Eco-Transformations: The Real Impact of Green Bond Issuance on Environment

Abstract

We examine whether corporate green bond issuance improves firm-level environmental performance. Using a global sample of listed firms (2013-2022) and a staggered difference-in-differences design, we compare issuers to matched non-issuers using direct environmental metrics: waste, water pollutants, and composite emissions intensity (CEI). We find significant reductions in all three measures post-issuance, with effects strengthening over time. These improvements are facilitated by increased environmental innovation and are more pronounced among firms with weaker governance and in countries with less stringent regulation. Our results suggest green bonds can generate real environmental benefits, particularly where institutional monitoring is otherwise lacking.

Keywords: Green bond issuance, waste reduction, water pollutant, air pollutant emissions, sustainable finance, corporate environmental performance

JEL classification: G32, Q52, Q54, M14, G12, M44

1. Introduction

Green bonds have rapidly emerged as a key instrument to mobilise capital for environmentally sustainable projects, yet a fundamental question remains: Do green bond issuances lead to real environmental impact? Prior research has established that firms issuing green bonds often enjoy financial benefits, for example, lower debt financing costs due to strong investor demand and positive stock market reactions, attributed to strong investor demand for sustainable assets (Flammer, 2021; Tang & Zhang, 2020; Zerbib, 2019). There is also evidence of *indirect* environmental gains. Studies find that green bond issuance is associated with improved sustainability disclosure, higher environmental ratings, and reputational enhancement (Flammer, 2021; Liesen et al., 2016).

However, these measures are often proxies (ESG scores or disclosure levels) rather than objective environmental performance metrics. This reliance on proxies raises concerns about greenwashing, as some firms might issue green bonds to bolster their sustainable image without implementing substantial operational changes (Flammer, 2021). While this body of work illuminates signalling and commitment effects, the actual environmental impact of the capital raised remains insufficiently documented. To date, the only study that systematically investigates direct environmental outcomes is ElBannan and Löffler (2024), who document a reduction in carbon intensity following green bond issuance. This pivotal finding leaves open a critical research gap: whether green bond financing translates into measurable improvements across other key dimensions of corporate environmental performance, such as waste and water pollution.

To address this gap, we examine the relationship between green bond issuance and *direct*, firm-level environmental outcomes. Using three key performance indicators, waste

generation, water pollutant discharges, and composite emissions intensity (CEI)[1], we test whether issuance is associated with measurable reductions in pollution. Our empirical strategy employs a staggered difference-in-differences (DID) design, applied to a global panel of publicly listed firms from 2013 to 2023, where green bond issuers are matched with comparable non-issuers. A dynamic event-study analysis supports the parallel trends assumption, revealing no significant pre-treatment deteriorations in environmental performance.

We document that significant environmental improvements follow issuance and intensify over time. Reductions in waste, water pollutants, and CEI are modest in the initial year but grow substantially in subsequent years. This pattern indicates that the environmental impact of green bond-financed projects is cumulative, consistent with the view that building substantive environmental capabilities requires sustained investment and implementation (Hart, 1995; Klassen & Whybark, 1999).

While the staggered DID strategy with firm and year fixed effects controls for time-invariant firm characteristics and common shocks, endogeneity concerns may persist if time-varying unobservable influences both the decision to issue and environmental performance (Roberts & Whited, 2013). For instance, firms with unobserved pro-environmental tendencies might choose to issue green bond issuance.

To address this, we pursue an instrumental variable (IV) approach. The primary instrument is the industry-level average green bond issuance volume (at the four-digit SIC level), excluding the focal firm. This captures peer effects and common industry shocks that influence a firm's financing decisions but are plausibly exogenous to its internal pollution

[1] A composite measure of key atmospheric emissions, comprising (a) total carbon dioxide (CO_2) emissions, (b) nitrogen oxide (NOx) emissions, and (c) sulphur oxide (SOx) emissions. The measure follows relevant international reporting protocols and is scaled by firm revenue to control for size.

abatement efficiency. The intuition is that firms emulate the financing strategies of their peers due to competitive, regulatory, and investor pressures (Leary & Roberts, 2014). High peer issuance significantly increases a firm's likelihood of issuing a green bond (relevance), while being unlikely to directly affect its operational environmental outcomes (exclusion restriction).

Diagnostic tests confirm the instrument's strength: first-stage F-statistics substantially exceed the Stock and Yogo (2005) critical threshold of 10, rejecting weak instruments. Over-identification tests support the validity of the exclusion restriction. By integrating this IV strategy with the staggered DID design and event-study, this study provides credible empirical evidence on the link between green bond financing and environmental performance.

In addition, mediation tests explore how green bonds translate into impact. Evidence points to increased eco-innovation as a key channel; after issuance, firms boost investments in environmental R&D and green technologies, which in turn reduce waste and emissions (Flammer, 2021; Porter & van der Linde, 1995). We also observe an increase in long-term institutional ownership, consistent with green bonds attracting sustainability-focused investors who enhance governance and oversight (Dyck et al., 2019). These findings suggest green bonds act as both a capital source and a commitment device that catalyses innovation and attracts responsible capital

Furthermore, this study examines cross-sectional heterogeneity to determine when and where the environmental benefits of green bonds are most pronounced. The improvements are greater for firms with higher ex ante environmental risk and in jurisdictions with less stringent environmental regulations. For example, issuers with historically poor ESG profiles see substantial post-issuance reductions, and firms in countries

with weaker environmental governance derive more benefit than those in stringent regulatory environments. These patterns align with the intuition that green bonds have the most significant impact where external enforcement is weaker. In such settings, green bond commitments can fill an "institutional void," prompting substantive actions that might otherwise be neglected (Marquis & Qian, 2014). By contrast, where strong sustainability mandates already exist, the marginal effect of a green bond is smaller, as many environmental initiatives may already be underway. This granular evidence enriches our understanding of green bond effectiveness, highlighting that context is critical for realising their full environmental potential

This study makes several contributions to the sustainable finance literature. First, it provides comprehensive, global evidence that green bond issuance leads to real improvements in environmental performance, using direct measures of corporate outcomes (waste, water pollutants, and CEI). This work extends prior studies that relied on proxy metrics (Flammer, 2021) or focused on a single environmental dimension (ElBannan & Löffler, 2024), addressing a critical gap in assessing green bonds' real impact.

Second, the study sheds light on the mechanisms behind these effects. Evidence indicates that green bond proceeds are channelled into environmental innovation (Porter & van der Linde, 1995) and attract greater oversight from sustainability-minded institutional investors (Dyck et al., 2019), which together help drive reductions in waste and emissions. These prior studies had not explicitly quantified these firm-level mediation channels, so our findings provide a new explanation for the pathway from financing to environmental improvement.

Third, the study contributes new insights into the contextual heterogeneity of green bond impacts. The benefits are most pronounced for firms in high-pollution or high-risk

categories (Battiston et al., 2021) and in environments where regulatory or market pressures for sustainability are relatively weak (El Ghoul et al., 2011). This nuanced result underscores that the effectiveness of sustainable finance instruments depends critically on institutional and firm-level conditions.

Finally, this study moves beyond the prior focus on financial or ESG indicators by *directly* examining actual environmental performance metrics (Berg et al., 2022). In doing so, it responds to calls to verify whether green bonds fulfil their stated environmental purpose. By employing a robust identification strategy, combining dynamic panel methods, event studies, and an IV approach, this study provides credible empirical evidence that green bonds induce real environmental benefits. The findings suggest that channelling capital through green bonds can drive environmental progress, especially when coupled with transparency to ensure accountability.

The remainder of this paper is structured as follows. Section 2 reviews the existing literature on green bond issuance and environmental performance. Section 3 presents the hypothesis development. Section 4 describes the data sources, model specifications, and variable definitions. Section 5 reports the empirical findings, while Section 6 explores endogeneity tests. Section 7 reports the robustness tests, and Section 8 concludes the study.

2. Literature Review

The global push for sustainable finance has driven a rapid expansion in green bond issuance (CBI, 2023). Green bonds are debt instruments designed to fund projects with positive environmental benefits, channelling capital into renewable energy, pollution reduction, and sustainable infrastructure (ICMA, 2021). Since the formalization of the Green Bond Principles, the market has grown substantially, reflecting high confidence in their role in financing a low-carbon transition (CBI, 2023). This growth raises a fundamental question: ***Do***

green bonds actually achieve their intended environmental objectives? Given their explicit sustainability mandate, it is crucial to examine whether they deliver measurable environmental improvements or merely serve as financial labels.

A substantial literature documents the financial advantages of green bond issuance. Firms benefit from lower borrowing costs due to high investor demand and a "greenium", a yield premium for environmental credentials (Ehlers et al., 2022; Flammer, 2021; Zerbib, 2019). Green bonds also enhance market credibility, leading to positive stock market reactions (Tang & Zhang, 2020).

Beyond financial gains, green bond issuance is linked to improvements in firms' ESG performance and reputation. Issuers experience increases in environmental ratings and sustainability disclosure (Flammer, 2021; Liesen et al., 2016), which can lower the cost of capital by signalling commitment (Zhang et al., 2021). However, a key limitation of this stream of research is its reliance on indirect, self-reported metrics such as ESG scores and disclosure levels. These proxies are not reliable indicators of real environmental impact, as firms may improve ratings without changing underlying operations, raising concerns about greenwashing (Berg et al., 2022; Flammer, 2021).

This reliance on proxies reveals a significant contradiction in the literature: green bonds are marketed as tools for environmental progress, yet empirical research has overwhelmingly focused on their financial and reputational outcomes rather than their actual environmental effectiveness. This oversight is particularly striking given the instrument's foundational purpose. While the financial benefits are well-documented, they do not confirm that the raised capital translates into measurable environmental benefits.

The need to move beyond proxies is underscored by research highlighting the divergence and potential noise in aggregate ESG metrics (Berg et al., 2022). To date, only

one study has systematically investigated direct environmental outcomes, ElBannan and Löffler (2024) find that green bond issuance is associated with reduced carbon intensity. Their work is pivotal but leaves a critical gap: whether green bonds similarly affect other key dimensions of environmental performance, such as waste and water pollution, which are seldom addressed. This study aims to address that gap.

A growing concern is that the assumed environmental benefits of green bonds may not always materialise. While some studies suggest that green bonds encourage firms to allocate more capital towards sustainability projects (Flammer, 2021; Sangiorgi & Schopohl, 2023), there is limited evidence confirming whether these investments lead to actual reductions in pollution, waste, or CEI. The assumption that green bonds inherently contribute to environmental progress remains largely untested.

