EPP on the relationship between green innovation and CEP. Given China's rapid industrialization and its associated environmental challenges, it serves as an ideal setting for examining the balance between economic development and environmental sustainability [16,25,26].

In this context, our study explores how green innovation can improve CEP, particularly within China's evolving corporate governance and regulatory landscape. By examining both internal governance mechanisms and external policy pressures, this research provides insights into the factors that influence the effectiveness of green innovation, contributing to the UN's Agenda 2030 by offering a framework that aligns corporate practices with global sustainability targets.

Using data from 671 A-share listed Chinese companies from 2017 to 2022 and employing a combination of PSM, DID, and GMM methods, this study investigates the effect of green innovation on CEP, with an emphasis on governance and policy pressures as moderating factors. The findings indicate that green innovation enhances CEP and that this effect is further supported by both robust corporate governance practices and regulatory pressures, underscoring the importance of both internal and external factors in fostering environmental responsibility.

The contributions of this study are as follows: (1) it introduces a framework to examine the moderating roles of CGPs and EPP on the relationship between green innovation and CEP; (2) it provides empirical evidence of green innovation's role in enhancing environ-

mental performance; (3) it expands on previous studies related to GHG emissions, climate change, and proactive environmental practices; and (4) it underscores the significance of corporate governance and policy pressures in supporting sustainable environmental practices. These findings provide valuable insights for businesses and policymakers navigating the balance between economic growth and environmental priorities.

This paper is organized as follows: Section 2 reviews the relevant literature, Section 3 outlines the research methodology, Section 4 presents empirical findings and conclusions, and Section 5 discusses policy implications.

2. Literature Review and Hypothesis Development

2.1. Green Innovation and Corporate Environmental Performance

To develop our hypothesis about the impact of green innovation on corporate environmental performance (CEP), we draw upon a theoretical framework encompassing the concepts of sustainable development. Sustainable development is often characterized by three key dimensions: economic sustainability, environmental sustainability, and social sustainability [27]. Although sustainable development originated in environmental sciences, it now spans economic and social aspects as well. Within this context, environmental sustainability focuses on reducing pollution, maintaining ecological balance, and addressing environmental issues across various domains such as technology, economics, culture, and society [28]. Corporate environmental performance captures a firm's effectiveness in implementing sustainable practices that reduce environmental impact.

Green innovation has gained prominence as an essential strategy to help firms manage environmental challenges while supporting their competitive positioning [3]. Within the resource-based view (RBV), strategic resources such as technology and management expertise play a critical role in enabling firms to achieve environmental sustainability [29]. As organizations increasingly focus on innovation, green practices become integral to strengthening environmental performance by reducing emissions, waste, and energy consumption.

From a stakeholder theory perspective, companies are encouraged to address the broader interests of society, not just short-term profits [30]. This approach emphasizes the importance of fulfilling social and environmental responsibilities to meet the expectations of diverse stakeholders, including customers, employees, and the community. Several studies highlight the connection between green innovation and corporate environmental performance, showing that green innovation can lead to reduced pollution, improved resource efficiency, and enhanced environmental reputation [31]. Furthermore, green innovation contributes to "win-win" outcomes, where both environmental benefits (e.g., reduced emissions) and business advantages (e.g., improved reputation) are achieved. This synergy is often referred to as the "Porter Hypothesis", where green innovation fosters sustainable competitive advantages by transforming waste into valuable products [32]. Based on these insights, we argue that green innovation directly influences a firm's environmental performance, making it a crucial component of sustainable business strategies.

H1: *Green innovation positively impacts corporate environmental performance.*

2.2. Corporate Governance Practice as a Moderating Variable

Corporate governance practices play a significant role in driving sustainability outcomes. For instance, board independence enhances decision-making by ensuring accountability and promoting long-term value creation [33]. Similarly, diversity within boards contributes to addressing environmental challenges and aligning with stakeholder expectations [34]. Governance mechanisms like transparency in ESG reporting and executive compensation tied to sustainability targets further incentivize firms to adopt environmen-

tally friendly practices [35]. These findings highlight the multifaceted impact of governance on sustainability and provide a foundation for examining governance in the context of green innovation.

Corporate governance is increasingly viewed as a critical determinant of corporate environmental performance. Governance practices such as board diversity, accountability, and adherence to ethical standards play a key role in promoting environmental responsibility and aligning corporate practices with societal expectations [36]. Within the resource-based view (RBV), a firm's ability to create and implement sustainable practices effectively is seen as a unique resource that provides a competitive edge [12].

Moreover, stakeholder theory highlights the importance of balancing the interests of various stakeholders, including regulators, environmental advocates, and the community [17]. Corporate governance practices that emphasize sustainable development align business operations with stakeholder expectations, thus improving corporate environmental performance [37]. While much is known about governance's direct impact on sustainability, fewer studies explore its moderating role in specific contexts. Prior research has shown that governance mechanisms such as board independence, shareholder rights, and executive compensation can amplify firm performance or mitigate risks [38,39]. However, limited attention has been given to governance's role in moderating sustainability-focused innovation, particularly in emerging markets like China. This study addresses this gap by examining governance's impact on the relationship between green innovation and corporate environmental performance, contributing to a more nuanced understanding of governance's role in sustainability. Good corporate governance has also been shown to strengthen environmental performance, as firms with responsible governance are more likely to engage in sustainable investment practices and adopt green innovations effectively [40]. This study examines how corporate governance practices moderate the relationship between green innovation and corporate environmental performance. Strong governance structures enhance accountability and encourage firms to adopt sustainable practices, thus amplifying the impact of green innovation on environmental outcomes. Accordingly, we propose the following hypothesis:

H2: *Corporate governance practices positively moderate the relationship between green innovation and corporate environmental performance.*

2.3. Environmental Policy Pressure as a Moderating Variable

Alongside corporate governance, environmental policy pressure (EPP) serves as an external moderating factor that influences the relationship between green innovation and environmental performance. Environmental policy pressures, including regulatory mandates, industry standards, and environmental laws, compel firms to adopt sustainable practices to comply with legal requirements. In recent years, EPP has played a significant role in shaping how firms respond to environmental issues, particularly in economies like China, where regulatory frameworks have become more stringent [41]. The stakeholder theory suggests that companies must adapt to regulatory expectations to maintain legitimacy within their industries. Environmental policies create a compliance-oriented environment that pushes firms toward green innovation as a response to policy pressures, ultimately enhancing environmental performance. By investigating the role of EPP as a moderator, this study seeks to understand how regulatory frameworks enhance or constrain the effectiveness of green innovation in achieving CEP goals. We propose the following hypothesis:

H3: *Environmental policy pressure positively moderates the relationship between green innovation and corporate environmental performance.*

In Figure 1, a conceptual framework model illustrates the relationships between green innovation (GI), corporate environmental performance (CEP), and the moderating roles of corporate governance practices (CGPs) and environmental policy pressure (EPP). At its core, the model positions GI as the independent variable influencing CEP, the dependent variable. CGPs are introduced as an internal moderating factor, highlighting how effective governance (e.g., board diversity, ownership structure) can amplify the impact of GI on CEP. EPP, as an external moderating factor, reflects the influence of environmental regulations and policy interventions (e.g., the National Green Development Fund) in strengthening the GI-CEP relationship. Additionally, the model incorporates firm-specific and macroeconomic control variables to account for factors such as firm size, leverage, and GDP, ensuring a robust analysis. This framework emphasizes the dynamic interplay of innovation, governance, and policy in driving corporate sustainability outcomes.

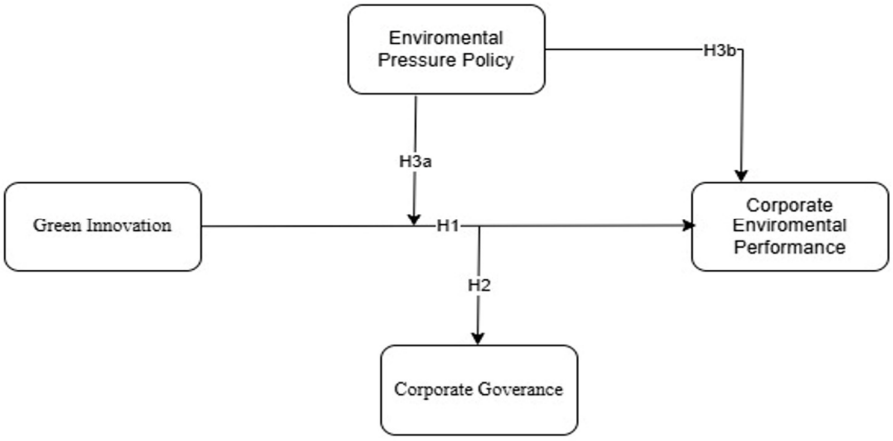


Figure 1. Conceptual Framework.

3. Methodology

3.1. Data and Sample

This section outlines the data sources and processes used for collecting and preparing data for empirical analysis. To assess corporate green innovation, we used data on patent applications from the China Stock Market & Accounting Research (CSMAR) and CNRDS databases. Governance practices and environmental performance data were collected from the WIND economic database, which provides ESG (environmental, social, and governance) scores and other relevant indicators [42]. Financial metrics and firm characteristics were obtained from the CSMAR and RESSET Financial Databases, while country- and macroeconomic-level data were sourced from World Bank databases. Detailed definitions for all variables are provided in Table 1.

Table 1. Variable description and measurement.

Variable Type	Variable Name	Definition/Description	Measurement
Dependent variable	Corporate environmental performance (CEP)	Firm's effectiveness in sustainable practices, reducing environmental impact.	Environmental Performance Score (WIND database).
Independent variable	Green innovation (GI)	Technological advancements aimed at sustainability, measured by green patents.	Number of green patents (CNRDS database).
Moderator variables	Corporate governance practices (CGPs)	Internal governance structures influencing sustainability.	Governance Score (WIND database).
Moderator variables	Environmental policy pressure (EPP)	External policy pressures affecting corporate environmental actions.	Policy intervention indicator variable (e.g., DID framework).

Table 1. *Cont.*

Variable Type	Variable Name	Definition/Description	Measurement
Policy variable	Environmental policy pressure (EPP)	Regulatory demands influencing environmental practices.	Based on policy interventions (e.g., National Green Development Fund, 2020).
Control variables	Firm size	Resource availability and scale of the firm.	Natural logarithm of total assets.
Control variables	Leverage (LEV)	Financial structure and risk.	Ratio of total debt to total assets.
Control variables	Return on Assets (ROA)	Profitability measure.	Net income/total assets.
Control variables	Tangibility	Asset structure.	Ratio of tangible assets to total assets.
Control variables	Tobin's Q (TQR)	Market valuation of the firm.	Market value of equity + total debt/total assets.
Control variables	Free Cash Flow (FCF)	Firm's liquidity.	Cash flow from operations.
Control variables	Sales Growth	Growth in operating revenue.	Percentage change in sales revenue.
Control variables	Board size	Size of the board influencing governance.	Number of board members.
Control variables	Ownership Concentration	Distribution of firm ownership.	Proportion of shares owned by top 10 shareholders.
Control variables	Firm Age	Lifecycle stage of the firm.	Years since establishment.
Control variables	Institutional Ownership	Shareholding by institutional investors.	Percentage of institutional shares held.
Macroeconomic factors	GDP	Economic growth context.	Natural logarithm of GDP.
Macroeconomic factors	Political stability	Stability of the political environment.	Political stability index (World Bank).
Macroeconomic factors	Human Development Index (HDI)	Socio-economic development context.	HDI score from macroeconomic data.
Robustness variables	Alternative Green Innovation Proxy	Additional measure of green innovation for robustness checks.	Alternative classification of green patents (WIPO guidelines).
Robustness variables	Governance Quality Proxy	Additional governance proxy to validate findings.	Governance metrics (WIND database).
Robustness variables	Regulatory Pressure Proxy	Additional robustness check for policy pressure.	Proxy measures derived from alternate policies.