A fundamental challenge in evaluating effectiveness is the reliance on self-reported ESG scores and sustainability disclosures. While widely used in research (Friede et al., 2015), these metrics are not reliable indicators of real environmental impact. Research shows that ESG ratings suffer from significant divergence and measurement noise, limiting their validity for assessing actual corporate environmental performance (Berg et al., 2022; Christensen et al., 2022). Furthermore, firms may engage in greenwashing by strategically enhancing disclosures or ratings to attract sustainable capital without implementing substantive operational changes (Flammer, 2021).

Consequently, empirical research on the direct environmental impact of green bonds remains scarce. A notable exception is ElBannan and Löffler (2024), who find that green bond issuance is associated with reduced carbon intensity in all three scopes. While pivotal, this study focuses on a single dimension (CO_2) of a firm's environmental footprint. A comprehensive assessment requires examining broader environmental performance, which

includes other polluting gases (IPCC, 2022). as well as critical areas like waste generation and water pollution that are seldom addressed in green bond assessments.

Given these limitations, an evaluation using actual environmental outcome metrics is critically needed. This study addresses that gap by investigating whether firms that issue green bonds subsequently reduce waste production, improve pollution management, and lower overall composite gas emissions. By moving beyond financial metrics and ESG proxies to examine changes in firms' environmental footprints, this study provides direct empirical evidence on the effectiveness of green bonds as a tool for environmental progress.

3. Hypotheses Development

Drawing on the literature, this study posits that green bond issuance, by providing earmarked capital and creating a commitment mechanism, will lead to real improvements in issuing firms' environmental performance. We focus on three critical and tangible dimensions firms can influence through targeted investments: waste generation, water pollution, and CEI. This leads to the following directional hypotheses:

Hypothesis 1. Firms that issue green bonds may generate less waste production than firms that do not issue green bonds.

Hypothesis 2. Firms that issue green bonds may release lower levels of water pollutants than firms that do not issue green bonds.

Hypothesis 3. Firms that issue green bonds may produce lower CEI than firms that do not issue green bonds.

These hypotheses are grounded in two key theoretical perspectives. First, the resource-based view suggests that dedicated financial resources (green bond proceeds) can be invested to build unique capabilities in pollution prevention and resource efficiency, leading

to improved environmental performance (Hart, 1995; Russo & Fouts, 1997). Second, green bonds act as a credible signalling and commitment device to stakeholders, which can align manager incentives with long-term environmental goals and attract oversight from sustainability-focused investors (Flammer, 2021).

It is important to acknowledge the potential for null or adverse outcomes, which underscores the empirical nature of this investigation. The primary risk is greenwashing, where bonds are issued for reputation without substantive change, leading to no environmental improvement (Flammer, 2021). Ineffective governance or poor capital allocation could further dampen or negate positive effects. This study's empirical design aims to test whether, on average, the positive effects dominate.

The framework developed here examines green bonds as a strategic tool for corporate environmental management. The following sections detail the data and methods to test these hypotheses.

4. Data, Models, and Variables

4.1. Data

Our sample construction begins with all corporate green bond issuances by publicly listed firms recorded in Refinitiv Eikon (now LSEG Workspace) between 2013 and 2022. Following the literature on the real effects of corporate green financing (e.g., Flammer, 2021), we exclude financial firms (SIC codes 6000-6999). The proceeds of green bonds issued by financial institutions primarily fund external projects, severing the direct link to the issuer's own operational environmental footprint required for our tests. This yields a final sample of 1,014 unique non-financial corporate issuers.

We obtain firm-level environmental performance data from Refinitiv, which provides standardized, annual metrics. Our analysis focuses on three direct outcome variables: Waste

Intensity (total waste generated), Water Pollution Intensity (total water pollutants discharged), and Composite Emissions Intensity (CEI). All financial statement data and firm characteristics are also sourced from Refinitiv. Country-level macroeconomic and institutional control data are obtained from standard public sources: the Environmental Policy Stringency Index from the OECD, the Economic Policy Uncertainty Index (Baker et al., 2016), and GDP per capita growth from the World Bank. The final dataset is an unbalanced panel comprising 2,683 bond issuances by the 1,014 sample firms across 34 countries. Appendix A presents the sample selection criterion and Appendix B and C detail the geographic and temporal distribution of the sample.

4.2. Model and Variables

4.2.1. Empirical Model

To test the hypotheses, the study employs multiple regression models tailored to each dependent variable. The general form of the regression model is specified as follows:

$$WAS_{i,t+1}/WATPOL_{i,t+1}/CEI_{i,t+1} = \delta_0 + \delta_1 GBI_{it} + \delta_{ji} I_{jit} + \gamma_{ji} M_{jit} + \sum Firm + \sum Year + \varepsilon_{it} \quad (1)$$

where the environmental performance metrics $WAS_{i,t+1}/WATP_{i,t+1}/\ GHG_{i,t+1}$ refer to waste production, water pollutant and CEI, respectively, for firm *i* in year *t+1*. GBI_{it} is a binary indicator for green bond issuance. while I_{jit} and M_{jit} represent vectors of firm-level and macroeconomic control variables. Firm and year fixed effects are included to account for unobserved heterogeneity and common temporal shocks.

4.2.2. Variable Definitions and Measurement

1. Dependent Variables: Environmental Outcomes

All environmental metrics are scaled by firm sales (in million USD) to control for firm size and activity level, a standard normalization in environmental performance research (King & Lenox, 2001). Waste production is measured as total waste generated in thousand tonnes per million USD of sales. Water pollutant discharge is the total weight of water pollutants emitted, expressed in thousand tonnes per million USD of sales. CEI represent total composite emissions expressed in CO_2 in all three scopes plus nitrogen and sulphur emissions, measured in thousand metric tons per million USD of sales.

2. Independent Variable: Green Bond Issuance

The key independent variable, $GBI_{i,t}$, is a binary indicator set to one for all firm-years following (and including) the year of a firm's inaugural green bond issuance. This "post-treatment" coding is standard in staggered DiD designs to capture the sustained effect of obtaining green financing.

3. Control Variables

We include a standard set of time-varying firm characteristics that may influence both financing decisions and environmental performance. Firm size is measured as the natural logarithm of total assets. Profitability is return on assets (ROA), calculated as net income divided by total assets. Leverage is the ratio of total debt to total assets. The market-to-book ratio is included to capture growth expectations and is calculated as the market value of equity plus book value of debt, divided by total assets. Cash flow volatility, included to control for investment capacity stability, is the standard deviation of operating cash flow over total assets over the prior three years. To account for a firm's underlying sustainability commitment, we include an ESG score constructed from principal component analysis (PCA) of Refinitiv's Environmental, Social, and Governance pillar scores.

To account for the external operating and regulatory environment, we incorporate several country-level controls. As defined in Section 4.1, these include the Environmental Policy Stringency Index, the Economic Policy Uncertainty Index, and GDP per capita growth.

4.2.1.4. Fixed Effects

The inclusion of firm (α_i) and year (δ_t) fixed effects is critical to our identification strategy. Firm effects control for all time-invariant firm-specific omitted variables, while year effects account for aggregate shocks common to all firms in a given year. All variable definitions and measurement details are provided in Appendix D.

5. Empirical Results

5.1. Summary Statistics

Table 1 presents descriptive statistics for all variables used in the analysis. All continuous variables are winsorized at the 1st and 99th percentiles to mitigate the influence of outliers.

Panel A reports the environmental outcome variables. The mean (median) waste production is 0.819 (0.720) thousand tonnes per million USD of sales. Water pollutant discharge has a mean of 0.469 and a median of 0.049 thousand tonnes per million USD of sales, indicating a right-skewed distribution. CEI have a mean of 1.622 and a median of 1.276 thousand metric tons of CO_2-equivalent per million USD of sales.

Panel B presents firm-level characteristics. The average firm has total assets of $22,712 million (log-transformed in regressions), a leverage ratio of 0.497, and a return on assets (ROA) of 0.100. The sample firms are generally profitable and have positive growth expectations, as reflected in the market-to-book ratio.

Panel C shows that the green bond issuance dummy has a mean of 0.043, indicating that 4.3% of the firm-year observations correspond to green bond issuers. Panel D reports that the average ESG score is 0.471. Overall, the sample's financial and environmental characteristics are comparable to those used in other global studies of corporate environmental performance (Flammer, 2021).

Appendix E presents the correlation matrix. It shows that green bond issuance is negatively correlated with waste production, water pollutants, and CEI in the univariate setting, providing preliminary support for the main hypotheses.

[Insert Table 1 here]

5.2. Baseline Results

This study examines the impact of green bond issuance on issuers' environmental performance. Table 2 presents the estimates from Equation (1), where the dependent variables are three environmental outcome metrics: waste production, water pollutant discharge, and CEI.

The coefficients on the green bond issuance dummy are negative and statistically significant across all three columns. This indicates a robust association between green bond issuance and improved environmental performance.

Column 1 shows that green bond issuance is associated with a reduction in waste intensity. The coefficient of −0.095 (significant at the 5% level) implies that for every million USD of sales, issuers produce 0.095 thousand tons (95 tons) less waste. Based on average firm sales, this translates to an average reduction of approximately 240.8 thousand tons of waste annually. This is consistent with the financing of circular economy and waste management projects, which are eligible under green bond frameworks (CBI, 2021b; ICMA, 2021).

Column 2 reports a coefficient of −0.295 ($p < 0.05$), indicating green bond issuers discharge 0.295 thousand cubic metres less water pollutant per dollar of sales. This reduction aligns with eligible project categories for water stewardship (CBI, 2021a), and mirrors the effect of environmental finance policies that incentivize cleaner production (He et al., 2019; Liu et al., 2019) .

Column 3 reveals the largest effect: a coefficient of −1.259 ($p < 0.01$), suggesting green bond issuers emit 1.259 thousand metric tons less CO_2-equivalent per dollar of sales. This result corroborates recent evidence linking green bonds to lower carbon intensity (ElBannan & Löffler, 2024).

[Insert Table 2 here]

The economic magnitude is substantial. Relative to comparable non-issuers, green bond-issuing firms generate 240.8 thousand fewer tons of waste and 747.7 thousand fewer tons of water pollutant post-issuance. The effect on CEI is larger still, at 3.19 million metric tons annually[2]. These reductions are consistent with the scale of impact anticipated from targeted environmental financing (Flammer, 2021).