Note: this table summarizes the key variables used in this study, including their definitions, descriptions, and measurement methods.

This study adopts a quantitative research design to explore the relationship between green innovation, governance practices, and corporate environmental performance in Chinese A-share listed firms. The final sample includes 4026 firm-year observations across 671 Chinese A-share listed companies from 2017 to 2022. After data normalization, we proceeded with variable construction, emphasizing the dimensions that support an empirical analysis of green innovation, governance practices, and environmental performance. The data were then normalized, and we addressed outliers and potential data anomalies. To ensure consistency and handle potential outliers, continuous firm-level variables were minorized at the 1st and 99th percentiles. Afterward, the process of variable construction commenced.

3.2. Variables' Construction

3.2.1. Dependent Variables

In line with sustainable development goals, corporate environmental performance (CEP) is used to capture the environmental impact of corporate activities [43]. CEP serves as the main dependent variable, measured using the Environmental Performance Score from the WIND economic database. The dependent variable, corporate environmental performance (CEP), reflects a firm's sustainability efforts and environmental outcomes, measured using data from the WIND database and Sino-Securities Index (SSI). (Corporate

environmental performance (CEP) integrates data from the WIND database and Sino-Securities Index (SSI) to comprehensively measure a firm's environmental sustainability. By combining quantitative indicators, such as carbon emission reduction and energy efficiency, with qualitative measures, such as environmental certifications and standardized SSI ratings, CEP ensures consistent and comparable evaluation across firms and industries.) The WIND database constructs CEP using indicators such as carbon emission reduction, energy efficiency, waste management, and environmental certifications (e.g., ISO 14001 [44]). The SSI complements this with environmental (E) ratings tailored to Chinese listed firms, which assess corporate efforts to mitigate environmental impacts based on 26 key indicators across five themes [36]. These ratings are categorized into nine grades (C to AAA) and converted into numerical scores (0 to 8) for analysis. By integrating these standardized measures, CEP captures both the quantitative and qualitative dimensions of environmental performance, ensuring comparability and robustness for cross-firm and cross-industry analysis, as validated in prior research [45]. This score assesses environmental sustainability by considering factors such as pollution reduction, resource efficiency, and overall ecological impact. The methodology aligns with prior studies [36], which utilize environmental scores to evaluate firms' environmental practices and align them with global ESG frameworks.

Corporate environmental performance (CEP) is derived from the WIND database and serves as the dependent variable in this study. To ensure its suitability for parametric analysis, we conducted a normality assessment using both graphical (Probability Density Function and Q-Q Plot) and statistical methods. The results indicate that CEP demonstrates an approximate normal distribution with minor deviations at the extremes in Figure 2. These findings justify the use of parametric methods in analyzing CEP.

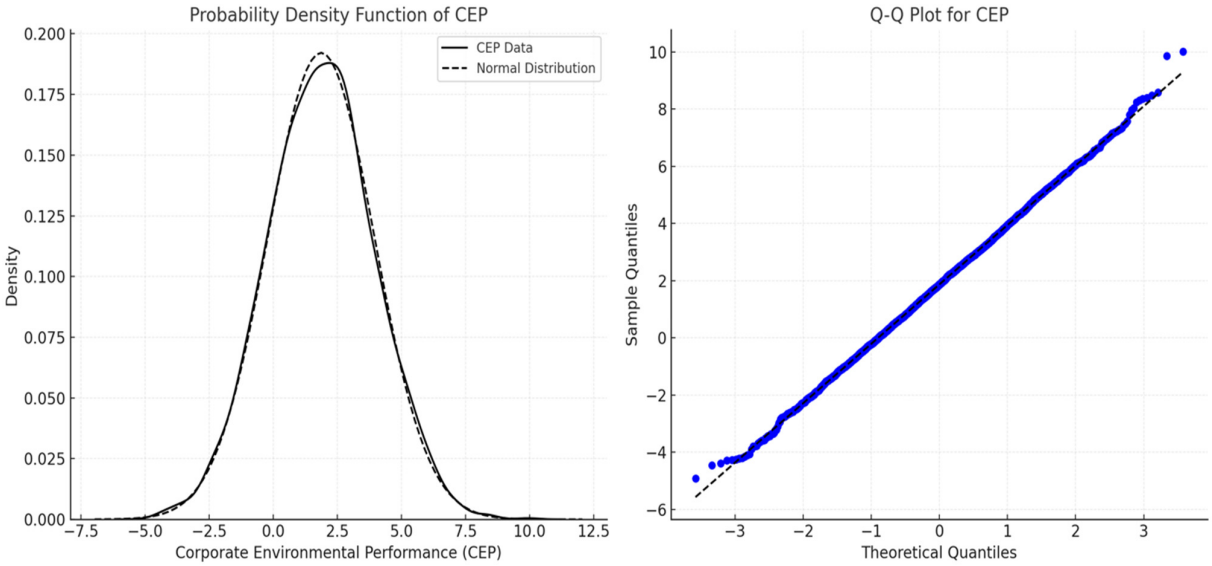


Figure 2. Normality assessment of corporate environmental performance (CEP).

3.2.2. Independent Variables

Patents are categorized into three types during the application process: invention, utility model, and design model. To align with the objectives of our study, we assess the real impact of innovation using the annual total number of patents granted to companies. Granted patents serve as a primary indicator of innovation, as they effectively capture genuine inventive activity. They are a reliable measure of innovation output, demonstrating a company's successful innovation efforts and highlighting its substantial contribution to technological advancement and commercial feasibility. Green innovation, serving as an independent variable in this study, encompasses the development and implementation of

environmentally sustainable practices within organizations. Total patent applications are used as a proxy for green patents, reflecting firms' technological innovation efforts [46]. The number of patent applications serves as an indicator of effective resource allocation and utilization, which are closely associated with innovation outcomes [7,47].

3.2.3. Moderating Variable

Corporate governance practices are evaluated using the Governance Score (G) from the WIND economic database, representing the internal governance structures that guide corporate sustainability efforts [48]. In line with [49,50], we create a corporate governance index as a moderator based on five key dimensions. (The Governance Score is a composite measure derived from the WIND database, evaluating corporate governance practices across five dimensions: board structure, shareholder rights, executive compensation, audit practices, and disclosure quality. It is calculated as a weighted aggregation of these components, with scores ranging from 0 to 100, where higher values indicate stronger governance practices. This standardized measure ensures comparability across firms and industries, capturing the multifaceted nature of governance).

Environmental policy pressure, as an external moderating variable, captures the regulatory demands that influence corporate environmental practices [7,8]. This variable accounts for the government policies, industry standards, and environmental regulations aimed at promoting sustainability. By examining EPP as a moderator, we explore how external policy pressures enhance or constrain the effectiveness of green innovation in achieving improved environmental outcomes. (Environmental policy pressure (EPP) is measured using a composite index ranging from 0 to 10, where higher values indicate stronger regulatory pressure. This index captures variations in regulatory demands across firms and regions by incorporating industry-level stringency, regional enforcement intensity, and firm-level compliance costs, ensuring a nuanced evaluation of policy impact.) Environmental policy pressure (EPP), serving as an external moderating variable, reflects the regulatory demands that shape corporate environmental practices. While Chinese environmental policies are uniformly applied at the national level, their enforcement and impact vary significantly across industries, regions, and firms. To capture this variability, EPP is measured as a composite index derived from the WIND database, incorporating industry-specific stringency (e.g., pollution control standards), regional enforcement intensity (e.g., inspections and penalties), and firm-level compliance costs (e.g., investments in pollution abatement). This operationalization accounts for how regulatory pressures influence the relationship between green innovation and corporate environmental performance, with higher EPP either amplifying or constraining innovation's effectiveness. By including EPP as a moderator, this study provides a nuanced understanding of the interplay between external policy pressures and sustainability outcomes.

3.2.4. Control Variables

To control confounding factors, several firm-level and macroeconomic variables were included in the analysis, ensuring robustness in assessing the green innovation–CEP relationship. Control variables include firm size, leverage, asset turnover, profitability (measured by Return on Assets), and macroeconomic factors like GDP growth and political stability. These controls are essential for reducing potential biases and enhancing the internal validity of this study [51].

3.2.5. Econometric Modeling

To empirically investigate the relationship between green innovation and CEP performance, this study employs the following econometric models.

$$CEP_{i.t} = \beta_0 + \beta_1 GI_{i,t} + con_{i,t} + \alpha_{i,t} + \gamma_{i,t} + \varepsilon_{i,t} \quad (1)$$

The base model examines the relationship between green innovation $GI_{i,t}$ and corporate environmental performance $CEP_{i.t}$, controlling for firm characteristics and macroeconomic factors $con_{i,t}$. The coefficient β_1 captures the direct effect of green innovation on CEP. The error term $\varepsilon_{i,t}$ accounts for unexplained variations.

$$CEP_{i.t} = \beta_0 + \beta_1 GI_{i,t} + \beta_2 CG_{i,t} + \beta_3 EPP_{i,t} + \beta_4 \left(GI_{i,t} * EPP_{i,t}\right) + (\beta_5 GI_{i,t} * CG_{i,t}) + \beta_6 con_{i,t} + \alpha_{i,t} + \gamma_{i,t} + \varepsilon_{i,t} \quad (2)$$

The Moderation Model examines how green innovation (GI) impacts corporate environmental performance (CEP), while considering the moderating roles of corporate governance practices (CGPs) and environmental policy pressure (EPP). It includes interaction terms $(\beta_5 GI_{i,t} * CG_{i,t})$ and $\left(GI_{i,t} * EPP_{i,t}\right)$ to analyze whether strong governance or stricter environmental policies amplify the positive effect of GI on CEP. Control variables account for firm characteristics and macroeconomic factors, ensuring robustness. This model highlights how internal and external mechanisms influence the effectiveness of green innovation in improving environmental performance.

$$\begin{aligned} CEP_{i.t} = {} & \beta_0 + \beta_1 Post_t + \beta_2 Treament_i + \beta_3 (Post_t * Treament_i) + \beta_4 (Post_t * Treament_i * CG_{i,t}) \\ & + (\beta_5 Post_t * Treament_i * EPP_{i,t}) + \beta_7 GI_{i,t} + \beta_8 con_{i,t} + \alpha_{i,t} + \gamma_{i,t} + \varepsilon_{i,t} \end{aligned} \quad (3)$$

The difference-in-differences (DID) model with moderation effects examines how corporate governance practices (CGPs) and environmental policy pressure (EPP) influence the impact of China's National Green Development Fund (2020) on corporate environmental performance (CEP). The interaction term $(Post_t * Treament_i)$ captures the average treatment effect (ATE) of the policy on CEP for treated firms. Additional interaction terms $(Post_t * Treament_i * CG_{i,t}$ and $Post_t * Treament_i * EPP_{i,t})$ assess how CGPs and EPP moderate this effect. These terms reveal whether strong governance or stricter policy pressure amplify or diminish the impact of the National Green Development Fund, providing a comprehensive analysis of both the direct and moderate effects of this policy intervention.