Regarding control variables, firm size is positively associated with environmental impact, consistent with a dominant scale effect (Grossman & Krueger, 1995), Conversely, ESG scores show a significant negative relationship, supporting the view that higher-rated firms manage environmental outputs more effectively (Eliwa et al., 2021).

In sum, the baseline results suggest green bond issuance is associated with significant reductions across multiple environmental dimensions. While the effect on CEI aligns with

[2] The average reductions in waste production, water pollutant discharge, and CEI emissions are calculated by multiplying the estimated coefficients by the sample's average total sales, which is 2,534.7 thousand dollars; specifically, 0.095 × 2,534.7 equals 240.8 thousand tons of waste reduction, 0.295 × 2,534.7 equals 747.7 thousand tons of water pollutant reduction, and 1.259 × 2,534.7 equals 3,191.2 thousand metric tons of CEI reduction, or approximately 3.19 million metric tons.

prior literature, we contribute new evidence that this impact extends to waste output and water pollution, outcomes central to green bond frameworks but less studied empirically.

5.3. Validating the Parallel Trends Assumption

A primary identification concern is that firms issuing green bonds might already be on superior environmental trajectories. We test this by replacing the single Green Bond Issuance dummy with event-time indicators for periods relative to the issuance year (t = 0). This event-study specification directly tests the parallel trends assumption underlying our design (Cunningham, 2021).

The results, presented in Table 3, show a consistent pattern across all three environmental metrics. The coefficients on the pre-issuance period indicators (t = -3, -2, -1) are statistically indistinguishable from zero. This absence of significant pre-trends is critical: it indicates that our treatment and control firms exhibited parallel paths in environmental performance before the green bond event.

The negative and statistically significant coefficients emerge only at or after issuance ($t \geq 0$). For waste (Column 1), the effect becomes significant at t = 0 (10% level) and persists. For water discharge (Column 2), significance begins at t = +1. The effects on CEI (Column 3) are the most pronounced, growing in magnitude and significance over the post-issuance window.

This temporal pattern, null effects pre-issuance followed by significant reductions post-issuance, directly addresses endogeneity from reverse causality or selection on pre-existing trends. It strengthens the inference that green bond issuance induces environmental improvements rather than merely reflecting them. The inclusion of firm and year fixed effects further controls for time-invariant heterogeneity and aggregate shocks.

[Insert Table 3 here]

5.4. The Dynamics of Post-Issuance Effects

The environmental benefits of capital-intensive projects are unlikely to be instantaneous. We therefore estimate a dynamic specification to trace the effects of green bond issuance over a multi-year horizon. This approach allows us to test whether improvements accumulate as financed projects are implemented.

The results in Table 4, reveal a consistent pattern: the negative coefficients grow in magnitude and significance over the post-issuance window for all three environmental outcomes. This indicates that the beneficial effects of green bond financing strengthen progressively over time.

For waste intensity, the effect in year two (−0.106, $p < 0.05$) nearly triples by year four (−0.136, $p < 0.01$). This increasing trajectory is consistent with the multi-year timeline required to deploy proceeds into circular economy infrastructure and operational changes in waste management.

The pattern is most pronounced for CEI, where the coefficient grows from −1.555 in year two to −2.534 in year four (both $p < 0.01$). This suggests issuers undertake progressively deeper decarbonization, likely through phased investments in energy efficiency and renewable energy (ElBannan & Löffler, 2024).

Effects on water pollution also display a clear lag, becoming strongly significant only from year two onward (−0.357, $p < 0.01$) and intensifying through year four (−0.585, $p < 0.01$). This delay aligns with the time required to commission and optimize water treatment systems and cleaner production processes.

Collectively, these dynamic results indicate that green bond proceeds fund substantive, multi-year environmental projects rather than superficial changes. The absence

of immediate, one-off reductions and the presence of growing, persistent effects reinforce an interpretation and help distinguish real investment from greenwashing.

[Insert Table 4 here]

The progressive strengthening of environmental benefits over multiple years provides critical insight into the nature of the observed relationship. A one-time improvement could reflect superficial changes or the re-labelling of existing projects. In contrast, the persistent and intensifying reductions we document are strongly indicative of substantive, multi-year capital investments. This dynamic temporal pattern, emerging only after issuance and growing thereafter, significantly bolsters the interpretation that green bond proceeds finance new environmental projects. Consequently, the trajectory of post-issuance effects emerges as a key empirical marker that, within our research design, helps differentiate genuine, investment-driven impact from symbolic adoption.

5.5. Mediation Tests

5.5.1. Eco-innovation

We examine whether increased investment in environmental research and development (eco-innovation) is a channel through which green bond issuance improves environmental performance. We measure *Eco-Innovation* (denoted as EI) as the proportion of a firm's R&D expenditure directed toward environmental initiatives.

To formally test for mediation, we follow the established three-step procedure (Baron & Kenny, 1986). The first step estimates Equation (2), where the mediator (*Eco-Innovation*) is regressed on green bond issuance. The second step estimates Equation (3), where future environmental performance is regressed on the mediator.

$$EI_{it} = \delta_0 + \delta_1 GBI_{it} + \delta_{ji} I_{jit} + \sum Firm + \sum Year + \varepsilon_{it} \quad (2)$$

$WAS_{i,t+1}/WATPOL_{i,t+1}/CEI_{i,t+1}$

$$= \delta_0 + \delta_1 EI_{it} + \delta_{ji} I_{jit} + \sum Firm + \sum Year + \varepsilon_{it} \quad (3)$$

Table 5 presents the estimates. Panel A shows that green bond issuance is associated with a 0.022 increase in the eco-innovation ratio ($p < 0.05$). This confirms that issuers allocate a greater share of R&D to environmental projects.

Panel B reports the key tests. For all three environmental outcomes, the coefficient on *Eco-Innovation* is negative and statistically significant ($p < 0.05$ for waste; $p < 0.01$ for water and CEI). Crucially, the direct effect of green bond issuance remains significant but is attenuated in magnitude relative to the baseline effect. For example, in the CEI regression, the direct effect shrinks by approximately 18%.

The results support eco-innovation as a partial mediating mechanism. Green bond issuance increases environmental R&D intensity, which in turn contributes to reduced pollution. The persistence of a direct effect indicates that other channels, such as direct capital expenditure on certified green assets, also operate concurrently. This finding aligns with the view that sustainable finance can redirect corporate innovation toward long-term environmental goals (Amore & Bennedsen, 2016; Flammer, 2021).

[Insert Table 5 here]

5.5.2. Institutional ownership

We next examine whether attracting institutional investors is a mechanism through which green bond issuance improves environmental performance. If green bonds signal a credible commitment to sustainability, they may appeal to institutional investors who value environmental governance. This influx of focused, long-term capital could then enhance monitoring and pressure for tangible environmental outcomes.

$$IO_{it} = \delta_0 + \delta_1 GBI_{it} + \delta_{ji} I_{jit} + \sum Firm + \sum Year + \varepsilon_{it} \quad (4)$$

$$WAS_{i,t+1}/WATPOL_{i,t+1}/CEI_{i,t+1} = \delta_0 + \delta_1 IO_{it} + \delta_{ji} I_{jit} + \sum Firm + \sum Year + \varepsilon_{it} \quad (5)$$

We formally test this mediation hypothesis using the same two-step procedure as we did for eco-innovation. The first step estimates if GBI increases our mediator, institutional ownership (IO). The second step tests if IO is associated with improved environmental performance while controlling for the mediator.

Table 6, Panel A shows the coefficient on *GBI* is 0.170 ($p < 0.01$), indicating issuers experience a significant increase in institutional ownership. Panel B reports the key tests: for all three environmental outcomes, the coefficient on *IO* is negative and significant ($p < 0.01$).

The results are consistent with partial mediation. The direct effect of *GBI* remains significant but is attenuated compared to the baseline. For example, in the CEI regression, the direct effect shrinks by approximately X%. This suggests part of green bonds' environmental impact operates by changing the firm's investor base toward more sustainability-conscious institutions, which subsequently fosters better environmental management (Dyck et al., 2019; Krueger et al., 2020).

[Insert Table 6 here]

5.6. Heterogeneity Analysis: Bond-Level and Firm-Level Credibility Attributes

The credibility of a green bond and the oversight environment of the issuing firm may condition its environmental effectiveness. We examine this heterogeneity by analysing three distinct attributes: (1) third-party certification by the Climate Bonds Initiative (CBI), (2) explicit disclosure of the use of proceeds (GUOP), and (3) the level of institutional ownership (IO). The first two are bond-specific credibility signals, while the third reflects firm-level

monitoring intensity. As these attributes represent firm choices or endogenous characteristics, they are unsuitable for a causal DID framework. Instead, we assess their role as moderating factors that may amplify the cross-sectional relationship between green bond issuance and environmental performance.

We augment our baseline staggered DID specification with interaction terms between the green bond issuance indicator GBI_{it} and time-varying measures of each moderator. The model is specified as:

$$WAS_{i,t+1}/WATPOL_{i,t+1}/CEI_{i,t+1} = \delta_0 + \delta_1 GBI_{it} + \delta_2 Moderators_{it} + \delta_3 (GBI_{it}\ X\ Moderators_{it}) + \delta_{ji} I_{jit} + \gamma_{ji} M_{jit} + \sum Firm + \sum Year + \varepsilon_{it} \quad (6)$$

A significantly negative coefficient on the interaction term (θ_3) would indicate that the negative association between green bond issuance and environmental impact is stronger for bonds or firms with higher levels of the credibility attribute.

The results are presented in Table 7. Panels A, B, and C report findings for CBI certification, use-of-proceeds disclosure, and institutional ownership, respectively.

- CBI Certification (Panel A): The interaction term GBI × CBI is negative and significant for waste ($\theta_3 = -0.110, p < 0.01$) and CEI ($\theta_3 = -0.660, p < 0.01$). This suggests that the environmental benefits, particularly for waste and emissions, are more pronounced for certified bonds.
- Use-of-Proceeds Disclosure (Panel B): The interaction term GBI × GUOP is negative and significant across all outcomes: waste ($\theta_3 = -0.119, p < 0.01$), water pollutants ($\theta_3 = -0.448, p < 0.05$), and CEI ($\theta_3 = -0.938, p < 0.01$).

Transparency regarding capital allocation appears to significantly strengthen the observed relationship.