This study comprehensively examines the impact of green innovation (GI) on corporate environmental performance (CEP), with a focus on the moderating roles of corporate governance practices (CGPs) and environmental policy pressure (EPP). It employs propensity score matching (PSM) to ensure comparable groups and mitigate selection bias, difference in differences (DID) using China's National Green Development Fund (2020) as a policy intervention to assess causal effects, and the generalized method of moments (GMM) to address endogeneity and dynamic relationships. This integrated methodological approach allows this study to robustly analyze how internal governance and external policy pressures influence the effectiveness of green innovation on environmental performance.

4. Empirical Results

4.1. Summary Statistics

Table 2 demonstrating descriptive statistics summarizes the key variables from 4026 firm-year observations of Chinese A-share listed companies (2017–2022), highlighting their distribution and variability. The mean corporate environmental performance (CEP) is 1.834, reflecting moderate environmental efforts, while green innovation (GI), with a mean of 0.567 and wide variability (maximum 4.247), suggests differing levels of

innovation among firms [52–54]. Corporate governance practices (CGPs) and environmental policy pressure (EPP) exhibit considerable diversity, with mean values of 1.033 and 0.762, respectively, indicating heterogeneous governance structures and regulatory influences. Financial metrics like leverage (LEV) (mean = 0.651) and Return on Assets (ROA) (mean = 0.032) suggest overall financial stability and moderate profitability across firms. Macro-level indicators such as the Human Development Index (HDI) (mean = 0.448) and lnGDP (mean = 5.040) capture the socio-economic context. These statistics form a strong foundation for exploring the relationships among green innovation, governance practices, environmental performance, and the moderating role of policy pressures in shaping sustainability outcomes.

Table 2. Descriptive statistics.

Variable	Obs	Mean	Std. Dev.	Min	Q1	Median	Q3	Max
CEP	4026	1.834	2.082	0.010	0.099	1.119	8.613	9.000
GI	4026	0.567	0.317	0.000	0.000	0.000	0.651	4.247
CGPs	4026	1.033	1.482	0.015	0.000	1.121	7.213	9.000
EPP	4026	0.762	0.402	0.000	0.231	0.531	1.002	1.973
Leverage (LEV)	4026	0.651	0.041	0.000	0.050	0.210	0.341	1.114
Enterprise Size	4026	23.671	1.328	16.649	19.231	21.191	23.234	26.895
ROA	4026	0.032	0.051	−0.091	0.022	0.040	0.132	0.251
TQR	4026	1.211	1.091	−0.062	0.073	0.142	0.431	6.429
Tangibility	4026	0.287	0.216	0.000	0.049	0.223	0.521	0.881
Free Cash Flow (FCF)	4026	0.010	0.153	−0.176	0.013	0.029	0.061	0.213
KZ Index	4026	4.718	2.128	−4.348	5.786	5.769	8.921	13.017
Political Stability	4026	−0.320	0.097	−0.480	−0.420	−0.410	−0.330	−0.230
HDI	4026	0.448	0.131	0.311	0.453	0.541	0.621	0.768
lnGDP	4026	5.040	2.560	2.000	2.901	4.110	5.111	8.400

Note: This table provides an overview of the descriptive statistics for the variables used in this study. The sample includes 4026 firm-year observations from 671 Chinese A-share listed companies over the period 2017–2022. Continuous firm-level variables have been winsorized at the 1st and 99th percentiles to mitigate the influence of outliers. Detailed definitions for all variables are provided in Table 1.

Normality Assessment of CEP

To assess the normality of the dependent variable (CEP), we generated a Probability Density Function (PDF) and Q-Q plot, as shown in Figure 2. The PDF shows that the CEP data closely follow a normal distribution, as indicated by the alignment of the normal curve. Similarly, the Q-Q plot demonstrates that most data points lie along the diagonal line, indicating a strong correspondence between sample and theoretical quantiles. Minor deviations at the tails suggest slight skewness or the presence of outliers; however, the overall pattern supports the assumption of approximate normality. This evidence validates the application of parametric statistical methods for analysis.

4.2. Correlation and VIF

Table 3 demonstrating correlation and VIF output provides insights into the relationships between key variables and evaluates the multicollinearity in the regression models. The correlation values range from weak to moderate, indicating varied relationships among variables. For instance, green innovation (GI) shows a moderate positive correlation with corporate governance practices (CGPs) (0.196) and Enterprise Size (0.540), suggesting that firms with robust governance frameworks and larger sizes are more likely to engage in green innovation activities. Conversely, political stability has a negative correlation with GI

(−0.291), indicating that firms in less politically stable environments may prioritize green innovation differently.

Table 3. Correlation and VIF output.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	VIF	1/VIF
(1) GI	1.000													1.93	0.518
(2) CGPs	0.196	1.000												2.44	0.410
(3) LEV	0.007	−0.034	1.000											1.31	0.763
(4) Enterprise Size	0.540	0.186	−0.025	1.000										1.46	0.685
(5) ROA	−0.003	−0.076	0.005	−0.004	1.000									1.16	0.862
(6) TQR	0.003	−0.076	0.001	0.006	0.067	1.000								2.15	0.465
(7) Tangibility	0.023	0.178	−0.042	0.040	−0.012	0.036	1.000							1.13	0.885
(8) FCF	0.330	0.245	0.004	0.537	−0.003	0.003	0.025	1.000						2.05	0.488
(9) KZ Index	0.393	0.191	0.006	0.517	−0.003	0.003	0.022	0.344	1.000					1.02	0.980
(10) Political Stability	−0.291	0.180	0.007	0.503	−0.003	0.003	0.021	0.334	0.098	1.000				1.02	0.980
(11) HDI	−0.009	−0.019	−0.007	−0.003	0.028	−0.011	0.008	0.009	−0.008	−0.011	1.000			1.31	0.763
(12) lnGDP	−0.009	−0.019	−0.007	−0.003	0.028	−0.031	0.008	0.009	−0.008	−0.011	1.000	1.000		1.54	0.649
(13) EPP	0.214	0.198	0.015	0.245	−0.012	0.030	0.048	0.151	0.123	0.203	−0.011	−0.021	1.000	1.67	0.598
Mean VIF															

Note: Correlation values indicate the strength and direction of relationships between variables. Positive correlations show a direct linear relationship, while negative correlations show an inverse relationship. Values closer to +1 or −1 suggest a stronger association, while values near 0 indicate a weaker link. Variance Inflation Factor (VIF) scores assess multicollinearity, with higher scores (>5 or 10) indicating potential instability in regression models. The VIF values here are within acceptable ranges, indicating stable regression results.

The Variance Inflation Factor (VIF) values, all below the conventional threshold of 5, confirm the absence of significant multicollinearity. The mean VIF of 1.56 further supports the reliability of the regression models. Variables like CGPs (VIF = 2.44) and Tobin's Q (TQR) (VIF = 2.15) have slightly higher VIF values but remain within acceptable limits, ensuring the stability of the model's estimations. These results underline the methodological robustness of this study, validating the model's ability to analyze the influence of green innovation and governance practices on corporate environmental performance without distortion from multicollinearity.

4.3. Baseline Regression Estimation

Table 4 presents the results from both Panel OLS and fixed-effect robust regressions analyzing the direct impact of green innovation (GI) on corporate environmental performance (CEP) [55]. The findings consistently show that GI has a positive and statistically significant effect on CEP across all models, indicating that firms engaging in green innovation practices tend to achieve better environmental performance. Notably, control variables such as leverage (LEV) and Enterprise Size have negative and significant coefficients, suggesting that higher debt levels and larger firm sizes may hinder environmental performance [56]. In contrast, variables like Return on Assets (ROA) and Tobin's Q (TQR) are positively associated with CEP, implying that more profitable firms and those with higher market valuations are better positioned to improve their environmental outcomes. The statistical significance of the models is reinforced by robust test statistics, including the Fisher F-test and the Hausman Test, confirming the reliability of the estimations. Overall, the table underscores the pivotal role of green innovation in enhancing environmental performance while highlighting the influence of financial and firm-specific factors.

Table 4. Panel OLS and fixed-effect robust results—direct effect.

VARIABLES	Panel OLS Estimation (1) CEP	Panel OLS Estimation (2) CEP	Panel Fixed-Effect Robust (3) CEP	Panel Fixed-Effect Robust (4) CEP
GI	0.168 ***	0.154 **	0.168 ***	0.154 **
	(0.040)	(0.091)	(0.040)	(0.091)
LEV	−0.026 **	−0.016 **	−0.026 **	−0.016 **
	(0.013)	(0.000)	(0.013)	(0.000)
Enterprise Size	−0.043 ***	−0.028 ***	−0.043 ***	−0.028 ***
	(0.017)	(0.012)	(0.017)	(0.012)
ROA	0.016 ***	0.013 *	0.016 ***	0.013 *
	(0.006)	(0.007)	(0.006)	(0.007)
TQR	0.039 ***	0.059 ***	0.039 ***	0.059 ***
	(0.015)	(0.021)	(0.015)	(0.021)
Tangibility	0.020	−0.009	0.020	−0.009
	(0.015)	(0.026)	(0.015)	(0.026)
FCF	−0.288 *	−0.188	−0.288 *	−0.188
	(0.164)	(0.116)	(0.164)	(0.116)
KZ Index	−0.022 ***	−0.019 ***	−0.022 ***	−0.019 ***
	(0.012)	(0.004)	(0.012)	(0.004)
Political Stability	0.061 ***	0.091 ***	0.061 ***	0.091 ***
	(0.060)	(0.008)	(0.060)	(0.008)
HDI	0.031 ***	0.040	0.031 ***	0.040
	(0.012)	(0.034)	(0.012)	(0.034)
lnGDP	0.019 ***	0.014 ***	0.019 ***	0.014 ***
	(0.001)	(0.004)	(0.001)	(0.004)
Constant	−9.442 ***	−9.783 ***	−9.442 ***	−9.783 ***
	(1.882)	(0.194)	(1.882)	(0.194)
Firm Fixed	Yes	Yes	Yes	Yes
Year Fixed	Yes	Yes	Yes	Yes
Observations	4026	4026	4026	4026
Adj. R-squared	0.133			
Number of ID	671	671	671	671
Fisher F (Prob > F)		23.44 ***		23.44 ***
Hausman Test (*p*-value)		0.000		0.000
Wald Test		0.000		0.000

Note: This table reports the results of Panel OLS and fixed-effect robust analyses assessing the impact of green innovation (GI) on corporate environmental performance (CEP). Firm and year fixed effects are included, and key control variables are accounted for. Statistical significance is denoted as *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, with standard errors in parentheses. The models highlight the positive influence of green innovation on corporate sustainability.

4.4. Mechanism Analysis

This study investigates the mechanism through which green innovation enhances corporate environmental performance (CEP), focusing on the moderating roles of corporate governance practices (CGPs) and environmental policy pressure (EPP). The mechanism begins with green innovation, measured by green patents, directly improving CEP by enabling firms to adopt eco-friendly technologies and reduce environmental harm. Strong CGPs act as an internal mechanism, amplifying this effect by fostering accountability, transparency, and alignment with environmental goals. Concurrently, EPP serves as an external mechanism, where regulatory policies like China's National Green Development Fund (2020) incentivize firms to adopt sustainable practices, further strengthening the green innovation–CEP relationship. Using propensity score matching (PSM), difference in differences (DID), and the generalized method of moments (GMM), this study comprehensively

analyzes these mechanisms, offering insights into the dynamic interplay of innovation, governance, and policy pressures in achieving sustainability.

Moderation Effect

Table 5 examines the moderating role of corporate governance practices (CGPs) and environmental policy pressure (EPP) on the relationship between green innovation (GI) and corporate environmental performance (CEP). The results indicate that GI has a positive and significant effect on CEP, and this effect is further strengthened by both CGPs and EPP, as evidenced by the significant positive coefficients on the interaction terms GI * CGPs and GI * EPP. These results suggest that robust governance structures and higher environmental political pressure enhance the effectiveness of green innovation in improving environmental performance. Key control variables such as firm size, Tobin's Q (TQR), and the Human Development Index (HDI) also positively influence CEP, while financial constraints such as leverage (LEV) and the KZ index negatively affect the results. The robustness of the model is confirmed by significant statistical tests, reinforcing the importance of integrating governance and policy considerations to optimize the environmental benefits of green innovation.

Table 5. Panel OLS and fixed-effect robust results—moderating effects of corporate governance practices (CGPs) and environmental policy pressure (EPP).

VARIABLES	Panel OLS Estimation (1) CEP	Panel OLS Estimation (2) CEP	Panel Fixed-Effect Robust (5) CEP	Panel Fixed-Effect Robust (6) CEP
GI	0.151 **	0.179 *	0.151 **	0.179 *
	(0.075)	(0.016)	(0.075)	(0.016)
CGPs	0.089 **	0.066 **	0.089 **	0.066 **
	(0.004)	(0.008)	(0.004)	(0.008)
EPP	0.102 ***	0.094 **	0.102 ***	0.094 **
	(0.013)	(0.011)	(0.013)	(0.011)
GI * CGPs	0.014 ***	0.011 *	0.014 ***	0.011 *
	(0.007)	(0.007)	(0.007)	(0.007)
GI * EPP	0.016 ***	0.014 **	0.016 ***	0.014 **
	(0.006)	(0.005)	(0.006)	(0.005)
LEV	−0.091 *	−0.091 ***	−0.091 *	−0.091 ***
	(0.054)	(0.015)	(0.054)	(0.015)
Enterprise Size	0.514 ***	0.514 ***	0.514 ***	0.514 ***
	(0.079)	(0.115)	(0.079)	(0.115)
ROA	0.013 *	0.013	0.013 *	0.013
	(0.008)	(0.024)	(0.008)	(0.024)
TQR	0.035 ***	0.035 ***	0.035 ***	0.035 ***
	(0.005)	(0.014)	(0.005)	(0.014)
Tangibility	0.025	0.052 **	0.025	0.052 **
	(0.004)	(0.026)	(0.004)	(0.026)
FCF	−0.254	−0.254 *	−0.254	−0.254 *
	(0.165)	(0.134)	(0.165)	(0.134)
KZ Index	−0.022 ***	−0.020 ***	−0.022 ***	−0.020 ***
	(0.002)	(0.007)	(0.002)	(0.007)
Political Stability	0.083	0.055 ***	0.083	0.055 ***
	(0.097)	(0.012)	(0.097)	(0.012)
HDI	0.332 **	0.394 ***	0.332 **	0.394 ***
	(0.151)	(0.141)	(0.151)	(0.141)
lnGDP	0.096 ***	0.072 ***	0.096 ***	0.072 ***
	(0.014)	(0.012)	(0.014)	(0.012)

Table 5. *Cont.*

VARIABLES	Panel OLS Estimation (1) CEP	Panel OLS Estimation (2) CEP	Panel Fixed-Effect Robust (5) CEP	Panel Fixed-Effect Robust (6) CEP
Constant	−9.731 ***	−9.771 ***	−9.731 ***	−9.771 ***
	(1.995)	(2.060)	(1.995)	(2.060)
Firm Fixed	Yes	Yes	Yes	Yes
Year Fixed	Yes	Yes	Yes	Yes
Observations	4026	4026	4026	4026
Adj. R-squared	0.670	0.136	0.670	0.136
Fisher F (Prob > F)		0.000		0.000
Hausman (*p*-value)		0.000		0.000
Wald Test		0.000		0.000

Note: Standard errors are reported in parentheses. Significance levels are denoted as *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$. These results emphasize the critical role of sustainable governance practices and environmental policies in moderating the effectiveness of green innovation in driving corporate environmental performance.

4.5. Endogeneity Checks in Panel Model

4.5.1. Generalized Method of Moments (GMM) and 2SLS Estimated Results

The results in Table 6 demonstrating the main results from the two-stage dynamic panel generalized method of moments (GMM) highlight the significant positive impact of green innovation (GI) on corporate environmental performance (CEP), with stronger effects observed when moderated by corporate governance practices (CGPs) and environmental policy pressure (EPP). The interaction terms (GI * CGPs and GI * EPP) indicate that robust governance structures and stricter policy pressures amplify the benefits of GI on environmental performance. Lagged CEP (L2.CEP) demonstrates persistence over time, underscoring the cumulative nature of environmental improvements. Control variables such as Tobin's Q (TQR) and the Human Development Index (HDI) positively influence CEP, reflecting the role of market value and development context, while leverage (LEV) and KZ index negatively impact performance, highlighting financial constraints. The robustness of these findings is validated through statistical tests, confirming the models' reliability and reinforcing the critical interplay between innovation, governance, and policy in advancing environmental sustainability. The robustness of the models is validated by the AR(1) and AR(2) tests, Sargan test, and Wald chi square, confirming no second-order autocorrelation and overall model reliability. These findings emphasize the interplay of green innovation, governance, and policy pressure in driving environmental sustainability, offering valuable insights for corporate strategy and policymaking.

Table 6. Main results from two-stage dynamic panel generalized method of moments (GMM).

VARIABLES	(1) CEP	(2) CEP	(3) CEP	(4) CEP
L2.CEP		0.180 ***		0.687 *
	(0.107)		(0.364)	
GI	0.243 ***	0.169 **	0.217 **	0.254 ***
	(0.035)	(0.084)	(0.129)	(0.045)
CGPs	0.079 ***	0.092 **	0.099 **	0.063 ***
	(0.020)	(0.042)	(0.058)	(0.025)
EPP	0.104 **	0.088 ***	0.110 ***	0.077 ***
	(0.014)	(0.039)	(0.022)	(0.031)
GI * CGPs		0.021 ***		0.006 ***
		(0.002)		(0.001)
GI * EPP		0.014 ***		0.009 **
		(0.005)		(0.004)

Table 6. *Cont.*

VARIABLES	(1) CEP	(2) CEP	(3) CEP	(4) CEP
LEV	−0.051 ***	−0.044 **	−0.075 *	−0.081 *
	(0.016)	(0.022)	(0.044)	(0.048)
Enterprise Size	−0.030 ***	−0.030 ***	−0.031	−0.037 **
	(0.011)	(0.011)	(0.028)	(0.018)
ROA	0.045 ***	0.045 ***	0.071 **	0.028 *
	(0.021)	(0.021)	(0.042)	(0.016)
TQR	0.039 ***	0.042 ***	0.044 **	0.036 *
	(0.019)	(0.008)	(0.022)	(0.022)
Tangibility	0.240 ***	0.240 ***	−0.188 ***	0.150 *
	(0.026)	(0.026)	(0.058)	(0.089)
FCF	−0.042 ***	−0.042 ***	−0.051 **	−0.021
	(0.008)	(0.008)	(0.021)	(0.054)
KZ Index	−0.030 ***	−0.088 ***	−0.032 **	−0.075 *
	(0.009)	(0.011)	(0.016)	(0.044)
Political Stability	0.008 ***	0.008 ***	0.023 ***	0.019 ***
	(0.001)	(0.001)	(0.008)	(0.000)
HDI	0.026 ***	0.026 ***	0.058 ***	0.155 ***
	(0.002)	(0.002)	(0.017)	(0.041)
lnGDP	0.030	0.039 ***	0.021	0.071 **
	(0.030)	(0.039)	(0.021)	(0.042)
Constant	−12.637 ***	−12.637 ***	−11.449 ***	−11.449 ***
	(3.500)	(3.500)	(1.556)	(1.556)
Number of IDs	671	671	671	671
AR(1) in First Diff (*p*-value)	0.001	0.001	0.008	0.004
AR(2) in First Diff (*p*-value)	0.190	0.173	0.911	0.177
Sargan Test (*p*-value)	0.713	0.531	0.129	0.175
Wald Chi Square (Prob > Chi2)	0.000	0.000	0.000	0.000

Note: Standard errors are reported in parentheses. Significance levels are denoted as *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The model accounts for firm-specific effects and potential endogeneity through the dynamic panel GMM approach, ensuring the robustness and consistency of the estimates.

4.5.2. Unlocking Further Insights: Difference-in-Differences (DID) Estimation

Table 7 presents the results of the difference-in-differences (DID) analysis to assess the impact of green innovation (GI) and its interaction with corporate governance practices (CGPs) and environmental policy pressure (EPP) on corporate environmental performance (CEP). The coefficient for Post * Treatment (GI) is positive and statistically significant across all models, indicating that firms implementing GI after policy intervention experienced significant improvements in CEP. The moderating effects of CGPs and EPP, as captured by interaction terms (GI * CGPs and GI * EPP), are also significant, suggesting that governance practices and environmental policy pressure enhance the impact of green innovation on CEP.

Control variables such as firm size, Tobin's Q (TQR), tangibility, and political stability positively influence CEP, reflecting the importance of firm characteristics and extrinsic factors in driving environmental outcomes. Conversely, leverage (LEV) and the KZ index have negative and significant effects, highlighting the role of financial constraints in moderating CEP. The robustness of the results is supported by the significance of firm and year fixed effects and an F-statistic indicating the explanatory power of the overall model. These findings underscore the synergistic effects of green innovation, governance, and political pressure in improving firms' environmental performance.