- Institutional Ownership (Panel C): The interaction term GBI × IO is also negative and significant for all three metrics (waste: $\theta_3 = -0.001, p < 0.01$; water pollutant: $\theta_3 = -0.011, p < 0.05$; CEI: $\theta_3 = -0.006, p < 0.1$). This indicates that the association between green issuance and environmental improvement is stronger in firms with greater oversight from institutional investors, consistent with their role as active monitors (Dyck et al., 2019; Krueger et al., 2020).

The consistent pattern across moderators indicates that the green bond-environmental performance link is not uniform; it is significantly stronger when bonds are externally certified, when proceeds are transparently allocated, and when firms are subject to greater institutional monitoring. These findings align with core finance theories: certification and disclosure help mitigate information asymmetry and credibly commit managers to environmental objectives (Healy & Palepu, 2001; Spence, 1973), while institutional ownership reduces agency costs and enforces longer-term, value-enhancing strategies (Shleifer & Vishny, 1986). In the context of sustainable finance, our results empirically substantiate the critical role of verification and governance in realizing the potential of labelled debt instruments (Baker et al., 2022; Flammer, 2021) . They suggest that the real effects of green bonds are contingent on the credibility mechanisms that accompany them.

[Insert Table 7 here]

6. Endogeneity Test

6.1. Difference-in-Differences Analysis Using an Exogenous Credibility Shock

To further mitigate endogeneity concerns and strengthen the identification of the green bond effect, we implement a Difference-in-Differences (DID) specification. This design leverages

a plausibly exogenous shock to the green bond market's institutional framework: the 2016 introduction of Moody's Green Bond Assessment (GBA) methodology (Moody's, 2016). This event represents a significant, market-wide enhancement in verification standards that is external to individual firms' financing and operational decisions, providing a suitable setting for a quasi-experimental design.

In this framework, firms that issue green bonds constitute the treatment group. We construct a control group of non-issuing firms using propensity score matching (PSM) on key firm characteristics (see Appendix G). The post-period is defined as years 2017 and onward. The coefficient of interest is the interaction between a time-invariant treatment indicator (GBI) and a post-2016-time dummy (POST), which captures the differential change in environmental performance for green bond issuers relative to the control group following the market-wide credibility shock.

$$WAS_{i,t+1}/WATPOL_{i,t+1}/CEI_{i,t+1} = \delta_0 + \delta_1 GBI_{it} + \delta_2 POST_t + \delta_3 (GBI_{it}\ X\ POST_t) + \delta_{ji} I_{jit} + \gamma_{ji} M_{jit} + \sum Firm + \sum Year + \varepsilon_{it} \quad (7)$$

where GBI_{it} is an indicator for firms that ever issue a green bond, $POST_t$ equals one for years ≥ 2017, and $GBI_{it}\ X\ POST_t$is the DID estimator. The model includes firm-level and macroeconomic controls, firm fixed effects, and year fixed effects. The parallel trends assumption, validated by our earlier event-study analysis showing no significant pre-trends (Table 3), underpins this design.

Table 8 presents the DID estimation results. The coefficient on the interaction term GBI × POST is negative and statistically significant across all three environmental outcomes.

- Waste Production: The DID estimate is -0.051 ($p < 0.10$), indicating that after the 2016 shock, green bond issuers reduced waste intensity by an additional 0.051 thousand tons per million USD of sales relative to the control group.
- Water Pollutants: The estimate is -1.137 ($p < 0.01$), suggesting a strong relative reduction in water pollutant discharge for the treatment group in the post-period.
- CEI: The estimate is -1.579 ($p < 0.01$), representing a substantial incremental decrease in emissions for issuers following the market credibility shock.

The consistently negative DID estimates provide evidence that the environmental benefits associated with green bond issuance became more pronounced following an exogenous enhancement of market-wide monitoring standards. This pattern supports the view that strengthening the credibility infrastructure of sustainable finance amplifies the real effects of green financing instruments (Flammer, 2021). By isolating a differential response to an external shock, this analysis helps alleviate concerns that the baseline association is driven solely by time-invariant unobserved heterogeneity between issuers and non-issuers.

[Insert Table 8 here]

6.2. Instrumental Variable Test

To further address endogeneity arising from unobserved firm characteristics that may influence both the decision to issue green bonds and environmental performance, we employ an instrumental variable (IV) approach. A valid instrument must be correlated with the endogenous regressor (green bond issuance) but affect the dependent variable (environmental outcomes) only through this channel (exclusion restriction).

We construct two instruments based on the green bond issuance activity of industry peers, a strategy grounded in the literature on peer effects in corporate finance (Leary &

Roberts, 2014). The intuition is that a firm's financing decisions are influenced by the actions of its competitors within the same industry, yet industry-wide issuance shocks are plausibly exogenous to the internal pollution abatement efficiency of any single firm after accounting for aggregate trends.

Our first instrument, HIGH_IND_ISSUE, is a binary variable equal to one if the number of green bonds issued by other firms within the same four-digit SIC industry in a given year exceeds the annual sample median. The second instrument, HIGH_ISS_AMT, equals one if the total dollar volume of peer green bond issuance within the industry-year exceeds the median. These threshold-based measures aim to capture non-linear, strategic responses to industry-wide shifts toward sustainable finance. We control for firm and year fixed effects in all specifications, absorbing time-invariant heterogeneity and common shocks.

Table 9 presents the two-stage least squares (2SLS) estimates. Panel A reports results using HIGH_IND_ISSUE as the instrument, and Panel B uses HIGH_ISS_AMT.

The first-stage statistics confirm the strength of the instruments. The Kleibergen-Paap F-statistics (13.708 in Panel A and 23.302 in Panel B) comfortably exceed the critical value of 10 proposed by Stock and Yogo (2005), rejecting the null of weak instruments. The partial R^2 values indicate a meaningful correlation between the instruments and green bond issuance.

In the second stage, the estimated coefficient on green bond issuance is negative and significant for waste and CEI across both instruments. For waste production, the coefficient is -0.869 ($p < 0.01$) with the first instrument and -0.658 ($p < 0.05$) with the second. For CEI, the coefficients are -25.138 ($p < 0.05$) and -22.613 ($p < 0.10$), respectively. The point estimates are notably larger in magnitude than the baseline OLS estimates, suggesting that conventional regression may understate the environmental impact of green bonds due to negative selection

bias (e.g., firms with unobserved challenges in improving environmental performance being more likely to issue). The coefficient on water pollutants, while negative, is not statistically significant in the IV specifications, which may indicate heterogeneous treatment effects or greater measurement noise for this outcome.

The IV results support the inference that the relationship between green bond issuance and reductions in waste and CEI is robust to corrections for endogeneity. The finding that peer group activity is a strong predictor of a firm's own issuance aligns with theories of strategic imitation and competitive isomorphism in financial markets.

We acknowledge the primary limitation of this design: the validity of the exclusion restriction cannot be tested directly. While we argue that peer issuance influences a firm's own financing choice through competitive and legitimacy pressures, one could posit that an unobserved industry-year shock (e.g., a new sector-wide technology or regulation) might drive both peer issuance and a firm's environmental performance. Our inclusion of year fixed effects and the industry-specific, threshold-based construction of the instruments are designed to mitigate this concern, but residual confounding remains a possibility common to quasi-experimental studies (Roberts & Whited, 2013). Nevertheless, the consistency of the IV results with our main findings and their larger economic magnitude strengthens the evidence for a substantive link between green bond financing and improved environmental performance.

[Insert Table 9 here]

6.3. Subsample Analyses

To examine the heterogeneity of the green bond effect, we conduct a series of cross-sectional tests. We split our sample based on country-level and firm-level characteristics and re-estimate our baseline model within each subsample. This approach allows us to assess

whether the environmental impact of green bonds varies systematically with a firm's institutional context or inherent attributes.

6.3.1. Country-level Heterogeneity

We first explore whether the national context influences the effectiveness of green bonds. We posit that the marginal impact of a voluntary financing instrument will be greater in settings where external pressures for environmental improvement are weaker, allowing green bonds to act as a compensating commitment device (Marquis & Qian, 2014).

6.3.1.1. Carbon Emissions Intensity

The baseline environmental footprint of a country may condition the potential for and scrutiny of corporate environmental actions. In nations with higher carbon emissions per capita (a proxy for greater industrial intensity and environmental degradation), firms face heightened visibility and stakeholder pressure regarding their environmental impact. We hypothesize that in these high-emission contexts, green bond issuance serves as a more critical and substantive signal, leading to stronger environmental improvements compared to low-emission countries where such pressure may be less acute. We classify countries annually based on the median value of carbon emissions per capita (sourced from CDP) into HIGH_CARBON and LOW_CARBON groups.

The results, presented in Table 10, Panel A, support this hypothesis. The negative association between green bond issuance and environmental impact is significantly more pronounced in high-carbon countries. For waste production, the coefficient is -0.121 ($p < 0.01$) in the HIGH_CARBON subsample, compared to an insignificant -0.005 in the LOW_CARBON subsample. Similarly, the reduction in CEI is substantially larger in high-carbon countries (coefficient = -1.873, $p < 0.01$) than in low-carbon countries. A Chow test confirms the statistical significance of these differences across subsamples (F-statistic =

58.14 for waste, 234.63 for CEI; $p < 0.01$ for both). This pattern is consistent with the view that green bonds help address environmental externalities where they are most severe and where regulatory or civil society oversight may create stronger demand for demonstrable action.

Other Country-Level Dimensions. We similarly examine heterogeneity based on Economic Policy Uncertainty, Environmental Policy Stringency, and Climate Change Performance. Detailed results for these dimensions are presented in Panels B, C, and D of Table 10, with the narrative following a parallel structure, focusing on the comparative magnitude and significance of coefficients across subsamples and the economic intuition for each split.

[Insert Table 10 Panel A here]

6.3.1.2. Economic policy uncertainty (EPU)

The macroeconomic decision-making environment may influence a firm's capacity to execute long-term environmental investments. We posit that in countries with high economic policy uncertainty, managers face shorter investment horizons and greater operational risk, making them more likely to defer or underinvest in the environmental projects funded by green bonds, which often have long payback periods. Conversely, in stable policy environments, firms can more confidently allocate proceeds to their intended, long-term green purposes. We measure uncertainty using the country-level Economic Policy Uncertainty (EPU) Index from Baker et al. (2016), sourced from www.policyuncertainty.com, and split the sample annually based on its median value.

The results in Table 10, Panel B, strongly support this hypothesis. The environmental benefits of green bond issuance are concentrated almost entirely in low-uncertainty environments. For waste, water pollutants, and CEI, the coefficients in the HIGH_EPU subsample are statistically insignificant. In contrast, in

the LOW_EPU subsample, the coefficients are negative, significant, and of meaningful magnitude (e.g., -0.101 for waste, -0.164 for water pollutants, and -0.753 for CEI; $p < 0.05$ for all). Chow tests confirm these cross-subsample differences are statistically significant (F-statistics range from 138.47 to 168.11, $p < 0.01$). This indicates that the stabilizing effect of a predictable policy landscape is a critical enabler for translating green finance commitments into tangible environmental outcomes.

[Insert Table 10 Panel B here]

6.3.1.3. Environmental policy stringency

The stringency of a country's formal environmental regulations may influence the marginal role of voluntary financial instruments like green bonds. We hypothesize a substitution effect: in nations with weaker regulatory frameworks (low EPS), green bonds can act as a compensating governance mechanism, filling an "institutional void" and prompting substantive environmental investment that might not otherwise occur (Marquis & Qian, 2014). Conversely, in high-EPS countries, firms are already subject to binding regulatory mandates, potentially diminishing the incremental impact of a voluntary green commitment. We measure regulatory pressure using the OECD's Environmental Policy Stringency Index and perform a median split to create HIGH_EPS and LOW_EPS subsamples.

The results in Table 10, Panel C, support this hypothesis. The association between green bond issuance and environmental improvement is significantly stronger in low-stringency environments. For instance, the reduction in CEI is markedly greater in the LOW_EPS subsample (coefficient = -1.776, $p < 0.01$) compared to the HIGH_EPS subsample. A parallel pattern holds for waste and water pollutants, with Chow tests confirming statistically significant differences across subgroups (all F-statistics significant at $p < 0.01$). This indicates that green bonds serve a particularly important

function in promoting environmental stewardship where traditional command-and-control regulation is less rigorous, effectively acting as a form of private-sector environmental governance.

[Insert Table 10 Panel C here]

6.3.1.4. Climate change performance

A country's existing momentum in climate action may influence the incremental value of firm-level green financing. We extend the institutional logic to examine the Climate Change Performance Index (CCPI), a composite metric of national CEI, energy use, renewable energy, and climate policy (Germanwatch, 2023). We hypothesize that in countries with lower CCPI scores, indicative of weaker national climate governance and progress, green bonds serve a more critical function. In such contexts, they provide a structured, market-based mechanism for firms to address significant environmental gaps and respond to latent stakeholder pressure. Where national performance is already high (HIGH_CCPI), comprehensive public policy and advanced corporate practices may limit the marginal additional impact of a green bond. We split the sample by the annual median CCPI score.

The results in Table 10, Panel D, confirm this pattern of contingent effectiveness. The environmental benefits of green bond issuance are statistically and economically significant only in countries with lower climate change performance (LOW_CCP). For example, the reduction in CEI is -1.516 ($p < 0.01$) in the LOW_CCP group, compared to an insignificant coefficient in the HIGH_CCP group. This finding is consistent across waste and water pollutant outcomes, with Chow tests verifying significant differences between subsamples (all F-statistics significant at $p < 0.01$). This reinforces the central theme that green bonds are most impactful as a tool for environmental improvement where they help compensate for deficiencies in public sector climate performance and policy.

[Insert Table 10 Panel D here]

6.3.2. Firm-level Heterogeneity

This section extends the cross-sectional analysis to firm-level attributes. We examine whether the impact of green bond issuance differs based on a firm's intrinsic characteristics, including its industry pollution intensity, size, systematic risk exposure, and corporate governance structures.

6.3.2.1. Industry Pollution Intensity

The potential for environmental improvement is not uniform across the economy. We hypothesize that firms in highly polluting industries—such as energy, chemicals, and metals—will exhibit stronger environmental responses to green bond issuance. These firms operate with a higher environmental liability and greater abatement potential; they face acute pressure from regulators, investors, and civil society, and their pollution-intensive processes offer more scope for meaningful, measurable reductions. Green bond financing can provide the targeted capital needed to upgrade technologies and meet these elevated expectations. In contrast, firms in less polluting sectors may have fewer and less costly environmental challenges, resulting in a weaker observed effect from green financing. We classify industries based on standard environmental intensity criteria.

The results, presented in Table 11, Panel A, strongly support this hypothesis. The association between green bond issuance and improved environmental performance is concentrated in high-pollution industries. For waste production, the coefficient in the high-pollution subsample is -0.375 ($p < 0.01$), compared to an insignificant -0.029 in the low-pollution subsample. This pattern is consistent and significant for water pollutants and CEI, with Chow tests confirming statistically meaningful differences across subgroups. This

indicates that green bonds are particularly effective at channelling capital to where the environmental need and potential for impact are greatest.

[Insert Table 11 Panel A here]

6.3.2.2. Firm size

The capacity to fund environmental investments internally may condition the marginal value of external green financing. We hypothesize that the environmental impact of green bond issuance will be more pronounced for smaller firms. These firms typically face greater financial constraints and have less established environmental management systems; thus, earmarked green capital can provide critical funding to initiate or scale substantive projects that would otherwise be deferred (Almeida & Campello, 2007; Brown et al., 2012). For larger firms, which generally possess greater internal resources and pre-existing sustainability programs, the incremental effect of a green bond on overall environmental performance may be attenuated.

Consistent with this hypothesis, the results in Table 11, Panel B show that the environmental benefits are almost entirely driven by smaller firms. For all three outcome variables—waste, water pollutants, and CEI—the coefficient on green bond issuance is statistically insignificant in the subsample of large firms. In stark contrast, the coefficients for small firms are negative, significant, and economically substantial (e.g., -2.092 for water pollutants and -2.822 for CEI, $p < 0.01$). Chow tests confirm these differences are statistically significant. This pattern indicates that green bonds play a particularly important role in alleviating financing frictions for smaller companies, enabling them to undertake meaningful environmental improvements.

[Insert Table 11 Panel B here]

6.3.2.3. Systematic risk (Beta)

A firm's exposure to market-wide volatility may shape its strategic use of sustainability-linked financing. We hypothesize that firms with higher systematic risk (Beta) will exhibit stronger environmental responses to green bond issuance. These firms, being more sensitive to market sentiment and external shocks, have a heightened incentive to manage non-financial risks and signal stability to investors. Issuing a green bond can serve as a credible commitment to long-term operational resilience, helping to mitigate perceptions of environmental and regulatory risk that could exacerbate their market volatility (Albuquerque et al., 2019; Krüger, 2015). For low-Beta firms, which are inherently less exposed to market fluctuations, the marginal reputational and risk-management benefits of a green bond may be smaller.

The results in Table 11, Panel C, support this hypothesis. The negative association between green bond issuance and environmental impact is significant only for firms with higher systematic risk. For example, the coefficient for waste reduction is -0.197 ($p < 0.05$) in the high-Beta subsample, compared to an insignificant coefficient in the low-Beta subsample. This indicates that green bonds are utilized as a more substantive tool for environmental and risk management by firms already navigating greater market uncertainty.

[Insert Table 11 Panel C here]

6.3.2.4. Corporate governance

The effectiveness of internal monitoring may influence how green bond proceeds are deployed. The literature presents two competing perspectives. First, a *complementarity view* suggests strong governance (e.g., independent audit committees) ensures capital is allocated effectively, enhancing the environmental impact of green bonds. Alternatively, a *substitution view* posits that in firms with weaker governance, green bonds act as an

external commitment device, substituting for internal oversight by attracting scrutiny from sustainability-focused investors and bond markets, thereby imposing discipline from the outside (Dyck et al., 2019).

To test these views, we examine several governance proxies (e.g., audit committee independence, board independence). The results, detailed in Appendix F, consistently support the substitution hypothesis. For instance, green bond issuance is associated with significant reductions in waste and emissions specifically in firms with lower audit committee independence, while the effect is insignificant in firms with strong independent oversight. This indicates that the green bond mechanism—with its associated reporting requirements and investor expectations—is particularly effective at driving real environmental improvements in firms where traditional internal governance structures are less robust.

7. Robustness Tests

7.1. Alternative Environmental Metrics

To assess the robustness of our baseline findings, we test whether the results hold across alternative operationalizations of environmental performance. This approach mitigates concerns that our conclusions are specific to a single set of metrics and examines whether green bond issuance is associated with broader environmental stewardship.

We employ three alternative dependent variables. First, we replace total waste with the waste recycled ratio (recycled waste/total waste), capturing circular economy efficiency. Second, we substitute water pollutant discharge with water purchased for industrial processes per unit of revenue, a direct measure of resource consumption intensity. Third, we replace CEI with volatile organic compounds (VOC), another important air pollutant emissions per unit of revenue, reflecting local air quality impacts. All variables are scaled by revenue for comparability.

The estimates, presented in Table 12, Panel A, confirm and extend our main results. Green bond issuance is associated with a higher waste recycled ratio (coefficient = 0.393, $p < 0.05$). This indicates that issuing firms not only produce less waste but also manage a greater proportion of their waste stream through recycling, aligning with principles of the circular economy. Issuance leads to a significant reduction in water purchased per unit of revenue (coefficient = -2.150, $p < 0.10$), demonstrating improved resource efficiency and conservation efforts beyond mere pollution control. We find a significant decrease in air pollutant emissions intensity (coefficient = -0.173, $p < 0.05$), showing that the benefits extend beyond global CEIs to include reductions in local pollutants with direct human health implications.

Collectively, these results provide robust evidence that the environmental benefits of green bonds are not an artifact of a specific metric. The positive effects span different dimensions of corporate environmental impact—pollution reduction, resource efficiency, and waste management—strengthening the conclusion that green bond financing is associated with substantive, multi-faceted operational improvements.

[Insert Table 12 Panel A here]

7.2. Alternative Independent Variable: Issuance Size

To verify that our findings reflect the scale of green financing rather than just its occurrence, we replace the binary issuance indicator with the continuous amount of green bonds issued (in millions of USD). This specification tests for a dose-response relationship: if the capital raised is used effectively, larger issuances should correlate with greater environmental improvements.

Re-estimating our baseline model with this continuous measure yields strongly supportive results (Table 12, Panel B). The coefficient on green bond amount is negative and

statistically significant for all three environmental outcomes: waste production (-0.032, $p < 0.01$), water pollutants (-0.494, $p < 0.05$), and CEI (-3.083, $p < 0.01$). This monotonic relationship indicates that the magnitude of environmental benefit is positively associated with the volume of green capital raised. The effect is economically meaningful; for instance, the coefficient on CEI suggests that for each additional million dollars of green bonds issued, a firm reduces its emissions intensity by approximately 3.083 thousand metric tons of CO_2-equivalent per million USD of sales.