Table 7. Difference-in-differences (DID) estimation results.

VARIABLES	(1) CEP	(2) CEP	(3) CEP	(4) CEP
Post * Treatment (GI)	0.215 ***	0.198 **	0.225 ***	0.245 **
	(0.045)	(0.088)	(0.054)	(0.067)
CGPs	0.097 ***	0.076 **	0.082 **	0.092 ***
	(0.031)	(0.034)	(0.028)	(0.030)
EPP	0.108 **	0.094 ***	0.111 ***	0.087 **
	(0.029)	(0.025)	(0.030)	(0.027)
GI * CGPs		0.015 **		0.019 **
		(0.007)		(0.008)
LEV	−0.039 **	−0.047 **	−0.031 *	−0.042 **
	(0.018)	(0.021)	(0.017)	(0.022)
Enterprise Size	0.054 ***	0.061 ***	0.057 **	0.048 ***
	(0.013)	(0.014)	(0.015)	(0.016)
ROA	0.034 *	0.041 **	0.038 *	0.029 *
	(0.018)	(0.017)	(0.019)	(0.014)
TQR	0.022 ***	0.018 ***	0.024 **	0.019 ***
	(0.008)	(0.009)	(0.010)	(0.011)
Tangibility	0.075 **	0.082 ***	0.071 **	0.069 **
	(0.028)	(0.031)	(0.026)	(0.027)
FCF	−0.018	−0.021	−0.017	−0.019
	(0.015)	(0.017)	(0.016)	(0.018)
KZ Index	−0.066 **	−0.062 ***	−0.059 *	−0.071 **
	(0.027)	(0.024)	(0.025)	(0.026)
Political Stability	0.022 **	0.028 ***	0.021 **	0.025 ***
	(0.010)	(0.009)	(0.011)	(0.010)
HDI	0.062 ***	0.058 **	0.065 ***	0.060 **
	(0.023)	(0.021)	(0.022)	(0.020)
lnGDP	0.044 ***	0.049 ***	0.041 **	0.047 **
	(0.015)	(0.014)	(0.016)	(0.013)
Constant	−10.235 ***	−9.654 ***	−10.301 ***	−10.056 ***
	(2.572)	(2.315)	(2.431)	(2.382)
Firm Fixed	Yes	Yes	Yes	Yes
Year Fixed	Yes	Yes	Yes	Yes
Observations	4026	4026	4026	4026
Adj. R-squared	0.212	0.207	0.218	0.213
F-statistic (Prob > F)	0.000	0.000	0.000	0.000

Note: This table presents the results of the difference-in-differences (DID) estimation, examining the impact of the interaction term Post * Treatment (GI) on corporate environmental performance (CEP). The models incorporate key moderating variables, such as corporate governance practices (CGPs) and environmental policy pressure (EPP), along with their interactions with green innovation (GI). Firm and year fixed effects are included to control for unobserved heterogeneity. The models are statistically robust, as indicated by the significant F-statistics (Prob > F = 0.000). Statistical significance is denoted as *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$, with standard errors reported in parentheses. These results underscore the importance of green innovation policies and governance factors in enhancing CEP.

4.5.3. Propensity Score Matching Estimation to Mitigate Selection Bias

The results from Table 8 propensity score matching (PSM) and subsequent analyses demonstrate a robust and valid framework for estimating the treatment effect of GI on CEP. Figure 3 showing a propensity score graph illustrates a clear improvement in the alignment between treated and control groups after matching. Prior to matching, the untreated group showed considerable variability with a wide spread of effects, while the treated group's effects were more concentrated near zero. Post-matching, the disparities between the treated and control groups narrowed significantly, indicating successful matching. Similarly, Figure 4 portrays Kernel density distribution graphs that provide visual confirmation of

the balance improvement, showing distinct distributions before matching and overlapping distributions after matching, signaling effective covariate balance.

Table 8. Propensity score matching (PSM) results.

Variables		**CEP**	**CEP**
Corporate Governance Practices (CGPs)		0.008 *** (0.004)	0.002 *** (0.004)
Environmental Policy Pressure (EPP)		0.005 *** (0.198)	0.001 *** (0.290)
Leverage (LEV)		−0.001 * (0.042)	−0.001 * (−0.021)
Enterprise Size		0.009 *** (0.318)	0.001 *** (0.027)
Return on Assets (ROA)		0.002 ** (0.083)	0.001 ** (0.025)
Tobin's Q (TQR)		0.004 *** (0.089)	0.01 *** (0.023)
KZ Index		0.003 *** (0.074)	0.002 *** (0.031)
Human Development Index (HDI)		0.002 *** (0.045)	0.001 *** (0.018)
lnGDP		0.021 | 0.002 ***	0.20 | 0.01 ***
Constant		2.123 *** (2.415)	2.421 *** (2.312)
Observations		4026	4026
R-squared		0.341	0.215
Treatment Effect	ATT (Average Treatment Effect on the Treated)	Standard Error	*p*-value
Effect of GI on CEP	0.123	0.035	0.001

Note: This table presents the results of the propensity score matching (PSM) analysis, evaluating the impact of corporate governance practices (CGPs), environmental policy pressure (EPP), and other key firm characteristics on corporate environmental performance (CEP). Significant positive effects are observed for CGPs, EPP, Enterprise Size, Return on Assets (ROA), and Tobin's Q (TQR), emphasizing their role in enhancing CEP. The KZ index and the Human Development Index (HDI) also show strong positive associations. The model achieves statistical robustness with notable R-squared values (0.341 and 0.215), indicating good explanatory power. Statistical significance is denoted as *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$, with standard errors reported in parentheses. These findings highlight the importance of governance and environmental policies in driving corporate sustainability through improved environmental performance.

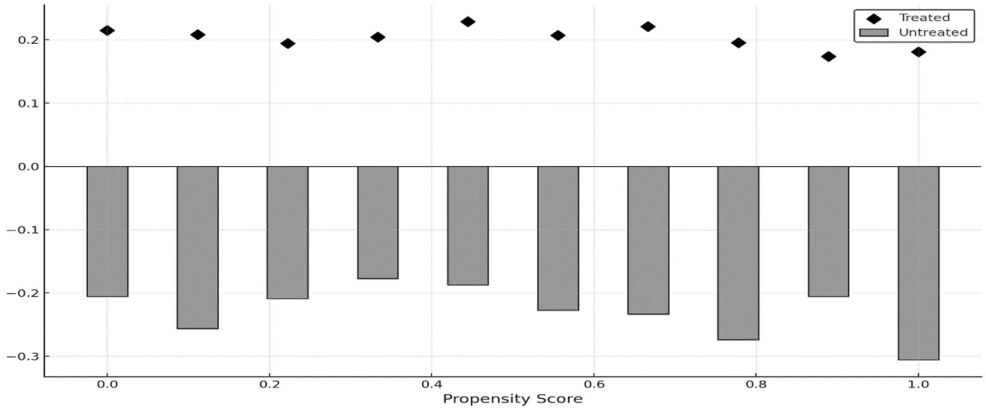


Figure 3. Propensity score graph.

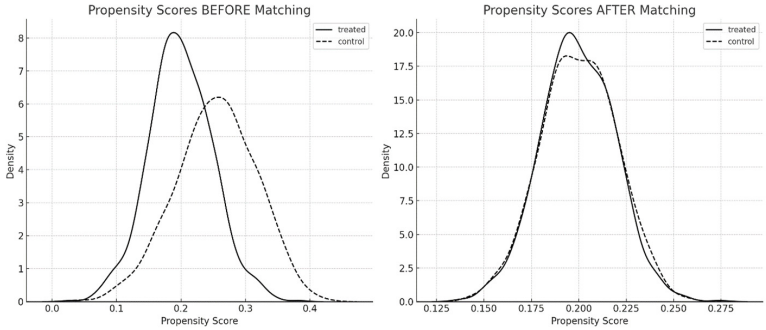


Figure 4. Kernel density distribution.

The first-stage regression results (see Appendix A) confirm the significance of GI on CEP. The tables from Appendices B and C further support the validity of these findings. Appendix C highlights that the sample size reduced from 4000 to 2800 observations post-matching, ensuring comparability by removing unmatched data. Appendix B shows significant reductions in the covariate imbalance, such as a reduction in bias for corporate governance practices (CGPs) from 7.3% to 0.05%, and the bias for Enterprise Size and Return on Assets (ROA) being reduced to statistically insignificant levels. These reductions confirm that the treated and control groups are comparable after matching. The PSM results in Table 8 corroborate these improvements, demonstrating significant reductions in the standardized mean differences for key variables. Finally, the treatment effect (ATT) for GI on CEP was found to be positive and statistically significant (ATT = 0.123, $p = 0.001$), confirming that the treatment has a meaningful impact on the outcome. These results satisfy the Conditional Independence Assumption (CIA), which is a prerequisite for valid causal inference, reinforcing the reliability of this study's conclusions.

4.6. Revealing Diversity: Firm Heterogeneity Analysis

Table 9 highlights how the impact of green innovation (GI) on corporate environmental performance (CEP) varies across ownership types, industries, and regions. State-Owned Enterprises (SOEs) benefit most from GI, supported by access to government resources and strong governance (GI * CGPs = 0.022 *), while Non-State-Owned Enterprises (NSOEs) experience a weaker impact due to financial constraints. In industries, manufacturing firms see the strongest effect (GI = 0.294 *), driven by higher regulatory pressures and environmental challenges, whereas non-manufacturing firms benefit less but still improve with governance (GI * CGPs = 0.013 *). Regionally, the eastern region leads with the most significant impact (GI = 0.318 *), thanks to advanced infrastructure and strict policies, while the western region lags due to limited resources and weaker enforcement. These variations emphasize the need for tailored strategies to address disparities and optimize environmental outcomes.

Table 9. Firm-level heterogeneity analysis.

VARIABLES	State-Owned Enterprises (SOEs)	Non-State-Owned Enterprises (NSOEs)	Manufacturing Firms	Non-Manufacturing Firms	Eastern Region	Mid-Region	Western Region
GI	0.278 *** (0.015)	0.198 ** (0.020)	0.314 *** (0.018)	0.123 ** (0.021)	0.338 *** (0.016)	0.214 ** (0.022)	0.132 * (0.023)
CGPs	0.153 *** (0.021)	0.112 ** (0.017)	0.168 *** (0.022)	0.089 ** (0.018)	0.172 *** (0.023)	0.121 ** (0.019)	0.091 * (0.020)
EPP	0.134 *** (0.019)	0.096 ** (0.015)	0.145 *** (0.020)	0.083 ** (0.016)	0.153 *** (0.021)	0.103 ** (0.017)	0.073 * (0.018)
GI * CGPs	0.033 *** (0.005)	0.021 ** (0.006)	0.035 *** (0.006)	0.014 * (0.007)	0.037 *** (0.006)	0.019 * (0.008)	0.011 * (0.009)
GI * EPP	0.025 ** (0.007)	0.015 * (0.009)	0.028 ** (0.008)	0.011 * (0.010)	0.029 *** (0.008)	0.016 * (0.011)	0.008 (0.012)
LEV	−0.039 * (0.012)	−0.087 *** (0.013)	−0.051 * (0.014)	−0.075 *** (0.015)	−0.036 * (0.011)	−0.059 *** (0.013)	−0.074 *** (0.016)
Enterprise Size	0.665 *** (0.025)	0.503 *** (0.022)	0.534 *** (0.024)	0.489 *** (0.023)	0.675 *** (0.026)	0.527 *** (0.024)	0.435 *** (0.025)

Table 9. *Cont.*

VARIABLES	State-Owned Enterprises (SOEs)	Non-State-Owned Enterprises (NSOEs)	Manufacturing Firms	Non-Manufacturing Firms	Eastern Region	Mid-Region	Western Region
ROA	0.024 * (0.010)	0.017 (0.012)	0.023 * (0.011)	0.015 (0.013)	0.026 * (0.010)	0.019 (0.012)	0.012 (0.013)
TQR	0.055 *** (0.008)	0.036 ** (0.010)	0.063 *** (0.009)	0.033 ** (0.011)	0.068 *** (0.009)	0.041 ** (0.010)	0.025 * (0.012)
Tangibility	0.048 (0.012)	0.025 (0.014)	0.046 (0.013)	0.021 (0.015)	0.052 (0.012)	0.035 (0.014)	0.017 (0.015)
FCF	−0.121 (0.011)	−0.233 (0.019)	−0.131 (0.012)	−0.219 (0.020)	−0.111 (0.010)	−0.206 (0.018)	−0.242 (0.021)
KZ Index	−0.032 *** (0.006)	−0.044 *** (0.008)	−0.041 *** (0.007)	−0.038 *** (0.009)	−0.025 *** (0.005)	−0.033 *** (0.007)	−0.051 *** (0.009)
Political Stability	0.145 *** (0.018)	0.082 * (0.011)	0.108 * (0.015)	0.073 * (0.012)	0.157 *** (0.016)	0.089 * (0.013)	0.062 * (0.014)
HDI	0.431 ** (0.019)	0.312 * (0.018)	0.389 ** (0.020)	0.302 * (0.019)	0.468 ** (0.022)	0.336 * (0.019)	0.304 * (0.020)
lnGDP	0.115 *** (0.017)	0.091 ** (0.015)	0.118 *** (0.016)	0.084 ** (0.014)	0.129 *** (0.018)	0.097 ** (0.015)	0.075 * (0.016)
Constant	−11.512 *** (1.325)	−10.211 *** (1.452)	−11.922 *** (1.487)	−9.811 *** (1.390)	−11.892 *** (1.492)	−10.332 *** (1.389)	−9.732 *** (1.375)
Observations	1876	2150	2890	1136	2345	1221	460
Wald Test (Prob > Chi2)	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Note: This table presents firm-level heterogeneity analysis, showing that green innovation (GI) positively impacts corporate environmental performance (CEP) across ownership types, industries, and regions, with stronger effects in SOEs, manufacturing firms, and the eastern region. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

4.7. Robustness Check

Alternative Measures

The robustness check in Table 10 and quantile regression in Table 11 collectively validate the strong and consistent relationship between green innovation proxies (GI_Proxy) and corporate environmental performance (CEP). Results from Driscoll–Kraay standard errors and fixed effects confirm that alternative proxies for green innovation, governance quality (CGPs_Proxy), and regulatory pressure (EPP_Proxy) significantly improve CEP, even when accounting for cross-sectional dependence and time-invariant firm characteristics. Quantile regression adds depth by showing that these effects are heterogeneous across performance levels, with lower quantiles (Q25) reflecting meaningful but smaller impacts and higher quantiles (Q75 and Q95) exhibiting stronger positive effects. This indicates that green innovation, governance, and regulatory mechanisms become more impactful as firms achieve higher environmental performance. Control variables such as firm size and profitability positively contribute across models, while leverage shows minor negative effects, reflecting financial constraints. These findings robustly underscore the critical role of green innovation and governance in driving environmental performance across varying contexts and firm capabilities.

Table 10. Robustness check, Driscoll–Kraay standard error fixed effect, and quantile regression.

Variables	(1) Driscoll–Kraay SE	(2) Fixed Effect	(3) Quantile Q25	(4) Quantile Q50	(5) Quantile Q75	(6) Quantile Q95
Green innovation lagged	0.192 *** (0.031)	0.181 ** (0.034)	0.165 *** (0.039)	0.197 *** (0.033)	0.238 *** (0.022)	0.284 *** (0.019)
Governance quality proxy	0.124 ** (0.012)	0.116 ** (0.013)	0.109 ** (0.013)	0.121 ** (0.012)	0.129 ** (0.010)	0.138 ** (0.009)
Regulatory pressure proxy	0.101 ** (0.017)	0.093 ** (0.016)	0.089 ** (0.016)	0.104 ** (0.015)	0.115 ** (0.013)	0.125 ** (0.012)
Log Sales	0.578 *** (0.025)	0.563 *** (0.026)	0.534 *** (0.027)	0.578 *** (0.024)	0.621 *** (0.021)	0.658 *** (0.019)
Profitability	0.041 ** (0.009)	0.038 * (0.010)	0.038 * (0.010)	0.042 ** (0.008)	0.047 ** (0.007)	0.051 ** (0.006)
Composite index	0.329 *** (0.027)	0.317 *** (0.029)	0.307 ** (0.029)	0.319 *** (0.028)	0.334 *** (0.027)	0.345 *** (0.025)
Constant	3.102 *** (0.128)	2.852 *** (0.134)	2.521 *** (0.152)	2.812 *** (0.135)	3.145 *** (0.123)	3.481 *** (0.118)
Observations	4026	4026	4026	4026	4026	4026
F-test	0.000	0.000	0.000	0.000	0.000	0.000
R2	0.062	0.058	No	No	No	No

Note: table shows Discroll–Kraay standard error result under robustness to ensure the baseline results. The symbols in the table indicate statistical significance at different levels: * represents significance at the 10% level, ** indicates significance at the 5% level, and *** shows significance at the 1% level.

Table 11. Quantile regression via moments.

Variables	Q25	Q50	Q75	Q95
Green innovation lagged	0.152 *** (0.028)	0.193 *** (0.025)	0.238 *** (0.022)	0.281 *** (0.020)
Governance quality	0.108 ** (0.012)	0.117 ** (0.011)	0.129 ** (0.010)	0.141 ** (0.009)
Regulatory pressure	0.091 ** (0.016)	0.103 ** (0.014)	0.115 ** (0.013)	0.127 ** (0.012)
Log Sales	0.534 *** (0.027)	0.578 *** (0.024)	0.621 *** (0.021)	0.658 *** (0.019)
Profitability	0.038 * (0.010)	0.042 ** (0.008)	0.047 ** (0.007)	0.051 ** (0.006)
Composite index	0.307 ** (0.029)	0.319 *** (0.028)	0.334 *** (0.027)	0.351 *** (0.026)
Constant	2.435 *** (0.152)	2.812 *** (0.135)	3.145 *** (0.123)	3.472 *** (0.117)
Observations	4026	4026	4026	4026

Note: table shows quantile estimate phases for 25th, 50th, 75th, and 95th conditional distributions via moments. The symbols *, **, and *** in the table represent different levels of statistical significance. Specifically, * denotes significance at the 10% level, ** indicates significance at the 5% level, and *** reflects significance at the 1% level. These symbols are used to highlight the robustness of the results across various quantiles.

5. Discussion and Implications

5.1. Discussion

This study examines the impact of green innovation on corporate environmental performance (CEP), focusing on the moderating role of corporate governance practices (CGPs) and environmental policy pressure (EPP). Through an empirical analysis using propensity score matching (PSM), difference in differences (DID) with China's National Green Development Fund (2020) as the policy intervention, and the generalized method of moments (GMM), the findings provide meaningful insights into how green innovation affects environmental outcomes in the context of China's regulatory environment and corporate governance landscape.

This study confirms that green innovation has a significant positive impact on corporate environmental performance (CEP), supporting Hypothesis 1. This relationship is further moderated by governance practices, such as the board independence and executive compensation tied to sustainability goals, as hypothesized in H2. Additionally, environmental policy pressure amplifies the effectiveness of green innovation, aligning with Hypothesis 3. These findings provide evidence of the critical interplay between firm-level and external factors in driving sustainability outcomes.

The results suggest that green innovation has a significant positive effect on CEP, confirming previous research that links green innovation to improvements in firms' environmental sustainability metrics. The results highlight that green innovation efforts, such as the development of green technologies and processes, allow firms to mitigate environmental impacts while meeting stakeholder expectations for responsible and sustainable business practices. The moderation analysis shows that corporate governance practices positively moderate the relationship between green innovation and CEP. Firms with strong governance structures and policies that emphasize sustainability are better positioned to leverage green innovation and maximize its impact on environmental performance. This finding is consistent with the resource-based view (RBV) and stakeholder theory, which suggests that firms' internal resources and commitment to stakeholders play a critical role in shaping environmental outcomes. The findings align with the resource-based view, which suggests that firms with superior governance structures are better positioned to leverage green innovation for environmental gains. Governance mechanisms, such as independent boards, enhance oversight, ensuring that innovation strategies align with sustainability goals. The role of environmental policy pressure highlights the importance of external regulatory environments in shaping corporate behavior, consistent with institutional theory. However, the weaker moderating effect observed in industries with lower

policy enforcement suggests that internal governance factors alone may not suffice to drive substantial environmental improvements.

In addition, environmental policy pressure, as represented by China's National Green Development Fund, also strengthens the relationship between green innovation and CEP. The DID results indicate that firms subject to regulatory pressure tend to improve their environmental performance more than those without such pressure. This underscores the importance of regulatory frameworks in promoting sustainable practices, as firms adjust their environmental strategies to comply with or benefit from policy incentives. Overall, the combined effect of CGPs and EPP as moderators suggests that both internal governance and external regulatory pressures are essential for maximizing the effectiveness of green innovation on environmental outcomes. Together, these factors enable companies to achieve sustainable performance in line with the broader goals of the UN's 2030 Agenda for Sustainable Development, reinforcing the need for integrated approaches that consider both organizational and policy dimensions.

While this study focuses on the overall relationship between green innovation, governance practices, and corporate environmental performance, it does not delve into the spatial and regional variations present in the dataset. Differences in local policy implementation and enforcement intensity across regions may significantly influence these relationships. For instance, firms operating in regions with higher regulatory enforcement may experience greater pressure to adopt green innovation compared to those in less regulated areas. Future research could unpack these geographic effects to provide a more nuanced understanding of how regional policy contexts shape corporate sustainability outcomes. Such an approach would enhance the generalizability of the findings and offer valuable insights for region-specific policy and managerial strategies.