This robustness check confirms that the link between green bonds and environmental performance is not merely a binary event study. The significant, negative coefficients on issuance amount strengthen the validity of our core findings by demonstrating a graded relationship where larger sustainable investments are associated with proportionally greater environmental gains.

[Insert Table 12 Panel B here]

7.3. Excluding the COVID-19 Pandemic Period

To ensure our results are not driven by the extraordinary economic and environmental disruptions of the COVID-19 pandemic, we re-estimate our baseline models after excluding the years 2020–2022. This period was characterized by severe supply chain interruptions, volatile industrial output, and sharp, non-strategic fluctuations in emissions, which could confound the measurement of intentional corporate environmental actions.

As shown in Table 12, Panel C, the core findings are robust to the exclusion of the pandemic period. The coefficients on green bond issuance remain negative and statistically significant for waste production (–0.095, $p < 0.05$), water pollutant discharge (–0.304, $p < 0.05$), and CEI (–1.328, $p < 0.01$). The magnitudes are consistent with the full-sample estimates.

This test confirms that the documented association between green bond issuance and environmental improvement is not an artifact of the pandemic's transient shocks. The results hold in a more stable economic context, reinforcing the conclusion that they reflect a substantive relationship driven by corporate investment rather than cyclical anomalies.

[Insert Table 12 Panel C here]

7.4. Excluding U.S.-Based Firms

To ensure our global results are not driven by the market dominance of a single country, we test the robustness of our findings by excluding all U.S.-based firms from the sample. The United States constitutes the largest segment of both the global green bond market and our dataset; this check verifies that the documented relationship holds across a diverse set of institutional environments beyond this single, influential market.

As presented in Table 12, Panel D, the negative association between green bond issuance and environmental impact remains robust. The coefficients for waste production (–0.011, $p < 0.01$), water pollutant discharge (–0.610, $p < 0.01$), and CEI (–1.647, $p < 0.01$) are all statistically significant and directionally consistent with the baseline model.

This analysis confirms that the environmental benefits linked to green bond issuance are observable across multiple national contexts. The persistence of significant results in a sample of 33 non-U.S. countries strengthens the external validity of our conclusions and underscores their relevance for global policymakers and international market participants

[Insert Table 12 Panel D here]

7.5. Repeated Green Bond Issuance

This analysis extends our investigation by testing whether the environmental impact of green bonds is stronger for firms that demonstrate sustained commitment through multiple

issuances. We augment our baseline model with a dummy variable indicating a repeat issuer (MI) and its interaction with the green bond issuance indicator (GBI×MI). A significantly negative interaction term would indicate that the benefits are concentrated in, or amplified by, repeated engagement with the green bond market, consistent with the view that building environmental capabilities requires persistent investment (Hart, 1995; Russo & Fouts, 1997).

The results, presented in Table 12, Panel E, reveal a clear and economically significant pattern. For waste, water pollutants, and CEI, the coefficients on the standalone GBI and MI variables are statistically insignificant. Critically, the interaction term GBI×MI is negative and significant across all outcomes (-1.259 for CEI, $p < 0.01$).

This indicates that the documented environmental improvements are driven predominantly by issuance activity from repeat issuers. The economic magnitude is substantial; for CEI, the interaction implies an incremental reduction of approximately 3.19 million metric tons for a firm with average sales when it conducts an issuance as a repeat participant.

This test provides compelling evidence that the environmental efficacy of green bonds is not a one-time event. It is significantly enhanced by repeated use, suggesting that sustained access to labelled sustainable finance helps firms build and deploy the specialized capabilities necessary for deep, long-term environmental transformation. This finding aligns with evidence that markets reward perceived long-term environmental commitment (Zerbib, 2019).

[Insert Table 12 Panel E here]

7.6. Disentangling issuer identity and issuance timing

To address potential identification challenges in our main staggered DID specification, we conduct a robustness test that disentangles the timing of the issuance event from the persistent

status of being an issuer. The binary treatment variable could conflate an immediate announcement effect, a sustained effect of issuer identity, and any dynamic interaction between the two. Following insights on the decomposition of treatment effects (Goodman-Bacon, 2021), we replace the single indicator with three orthogonal components: (1) an Exact Issuance Year dummy (equals 1 only in the year of the first green bond issuance), (2) a Persistent Issuer dummy (equals 1 for all years after the first issuance), and (3) their interaction term.

The results, presented in Table 12, Panel F, reveal a consistent pattern. For waste and water pollutants, only the interaction term is statistically significant (coefficients of -0.008 and -0.227, respectively, $p < 0.01$). For CEI, both the *Persistent Issuer* dummy (-0.196, $p < 0.05$) and the interaction term (-1.288, $p < 0.01$) are significant. The *Exact Issuance Year* dummy is insignificant across all outcomes. This indicates that the association between green bond issuance and environmental improvement is driven by the combined state of being a new issuer in the issuance year, not by the isolated event or status alone.

[Insert Table 12 Panel F here]

This decomposition addresses two key methodological concerns. First, it mitigates temporal aggregation bias by separating potential transient effects from persistent ones (Sun & Abraham, 2021). Second, the significant interaction term suggests that models using a single, post-treatment indicator may underestimate the true association when the treatment effect is dynamic. The results imply that the act of issuing a green bond initiates a change in firm behaviour or commitment that is realized in the years following the inaugural issuance, aligning with the view that such financing signals and facilitates substantive, multi-year environmental projects.

8. Conclusion

This study provides robust, large-sample evidence that corporate green bond issuance leads to measurable improvements in firm-level environmental performance. Using a staggered difference-in-differences design on a global panel from 2013 to 2022, we document significant post-issuance reductions in three direct environmental metrics: waste generation, water pollutant discharge, and composite emissions intensity. Event-study analyses confirm these improvements begin at issuance and intensify over time, supporting a causal interpretation that the earmarked capital enables substantive, multi-year environmental projects.

Our primary contribution is to move beyond financial outcomes and ESG proxies to establish a credible link between sustainable finance and real environmental outcomes. While prior research focuses on yield benefits or disclosure improvements (Flammer, 2021; Tang & Zhang, 2020), and a recent study documents carbon reduction (ElBannan & Löffler, 2024), we demonstrate that the impact extends across a broader range of critical environmental dimensions. This evidence directly addresses greenwashing concerns by showing that, on average, green bonds are associated with operational changes, not merely reputational signalling.

The cross-sectional analyses further reveal that the impact is conditional. The environmental benefits are most pronounced for firms in highly polluting industries, smaller firms, and those operating in countries with weaker environmental governance or lower climate policy performance. This pattern suggests green bonds serve a particularly important substitutive or complementary governance role in contexts where traditional regulatory or internal corporate pressures are less stringent.

Our findings have direct relevance for multiple stakeholders. For policymakers and regulators, the results underscore the value of supporting transparent, well-defined green bond markets, particularly as a tool to catalyse environmental action in jurisdictions with developing regulatory frameworks. For investors, the evidence that green bonds generate positive environmental externalities can strengthen the case for incorporating them into sustainable portfolios, especially when coupled with active engagement to monitor the use of proceeds.

As with any observational study, our causal claims, while strengthened by a battery of identification strategies, are subject to residual confounding. The sample is limited to publicly listed firms, and the environmental data, though direct, is subject to reporting standards. Future research should pursue several promising avenues. First, investigating the longer-term dynamics (beyond 5–10 years) of green bond-financed projects is critical to understanding the permanence of these improvements. Second, more granular analysis of project-level data tied to specific bond proceeds could further tighten the link between financing and impact. Third, exploring the effectiveness of specific bond contract features, such as third-party certification, sustainability-linked covenants, and post-issuance reporting rigor, would provide practical guidance for market design.

In conclusion, this study strengthens the empirical foundation for sustainable finance. By demonstrating that green bond issuance is systematically followed by reductions in waste, water pollution, and CEI, especially when issued by firms with the greatest need or capacity for change, we provide compelling evidence that this financial instrument can be a viable mechanism for improving corporate environmental performance. While not a panacea, green bonds, when implemented with transparency and accountability, represent a meaningful innovation in the toolkit for financing a transition to a more sustainable global economy.

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Tables

Table 1 Summary statistics of key variables

Variables	Number	Mean	SD	P25%	Median	P75%
Panel A: Environmental factors						
Waste production	24910	0.819	1.850	0.462	0.720	1.197
Water pollutant	24655	0.469	17.899	0.012	0.049	0.204
Green House Gas (CEI) emissions	27232	1.622	1.422	0.558	1.276	2.78
Panel B: Firm characteristics						
Firm size (million USD)	27232	22,711.870	58,271.600	2,505.219	6,612.872	17,555.980
Leverage	27232	0.497	0.180	0.378	0.490	0.616
Profitability	27232	0.100	0.057	0.066	0.097	0.137
Market-to-book ratio	27232	1.307	1.505	0.520	0.863	1.548
Cash	27232	0.721	0.623	0.037	0.190	0.580
Panel C: Green bond						
Green bond issuance	27232	0.043	0.006	0.000	0.000	0.000
Panel D: Other control variables						
ESG scores	27232	0.471	0.174	0.349	0.476	0.597

All continuous variables are winsorised at the 1st and 99th percentiles.

Table 2 Baseline model

This table reports the regression results examining the effect of green bond issuance on waste production, water pollutants, and CEI. All models include firm, industry, country, and year fixed effects.

	1	2	3
	WAS	WATPOL	CEI
GBI	-0.095**	-0.295**	-1.259***
	(0.041)	(0.121)	(0.135)
Total assets	0.055***	0.220***	1.120***
	(0.007)	(0.031)	(0.041)
Profitability	0.029	-0.057	-0.149**
	(0.022)	(0.050)	(0.068)
Leverage	-0.001	-0.019	-0.083***
	(0.010)	(0.014)	(0.018)
Market-to-book ratio	0.000	0.019***	0.026***
	(0.003)	(0.007)	(0.009)
Cash	0.000*	-0.001	-0.003
	(0.000)	(0.002)	(0.003)
ESG score	-0.001***	-0.002**	-0.001*
	(0.000)	(0.001)	(0.001)
Environmental policy stringency	0.008	-0.027	-0.200**
	(0.009)	(0.063)	(0.083)
Economic policy uncertainty	-0.001	0.064	0.427***
	(0.011)	(0.057)	(0.074)
GDP per capita growth annual	0.002	-0.007	-0.068***
	(0.001)	(0.008)	(0.011)
Constant	-0.476***	-1.577***	-6.852***
	(0.066)	(0.297)	(0.395)
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Adjusted R2	0.3014	0.9097	0.9482
Observations	24910	24655	27232

Levels of significance, denoted by *, **, and ***, for 10%, 5%, and 1%, respectively, accompany the results.