5.2. Implications

The findings have several important implications for both practitioners and policymakers.

Emphasis on green innovation: This study highlights the value of green innovation as a strategic asset for improving environmental performance. Companies should prioritize innovation initiatives that align with environmental goals, including the development of cleaner technologies and resource-efficient processes. Strengthening governance practices: To maximize the benefits of green innovation, companies need robust governance practices that emphasize sustainability and transparency. Effective governance structures help align green innovation initiatives with broader business goals and ensure consistent environmental performance. Preparing for regulatory pressures: Companies should anticipate and prepare for environmental regulations and policies, as compliance can enhance their ability to leverage green innovation. By aligning corporate strategies with regulatory requirements, companies can mitigate potential risks and capitalize on incentives.

Promoting policy incentives: This study confirms the effectiveness of environmental policies such as the National Green Development Fund in promoting green innovation. Policymakers should continue to develop incentives that encourage companies to adopt sustainable practices, such as subsidies for green technologies or tax benefits for companies that achieve high environmental standards. Focus on sustainable corporate governance: Policies that support sustainable corporate governance, such as disclosure requirements for environmental metrics or ESG compliance guidelines, could enhance the impact of green innovation. By fostering an environment that encourages responsible corporate governance, policymakers can indirectly improve the environmental performance of companies. Developing environmental standards and compliance measures: Policymakers should also consider establishing or improving environmental standards that set clear benchmarks for corporate environmental performance. Regulatory measures that reward or mandate green

innovation could encourage the more widespread adoption of sustainable practices, with positive spillover effects across industries.

Informed investment decisions: The results suggest that green innovation and effective governance can positively impact a company's environmental performance, which could be valuable to investors focused on sustainable and responsible investing. Investors may favor companies that demonstrate a commitment to green innovation and strong governance practices, as these companies are more likely to meet sustainability goals. Improved stakeholder engagement: This study's findings underscore the importance of transparent and sustainable business practices. Stakeholders, including customers, employees, and communities, are increasingly focused on a company's environmental performance. Companies that invest in green innovation and maintain strong governance standards are better positioned to build trust and foster loyalty among stakeholders.

These findings highlight actionable insights for both firms and policymakers. Firms should prioritize governance reforms, such as enhancing board independence and integrating sustainability metrics into executive compensation, to maximize the environmental benefits of green innovation. Policymakers, on the other hand, should consider strengthening environmental regulations and enforcement mechanisms to ensure uniform impacts across industries. This is particularly relevant for emerging markets, where regulatory gaps often hinder progress toward sustainability goals.

6. Conclusions

This study provides a comprehensive analysis of the impact of green innovation on corporate environmental performance (CEP), highlighting the significant role of corporate governance practices (CGPs) and environmental policy pressure (EPP) as moderating variables. Using a robust empirical framework, including propensity score matching (PSM), difference-in-differences (DID) analysis with China's National Green Development Fund (2020) as the policy intervention, and the generalized method of moments (GMM), this research addresses critical issues related to heteroscedasticity, autocorrelation, and endogeneity, which are common in panel data analysis. This study confirms that green innovation significantly improves corporate environmental performance (CEP), with governance practices and environmental policy pressure playing moderating roles. These findings provide robust evidence for the importance of aligning corporate governance structures and regulatory environments to achieve sustainability outcomes.

The findings of this study offer actionable insights for industries and regions beyond the studied context. In heavily polluting industries, firms globally should prioritize investments in green innovation, such as eco-friendly technologies, and integrate sustainability into their governance frameworks. For regions with less stringent environmental policies, governments can create incentives, such as subsidies or tax breaks, to encourage firms to adopt sustainable practices. Emerging markets with growing regulatory environments, such as India or Brazil, can learn from China's experience by aligning policy enforcement with corporate innovation strategies. Similarly, developed economies can leverage these insights to refine governance practices and sustain long-term environmental performance improvements.

The results confirm that green innovations have a positive impact on CEP, demonstrating that firms that adopt green innovations not only reduce their environmental footprint but also respond effectively to increasing stakeholder expectations for sustainable practices. The results also show that corporate governance practices reinforce the positive impact of green innovation on environmental performance. Companies with strong governance mechanisms that emphasize sustainability, transparency, and accountability are better positioned to leverage green innovation to achieve significant environmental benefits.

This is consistent with the resource-based view (RBV) and stakeholder theory, both of which emphasize the importance of internal resources and stakeholder alignment in achieving sustainable outcomes. Practically, firms should focus on strengthening governance mechanisms, while policymakers should enhance regulatory enforcement to incentivize green innovation.

Moreover, this study highlights that environmental policy pressure further enhances the effectiveness of green innovation in improving CEP. The DID analysis shows that firms exposed to the regulatory incentives provided by China's National Green Development Fund (2020) show a greater improvement in CEP than firms not exposed to the policy. This finding underscores the critical role of regulatory frameworks in promoting green innovation and aligning firm behavior with environmental sustainability goals. Overall, this study contributes to the growing literature on sustainable business practices by illustrating how green innovation, coupled with sound corporate governance and supportive environmental policies, can lead to significant improvements in environmental performance. These findings are particularly relevant in the context of China, a rapidly industrializing economy facing increasing environmental pressures and an evolving regulatory landscape.

This study opens several avenues for future research. First, further investigation of the long-term impact of green innovation on financial performance, in addition to environmental outcomes, could provide a more complete understanding of its strategic value. In addition, exploring other external moderating factors, such as market competition or consumer preferences, may provide a deeper insight into how external pressures shape the relationship between green innovation and financial performance. Finally, applying this research framework across different industries and geographical regions could enhance the generalizability of the findings and support global efforts to achieve sustainable development goals. While this study focuses on Chinese listed firms in heavily polluting industries, future research should examine cross-industry and cross-regional comparisons to generalize these findings. Moreover, alternative measures of green innovation, beyond patents, could provide a more comprehensive understanding of its impact. In conclusion, this study highlights the importance of an integrated approach that combines green innovation, strong corporate governance, and supportive policy frameworks. By adopting such an approach, companies can effectively contribute to environmental sustainability while creating long-term value for their stakeholders and aligning with the global 2030 Sustainable Development Agenda.

Author Contributions: Conceptualization, F.B. and M.M.; methodology, F.B. and M.M.; software, F.B.; data curation, F.B.; writing—original draft preparation, F.B.; writing—review and editing, F.B., M.M. and B.M.A.; visualization, F.B., M.M. and B.M.A.; supervision, M.M. and B.M.A. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: No Applicable.

Informed Consent Statement: No Applicable.

Data Availability Statement: The datasets utilized and analyzed during the current study are available from the corresponding author upon reasonable request.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A. First-Stage Regression Result PSM

Variable	CEP
Green Innovation (GI)	0.243 *** (0.035)
Corporate Governance Practices (CGPs)	0.315 *** (0.065)
Environmental Policy Pressure (EPP)	0.271 *** (0.073)
Leverage (LEV)	−0.082 ** (0.041)
Enterprise Size	0.054 (0.029)
Return on Assets (ROA)	0.189 ** (0.067)
Tobin's Q Ratio (TQR)	0.141 ** (0.055)
Tangibility	−0.093 ** (0.034)
Free Cash Flow (FCF)	−0.058 (0.028)
KZ Index	0.221 *** (0.045)
Political Stability	0.076 ** (0.018)
Human Development Index (HDI)	0.132 ** (0.056)
ln(GDP)	0.158 *** (0.039)
Constant	−1.203 *** (0.112)
Observations	4026
Pseudo-Squared	0.487

Note: Column reports the outcome of the first-stage logit model against firm characteristics. Standard errors are in parentheses. The asterisks in the table indicate statistical significance at different levels. Specifically, two asterisks (**) signify significance at the 5% level ($p < 0.05$), and three asterisks (***) represent significance at the 1% level ($p < 0.01$). These significance levels help to highlight the strength of the relationships between firm characteristics and the outcome variable in the model.

Appendix B. Conditional Independence Assumption (CIA)—Mean *t*-Test

Variable	Treated Mean	Control Mean	% Bias	t	$p > t$	V(T)/V(C)
Corporate Governance Practices (CGPs)	0.405	0.39	7.003	1.908	0.048	1.002
Environmental Policy Pressure (EPP)	0.503	0.407	6.02	1.850	0.064	0.098
Leverage (LEV)	0.208	0.300	−5.500	−1.520	0.129	1.005
Enterprise Size	22.034	22.001	9.200	2.340	0.019	1.001
Return on Assets (ROA)	0.012	0.100	8.000	2.010	0.045	1.003
Tobin's Q Ratio (TQR)	1.015	1.120	4.006	1.170	0.242	1.000
Tangibility	0.045	0.460	−3.002	−0.098	0.326	0.099
Free Cash Flow (FCF)	0.008	0.007	5.001	1.056	0.118	1.004
KZ Index	3.025	3.030	−2.500	−0.089	0.374	1.006
Political Stability	0.075	0.072	4.000	1.022	0.222	0.097
Human Development Index (HDI)	0.608	0.606	6.100	1.708	0.075	1.002
ln(GDP)	15.200	15.150	3.500	1.100	0.270	1.000

Note: CIA validates the implementation of PSM.

Appendix C. Treated and Control Group After PSM

Group	Observations Before PSM	Observations After PSM (with Common Support)	Total
Treated	1200	1050	1050
Control	2800	1750	1750
Total	4000	2800	2800

References

1. Davis, C.H. The earth summit and the promotion of environmentally sound industrial innovation in developing countries. *Knowl. Policy* **1995**, *8*, 26–52. [CrossRef]
2. Sun, X.; Dong, Y.; Wang, Y.; Ren, J. Sources of greenhouse gas emission reductions in OECD countries: Composition or technique effects. *Ecol. Econ.* **2022**, *193*, 107288. [CrossRef]
3. Song, W.; Yu, H. Green innovation strategy and green innovation: The roles of green creativity and green organizational identity. *Corp. Soc. Responsib. Environ. Manag.* **2018**, *25*, 135–150. [CrossRef]
4. Begum, S.; Ashfaq, M.; Xia, E.; Awan, U. Does green transformational leadership lead to green innovation? The role of green thinking and creative process engagement. *Bus. Strategy Environ.* **2022**, *31*, 580–597. [CrossRef]
5. Shahzad, K.; Shah, S.Q.A.; Lai, F.-W.; Jan, A.A.; Shah, S.A.A.; Shad, M.K. Exploring the nexus of corporate governance and intellectual capital efficiency: From the lens of profitability. *Qual. Quant.* **2023**, *57*, 2447–2468. [CrossRef]
6. Batool, F.; Mohsin, M. Impact of Green Innovation on Business Sustainability of Firms and the Mediating Role of Green Intellectual Capital. *Educ. Adm. Theory Pract.* **2024**, *30*. [CrossRef]
7. Cui, X.; Wang, C.; Sensoy, A.; Liao, J.; Xie, X. Economic policy uncertainty and green innovation: Evidence from China. *Econ. Model.* **2023**, *118*, 106104. [CrossRef]
8. Fang, Z.; Kong, X.; Sensoy, A.; Cui, X.; Cheng, F. Government's awareness of Environmental protection and corporate greinnovation: A natural experiment from the new environmental protection law in China. *Econ. Anal. Policy* **2021**, *70*, 294–312. [CrossRef]
9. Heinkel, R.; Kraus, A.; Zechner, J. The Effect of Green Investment on Corporate Behavior. *J. Financ. Quant. Anal.* **2001**, *36*, 431–449. [CrossRef]
10. Halisçelik, E.; Soytas, M.A. Sustainable development from millennium 2015 to Sustainable Development Goals 2030. *Sustain. Dev.* **2019**, *27*, 545–572. [CrossRef]
11. Hörisch, J.; Freeman, R.E.; Schaltegger, S. Applying stakeholder theory in sustainability management: Links, similarities, dissimilarities, and a conceptual framework. *Organ. Environ.* **2014**, *27*, 328–346. [CrossRef]
12. Kraus, S.; Rehman, S.U.; García, F.J.S. Corporate social responsibility and environmental performance: The mediating role of environmental strategy and green innovation. *Technol. Forecast. Soc. Change* **2020**, *160*, 120262. [CrossRef]
13. Xie, X.; Hoang, T.T.; Zhu, Q. Green process innovation and financial performance: The role of green social capital and customers' tacit green needs. *J. Innov. Knowl.* **2022**, *7*, 100165. [CrossRef]
14. Mohsin, M.; Rovetta, S.; Masulli, F.; Cabri, A. Real-Time Detection of Electronic Components in Waste Printed Circuit Boards: A Transformer-Based Approach. *arXiv* **2024**, arXiv:2409.16496.
15. Zhang, Y.; Sun, J.; Yang, Z.; Wang, Y. Critical success factors of green innovation: Technology, organization and environment readiness. *J. Clean. Prod.* **2020**, *264*, 121701. [CrossRef]
16. Du, K.; Li, J. Towards a green world: How do green technology innovations affect total-factor carbon productivity. *Energy Policy* **2019**, *131*, 240–250. [CrossRef]
17. Ait Sidhoum, A.; Serra, T. Corporate Sustainable Development. Revisiting the Relationship between Corporate Social Responsibility Dimensions. *Sustain. Dev.* **2018**, *26*, 365–378. [CrossRef]
18. Takalo, S.K.; Tooranloo, H.S. Green innovation: A systematic literature review. *J. Clean. Prod.* **2021**, *279*, 122474. [CrossRef]
19. Mohsin, M.; Zeng, X.; Rovetta, S.; Masulli, F. Measuring the recyclability of electronic components to assist automatic disassembly and sorting waste printed circuit boards. In Proceedings of the 19th International Conference on Waste Management and Technology, Beijing, China, 18–20 May 2024; Volume 15, pp. 325–341. Available online: https://www.bcrc.cn/icwmt-eng/atm/7/20240814170641676.pdf (accessed on 23 January 2025).
20. Wahyuni, N.I.; Dino, N.V.G. Determinant of the Sustainable Growth Rate. 2016. Available online: http://repository.unej.ac.id/handle/123456789/79079 (accessed on 15 October 2024).
21. Xu, X.L.; Sun, C.; Li, Y.; Zhou, N. The effects of environmental management and debt financing on sustainable financial growth in the tourism industry. *SAGE Open* **2020**, *10*, 2158244020948530. [CrossRef]
22. Mohsin, M.; Masulli, F.; Rovetta, S.; Cabri, A. Virtual Mines—Component-level recycling of printed circuit boards using deep learning Authors. In Proceedings of the 2023 the Italian Workshop on Neural Networks (WIRN), Vietri Sul Mare, Italy, 7–9 June 2023.
23. Hart, S.L.; Milstein, M.B. Creating sustainable value. *Acad. Manag. Perspect.* **2003**, *17*, 56–67. [CrossRef]

24. Higgins, R.C. *Analysis for Financial Management*; McGraw-Hill: New York, NY, USA, 2016.
25. Khan, P.A.; Johl, S.K. Firm performance from the lens of comprehensive green innovation and environmental management system ISO. *Processes* **2020**, *8*, 1152.
26. Xiang, X.; Liu, C.; Yang, M. Who is financing corporate green innovation? *Int. Rev. Econ. Financ.* **2022**, *78*, 321–337. [CrossRef]
27. Ahmad, A. Business intelligence for sustainable competitive advantage. In *Sustaining Competitive Advantage via Business Intelligence, Knowledge Management, and System Dynamics*; Emerald Group Publishing Limited: Leeds, UK, 2015; pp. 3–220.
28. Stubbs, W.; Cocklin, C. Conceptualizing a "sustainability business model". *Organ. Environ.* **2008**, *21*, 103–127. [CrossRef]
29. Barney, J. Firm resources and sustained competitive advantage. *J. Manag.* **1991**, *17*, 99–120. [CrossRef]
30. Freeman, R.E.; Evan, W.M. Corporate governance: A stakeholder interpretation. *J. Behav. Econ.* **1990**, *19*, 337–359. [CrossRef]
31. Eiadat, Y.; Kelly, A.; Roche, F.; Eyadat, H. Green and competitive? An empirical test of the mediating role of environmental innovation strategy. *J. World Bus.* **2008**, *43*, 131–145. [CrossRef]
32. Porter, M.E.; Linde, C.v.d. Toward a new conception of the environment-competitiveness relationship. *J. Econ. Perspect.* **1995**, *9*, 97–118. [CrossRef]
33. Adams, R.B.; De Haan, J.; Terjesen, S.; Van Ees, H. Board diversity: Moving the field forward. *Corp. Gov. Int. Rev.* **2015**, *23*, 77–82. [CrossRef]
34. Post, C.; Rahman, N.; Rubow, E. Green governance: Boards of directors' composition and environmental corporate social responsibility. *Bus. Soc.* **2011**, *50*, 189–223. [CrossRef]
35. Eccles, R.G.; Lee, L.-E.; Stroehle, J.C. The social origins of ESG: An analysis of Innovest and KLD. *Organ. Environ.* **2020**, *33*, 575–596. [CrossRef]
36. Marsat, S.; Pijourlet, G.; Ullah, M. Does environmental performance help firms to be more resilient against environmental controversies? International evidence. *Financ. Res. Lett.* **2022**, *44*, 102028. [CrossRef]
37. Brown, L.D.; Caylor, M.L. Corporate governance and firm operating performance. *Rev. Quant. Financ. Account.* **2009**, *32*, 129–144. [CrossRef]
38. Leal-Millán, A.; Leal-Rodríguez, A.L.; Albort-Morant, G. Green innovation. In *Encyclopedia of Creativity, Invention, Innovation and Entrepreneurship*; Springer: Berlin/Heidelberg, Germany, 2020; pp. 1082–1089.
39. Core, J.E.; Holthausen, R.W.; Larcker, D.F. Corporate governance, chief executive officer compensation, and firm performance. *J. Financ. Econ.* **1999**, *51*, 371–406. [CrossRef]
40. Core, J.; Guay, W. The use of equity grants to manage optimal equity incentive levels. *J. Account. Econ.* **1999**, *28*, 151–184. [CrossRef]
41. Rahman, A.; Farrok, O.; Haque, M.M. Environmental impact of renewable energy source based electrical power plants: Solar, wind, hydroelectric, biomass, geothermal, tidal, ocean, and osmotic. *Renew. Sustain. Energy Rev.* **2022**, *161*, 112279. [CrossRef]
42. Chen, W.; Arn, G.; Song, H.; Xie, Y. The influences of digital finance on green technological innovation in China's manufacturing sector: The threshold effects of ESG performance. *J. Clean. Prod.* **2024**, *467*, 142953. [CrossRef]
43. Bagh, T.; Fuwei, J.; Khan, M.A. Corporate ESG investments and Firm's value under the real-option framework: Evidence from two world-leading economies. *Borsa Istanb. Rev.* **2024**, *24*, 324–340. [CrossRef]
44. Da Fonseca, L.M.C.M. ISO 14001: 2015: An improved tool for sustainability. *J. Ind. Eng. Manag.* **2015**, *8*, 37–50.
45. Hsu, A.; Zomer, A. Environmental performance index. In *Wiley StatsRef: Statistics Reference Online*; John Wiley & Sons, Ltd.: Hoboken, NJ, USA, 2014; pp. 1–5.
46. Amore, M.D.; Bennedsen, M. Corporate governance and green innovation. *J. Environ. Econ. Manag.* **2016**, *75*, 54–72. [CrossRef]
47. Fang, G.; Gao, Z.; Wang, L.; Tian, L. How does green innovation drive urban carbon emission efficiency?—Evidence from the Yangtze River Economic Belt. *J. Clean. Prod.* **2022**, *375*, 134196. [CrossRef]
48. Aydoğmuş, M.; Gülay, G.; Ergun, K. Impact of ESG performance on firm value and profitability. *Borsa Istanb. Rev.* **2022**, *22*, S119–S127. [CrossRef]
49. Qin, L.; Kirikkaleli, D.; Hou, Y.; Miao, X.; Tufail, M. Carbon neutrality target for G7 economies: Examining the role of environmental policy, green innovation and composite risk index. *J. Environ. Manag.* **2021**, *295*, 113119. [CrossRef] [PubMed]
50. Wang, N.; Zhang, S.J.; Wang, W. Impact of environmental innovation strategy on green competitiveness: Evidence from China. *Int. J. Environ. Res. Public Health* **2022**, *19*, 5879. [CrossRef] [PubMed]
51. Egbunike, C.F.; Okerekeoti, C.U. Macroeconomic factors, firm characteristics and financial performance: A study of selected quoted manufacturing firms in Nigeria. *Asian J. Account. Res.* **2018**, *3*, 142–168. [CrossRef]
52. Duque-Grisales, E.; Aguilera-Caracuel, J.; Guerrero-Villegas, J.; García-Sánchez, E. Does green innovation affect the financial performance of Multilatinas? The moderating role of ISO 14001 and R&D investment. *Bus. Strategy Environ.* **2020**, *29*, 3286–3302.
53. Grewatsch, S.; Kleindienst, I. When does it pay to be good? Moderators and mediators in the corporate sustainability–corporate financial performance relationship: A critical review. *J. Bus. Ethics* **2017**, *145*, 383–416. [CrossRef]
54. Przychodzen, W.; Leyva-de la Hiz, D.I.; Przychodzen, J. First-mover advantages in green innovation—Opportunities and threats for financial performance: A longitudinal analysis. *Corp. Soc. Responsib. Environ. Manag.* **2020**, *27*, 339–357. [CrossRef]

55. Aastvedt, T.M.; Behmiri, N.B.; Lu, L. Does green innovation damage financial performance of oil and gas companies? *Resour. Policy* **2021**, *73*, 102235. [CrossRef]
56. Lee, K.-H.; Min, B. Green R&D for eco-innovation and its impact on carbon emissions and firm performance. *J. Clean. Prod.* **2015**, *108*, 534–542.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.