Table 3 Pre-trend test before and after green issuance

This table presents results from extended models estimating the impact of green bond issuance on firms' environmental performance over a multi-year window. Panel A report estimates from one to three years before green bond issuance (pre-issuance), while Panels B and C report estimates from two to four years after issuance (post-issuance). The dependent variables include waste production (scaled by total sales), water pollutant emissions (scaled by total sales), and composite emissions intensity (scaled by total sales). The key independent variable is a dummy indicating green bond issuance. All models include the same firm level and country-level controls, as well as year and firm fixed effects, as in the baseline regressions.

	1	2	3
	WAS	WATPOL	CEI
GBI_{t-3}	-0.020	-0.034	-0.213
	(0.013)	(0.112)	(0.126)
GBI_{t-2}	-0.013	-0.013	-0.256
	(0.010)	(0.141)	(0.212)
GBI_{t-1}	-0.032	-0.138	-0.339
	(0.041)	(0.160)	(0.245)
GBI_{t}	-0.034*	-0.063	-0.213*
	(0.016)	(0.202)	(0.126)
GBI_{t+1}	-0.033*	-0.237**	-0.316**
	(0.019)	(0.147)	(0.152)
GBI_{t+2}	-0.027***	-0.252***	-0.520***
	(0.010)	(0.075)	(0.171)
GBI_{t+3}	-0.041**	-0.222*	-0.949***
	(0.017)	(0.119)	(0.253)
All control variables	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Adjusted R2	0.3019	0.9097	0.9483
Observations	24910	24910	27232

Standard errors are clustered at the firm level.
Significance levels are denoted as *** p<0.01, ** p<0.05, * p<0.10.

Table 4 Post-Issuance Effect test

This table reports dynamic treatment effects from a distributed-lag model estimating the impact of green bond issuance on environmental outcomes over time. Coefficients represent the average effect relative to the first year after issuance (t+1). Standard errors, clustered at the firm level, are reported in parentheses. Columns (1) to (9) reveal a distinct temporal pattern: the effects in the first year after issuance (t+1) are statistically significant in the baseline model, significant reductions in all three environmental outcomes emerge starting in the second year post-issuance (t+2) and persist through the fourth year (t+4). This demonstrates that the environmental benefits of green bonds materialise gradually and are sustained over a multi-year horizon.

	1	2	3	4	5	6	7	8	9
	2 years post-issuance WAS	3 years post-issuance WAS	4 years post-issuance WAS	2 years post-issuance WATPOL	3 years post-issuance WATPOL	4 years post-issuance WATPOL	2 years post-issuance CEI	3 years post-issuance CEI	4 years post-issuance CEI
GBI	-0.106**	-0.119***	-0.136***	-0.357***	-0.462***	-0.585***	-1.555***	-2.000***	-2.534***
	(0.044)	(0.046)	(0.049)	(0.137)	(0.154)	(0.174)	(0.145)	(0.164)	(0.186)
All control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R2	0.3031	0.3044	0.3066	0.9095	0.9097	0.9109	0.9523	0.9503	0.9498
Observations	23062	21449	20041	22881	21281	19928	25208	23387	21831

Standard errors are clustered at the firm level.
Significance levels are denoted as *** p<0.01, ** p<0.05, * p<0.10.

Table 5 Mediation test: Eco-innovation

This table presents the two-stage regression examining whether eco-innovation mediates the effect of green bond issuance on environmental outcomes. Stage 1 estimates the impact of green bond issuance on eco-innovation. Stage 2 regresses environmental outcomes on eco-innovation.

	1	2	3	4
	Stage 1	Stage 2	Stage 2	Stage 2
	Eco-innovation	WAS	WATPOL	CEI
GBI	0.022**			
	(0.011)			
Eco-innovation		-0.003**	-0.023***	-0.194***
		(0.001)	(0.003)	(0.067)
All control variables	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Adjusted R2	0.6372	0.9629	0.9093	0.9480
Observations	28842	24655	24655	27232

All regressions include baseline control variables and fixed effects.
Levels of significance, denoted by *, **, and ***, for 10%, 5%, and 1%, respectively, accompany the results.

Table 6 Mediation test institutional ownership

	1	2	3	4
	Stage 1	Stage 2	Stage 2	Stage 2
	institutional ownership	WAS	WATPOL	CEI
GBI	0.170***			
	(0.049)			
IO		-0.034***	-0.232***	-0.403***
		(0.011)	(0.059)	(0.060)
All control variables	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Adjusted R2	0.1066	0.3069	0.0246	0.9481
Observation	30220	24910	24910	27232

All regressions include baseline control variables and fixed effects.
Levels of significance, denoted by *, **, and ***, for 10%, 5%, and 1%, respectively, accompany the results.

Table 7: The Moderating Role of Credibility Attributes

(Table with three panels for CBI, GUOP, and IO. Each panel shows regression results for the three environmental outcomes, highlighting the coefficient on the GBI × Moderator interaction term.)

Panel A			
	1	2	3
	WAS	WATPOL	CEI
GBI X CBI	-0.119***	-0.448**	-0.938***
	(0.045)	(0.226)	(0.239)
CBI	-0.018	-0.040	0.231
	(0.023)	(0.215)	(0.146)
GBI	-0.061*	0.120	-0.867***
	(0.034)	(0.126)	(0.222)
All control variables	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Adjusted R2	0.3017	0.9147	0.9482
Observation	24910	24655	27232
Panel B			
	1	2	3
	WAS	WATPOL	CEI
GBI X GUOP	-0.110***	-0.436*	-0.660***
	(0.043)	(0.228)	(0.246)
GUOP	0.000	0.000	0.000
	(0.001)	(0.001)	(0.001)
GBI	0.020	-0.177	-0.779***
	(0.032)	(0.242)	(0.224)
All control variables	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Adjusted R2	0.3014	0.9097	0.9275
Observation	24910	24655	27232
Panel C			
	1	2	3
	WAS	WATPOL	CEI
GBI X IO	-0.001***	-0.011**	-0.006*
	(0.000)	(0.005)	(0.003)
IO	0.000	0.000	-0.001
	(0.000)	(0.000)	(0.000)
GBI	-0.0168***	-0.802***	-1.441***
	(0.005)	(0.241)	(0.303)
All control variables	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Adjusted R2	0.9626	0.9097	0.9476
Observation	24410	24410	26969

Levels of significance, denoted by *, **, and ***, for 10%, 5%, and 1%, respectively, accompany the results.

Table 8: Difference-in-Differences Estimation Using the Moody's 2016 Announcement
(Table presented here with columns for Waste, Water Pollutants, and CEI. Includes coefficients for GBI, POST, GBI×POST, controls, fixed effects, adjusted R^2, and observations.)

	1	2	3
	WAS	WATPOL	CEI
GBI X MOODY	-0.051*	-1.137***	-1.579***
	(0.027)	(0.367)	(0.349)
MOODY	0.003	0.001	0.001
	(0.002)	(0.004)	(0.002)
GBI	-0.047	-0.905**	0.179
	(0.042)	(0.373)	(0.346)
All control variables	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Adjusted R2	0.3046	0.9098	0.9186
Observation	24910	24655	27232

Levels of significance, denoted by *, **, and ***, for 10%, 5%, and 1%, respectively, accompany the results.

Table 9: Instrumental Variable Estimates

(Table with Panels A and B for the two instruments. Each panel shows the second-stage coefficients for Waste, Water Pollutants, and CEI, along with first-stage F-statistics and partial R^2.)

	1	2	3
Panel A			
	HIGH_IND_ISSUE	HIGH_IND_ISSUE	HIGH_IND_ISSUE
	WAS	WATPOL	CEI
GBI	-0.869***	-8.683	-25.138**
	(0.301)	(5.873)	(12.710)
All control variables	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	24885	24885	27495
First stage F-statistics		13.708***	
First stage P-value		(0.0002)	
First stage Partial R^2		0.0385	
Panel B			
	HIGH_ISS_AMT	HIGH_ISS_AMT	HIGH_ISS_AMT
	WAS	WATPOL	CEI
GBI	-0.658**	-10.097	-22.613*
	(0.276)	(6.934)	(12.045)
All control variables	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	24885	24885	27495
First stage F-statistics		23.302***	
First stage P-value		(0.0000)	
First stage Partial R^2		0.0333	

Levels of significance, denoted by *, **, and ***, for 10%, 5%, and 1%, respectively, accompany the results.

Table 10 (Panel A) Country-level subsample analysis -Carbon emissions per capita

Each panel shows results from subsample regressions by country-level characteristics. Chow tests are used to examine cross-group differences.

	1	2	3	4	5	6
Panel A						
	HIGH_CARBON WAS	LOW_CARBON WAS	HIGH_CARBON WATPOL	LOW_CARBON WATPOL	HIGH_CARBON CEI	LOW_CARBON CEI
GBI	-0.121***	-0.005	-0.774***	0.474	-1.873***	-0.357
	(0.035)	(0.067)	(0.071)	(0.368)	(0.164)	(0.235)
All control variables	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R2	0.3535	0.3040	0.7666	0.9162	0.9522	0.9452
Observation	11164	13746	10995	13604	12429	14741
Chow test		161.62***		234.63***		58.14***
Test statistic		(0.0000)		(0.0000)		(0.0000)

Standard errors are clustered at the firm level.

Levels of significance, denoted by *, **, and ***, for 10%, 5%, and 1%, respectively, accompany the results.

Table 10 (Panel B) Country-level subsample analysis -Economic policy certainty

Each panel shows results from subsample regressions by country-level characteristics. Chow tests are used to examine cross-group differences.

Panel B						
	1	**2**	**3**	**4**	**5**	**6**
	HIGH_EPU	LOW_EPU	HIGH_EPU	LOW_EPU	HIGH_EPU	LOW_EPU
	WAS	WAS	WATPOL	WATPOL	CEI	CEI
GBI	-0.081	-0.101***	-0.218	-0.164**	-0.504	-0.753***
	(0.075)	(0.022)	(0.155)	(0.059)	(0.493)	(0.202)
All control variables						
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R2	0.2913	0.3187	0.9262	0.9257	0.9559	0.9475
Observations	10293	14617	14408	14408	15650	11436
Chow test		138.47***		152.59***	168.11***	
Test statistic		(0.0000)		(0.0000)	(0.0000)	

Standard errors are clustered at the firm level.

Levels of significance, denoted by *, **, and ***, for 10%, 5%, and 1%, respectively, accompany the results.

Table 10 (Panel C) Country-level subsample analysis -Environmental policy stringency

Each panel shows results from subsample regressions by country-level characteristics. Chow tests are used to examine cross-group differences.

	1	2	3	4	5	6
	HIGH_EPS	LOW_EPS	HIGH_EPS	LOW_EPS	HIGH_EPS	LOW_EPS
	WAS	WAS	WATPOL	WATPOL	CEI	CEI
GBI	-0.030	-0.121***	-0.024	-0.729***	-0.840	-1.776***
	(0.073)	(0.044)	(0.117)	(0.133)	(0.661)	(0.161)
All control variables	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R2	0.2847	0.3079	0.9115	0.9374	0.9442	0.9528
Observations	14343	10567	14134	10366	14758	12307
Chow test		66.73***		140.48***		27.50***
Test statistic		(0.0000)		(0.0000)		(0.0000)

Standard errors are clustered at the firm level.

Levels of significance, denoted by *, **, and ***, for 10%, 5%, and 1%, respectively, accompany the results.

Table 10 (Panel D) Country-level subsample analysis -Climate change performance

Each panel shows results from subsample regressions by country-level characteristics. Chow tests are used to examine cross-group differences.

	1	2	3	4	5	6
	HIGH_CCP	LOW_CCP	HIGH_CCP	LOW_CCP	HIGH_CCP	LOW_CCP
	WAS	WAS	WATPOL	WATPOL	CEI	CEI
GBI	-0.001	-0.011***	-0.045	-0.378***	-0.888	-1.516***
	(0.005)	(0.004)	(0.141)	(0.145)	(0.552)	(0.155)
All control variables	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R2	0.9579	0.9637	0.8330	0.9117	0.9281	0.9507
Observations	13302	11242	13302	11242	13857	13258
Chow test		83.52***	48.13***			72.78***
Test statistic		(0.0000)	(0.0000)			(0.0000)

Standard errors are clustered at the firm level.
Levels of significance, denoted by *, **, and ***, for 10%, 5%, and 1%, respectively, accompany the results.

Table 11 (Panel A) Firm level subsample analysis - Industry pollution levels

Each panel shows results from subsample regressions by country-level characteristics. Chow tests are used to examine cross-group differences.

	1	2	3	4	5	6
	Highly polluting	Non-Highly polluting	Highly polluting	Non-Highly polluting	Highly polluting	Non-Highly polluting
	WAS	WAS	WATPOL	WATPOL	CEI	CEI
GBI	-0.375***	-0.029	-0.682***	0.403	-1.730***	0.445
	(0.136)	(0.031)	(0.115)	(0.554)	(0.151)	(0.434)
All control variables	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R2	0.4350	0.3211	0.9337	0.8752	0.9514	0.9599
Observations	13368	11542	11267	13264	13602	13492
Chow test		80.09***		135.27***		136.72***
Test statistic		(0.0000)		(0.0000)		(0.0000)

Standard errors are clustered at the firm level.

Levels of significance, denoted by *, **, and ***, for 10%, 5%, and 1%, respectively, accompany the results.

Table 11 (Panel B) Firm level subsample analysis – Firm size

Each panel shows results from subsample regressions by country-level characteristics. Chow tests are used to examine cross-group differences.

	1	2	3	4	5	6
	BIG	SMALL	BIG	SMALL	BIG	SMALL
	WAS	WAS	WATPOL	WATPOL	CEI	CEI
GBI	-0.065	-0.092**	0.014	-2.092***	-0.217	-2.822***
	(0.037)	(0.036)	(0.136)	(0.479)	(0.143)	(0.753)
All control variables	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R2	0.3165	0.2999	0.9225	0.7301	0.9513	0.9512
Observations	6214	18696	18542	6063	14421	12755
Chow test		50.82***		39.59***		24.43***
Test statistic		(0.0000)		(0.0000)		(0.0000)

Standard errors are clustered at the firm level.

Levels of significance, denoted by *, **, and ***, for 10%, 5%, and 1%, respectively, accompany the results.

Table 11 (Panel C) Firm level subsample analysis – Systematic risk (Beta)

Each panel shows results from subsample regressions by country-level characteristics. Chow tests are used to examine cross-group differences.

	1	2	3	4	5	6
	Higher systematic risk	Lower systematic risk	Higher systematic risks	Lower systematic risks	Higher systematic risks	Lower systematic risks
	WAS	WAS	WATPOL	WATPOL	CEI	CEI
Green bond issuance	-0.197**	-0.029	-0.771***	-0.792	-1.780**	-0.735
	(0.085)	(0.023)	(0.278)	(0.652)	(0.608)	(0.563)
All control variables	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R2	0.3564	0.3069	0.0352	0.0334	0.9491	0.9518
Observations	12813	12097	12813	12097	14051	12850
Chow test		56.05***		82.59***		86.39***
Test statistic		(0.0000)		(0.0000)		(0.0000)

Standard errors are clustered at the firm level.

Levels of significance, denoted by *, **, and ***, for 10%, 5%, and 1%, respectively, accompany the results.

Table 12 (Panel A) Alternative Dependent Variables

All models include firm and year fixed effects and standard errors clustered at the firm level. Robustness checks test the consistency of baseline findings using alternative specifications and samples.

	1	2	3
	WASREC	WATPUR	VOC
GBI	0.393**	-2.150*	-0.173**
	(0.177)	(1.047)	(0.076)
All control variables	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Adjusted R2	0.5795	0.8336	0.2567
Observations	12257	26754	26754

Levels of significance, denoted by *, **, and ***, for 10%, 5%, and 1%, respectively, accompany the results.

Table 4 (Panel B) Alternative Independent Variables

All models include firm and year fixed effects and standard errors clustered at the firm level. Robustness checks test the consistency of baseline findings using alternative specifications and samples.

	1	2	3
	WAS	WATPOL	CEI
Green bond size in millions	-0.032***	-0.494**	-3.083***
	(0.005)	(0.209)	(0.248)
All control variables	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Adjusted R2	0.9633	0.9100	0.9483
Observations	24302	24302	26860

Levels of significance, denoted by *, **, and ***, for 10%, 5%, and 1%, respectively, accompany the results.

Table 5 (Panel C) Exclusion of the COVID-10 period (2020–2022)

All models include firm and year fixed effects and standard errors clustered at the firm level. Robustness checks test the consistency of baseline findings using alternative specifications and samples.

	1	2	3
	WAS	WATPOL	CEI
GBI	-0.095**	-0.304**	-1.328***
	(0.043)	(0.124)	(0.139)
All control variables	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Adjusted R2	0.3024	0.9100	0.9482
Observations	17437	17259	19062

Levels of significance, denoted by *, **, and ***, for 10%, 5%, and 1%, respectively, accompany the results.

Table 0.6 (Panel D) Exclusion of U.S. Firms

All models include firm and year fixed effects, and standard errors clustered at the firm level. Robustness checks test the consistency of baseline findings using alternative specifications and samples.

	1	2	3
	WAS	WATPOL	CEI
Green bond issuance	-0.011***	-0.610***	-1.647***
	(0.003)	(0.057)	(0.133)
All control variables	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Adjusted R2	0.9556	0.7977	0.9465
Observations	15244	14989	17566

Levels of significance, denoted by *, **, and ***, for 10%, 5%, and 1%, respectively, accompany the results.

Table 7 (Panel E) Multiple Green Bond Issuance

All models include firm and year fixed effects, and standard errors clustered at the firm level. Robustness checks test the consistency of baseline findings using alternative specifications and samples.

	1	2	3
	WAS	WATPOL	CEI
GBI X MI	-0.140**	-0.295**	-1.259***
	(0.061)	(0.121)	(0.135)
MI	0.056	-0.002	-0.001
	(0.041)	(0.008)	(0.002)
GBI	-0.003	0.003	-0.005
	(0.004)	(0.010)	(0.009)
All control variables	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Adjusted R2	0.3121	0.9097	0.9482
Observations	24910	24910	27232

Levels of significance, denoted by *, **, and ***, for 10%, 5%, and 1%, respectively, accompany the results.

Table 8 (Panel F) Disentangling Issuer Identity and Issuance Timing Test

All models include firm and year fixed effects, and standard errors clustered at the firm level. Robustness checks test the consistency of baseline findings using alternative specifications and samples.

	1	2	3
	WAS	WATPOL	CEI
GB Issuer X GBI exact year	-0.008**	-0.227*	-1.288***
	(0.003)	(0.130)	(0.150)
GB Issuer	0.005	-0.042	-0.196**
	(0.007)	(0.060)	(0.078)
GB Issuance exact year	-0.000	0.000	-0.000
	(0.000)	(0.000)	(0.000)
All control variables	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Adjusted R2	0.9630	0.9097	0.9482
Observations	24655	24655	27232

Levels of significance, denoted by *, **, and ***, for 10%, 5%, and 1%, respectively, accompany the results.

Appendix A

The variation in number of green bond issuers is shown below.

	Number of green bond issuers
Refinitiv	2,173
Issuers lacking RIC	824
Financial companies	335
Number of available issuers	1014

Appendix B

Study 3. Panel E Green and non-green bond issuers country distribution

	Green bond issuers	Non-green bond issuers
Australia	41	123
Austria	2	5
Belgium	4	12
Brazil	2	2
Canada	52	140
Chile	3	6
China	90	385
Denmark	2	3
Finland	5	15
France	31	97
Germany	26	84
Chinese Hong Kong	10	28
Iceland	2	3
India	31	91
Indonesia	9	24
Ireland	8	21
Italy	10	28
Japan	188	728
Luxembourg	2	4
Mexico	12	33
Netherlands	11	31
New Zealand	16	43
Norway	5	13
Portugal	2	4
Singapore	4	11
South Africa	5	13
South Korea	3	8
Spain	16	50
Sweden	10	28
Switzerland	16	37
Thailand	5	14
United Arab Emirates	5	14
United Kingdom	52	176
United States	334	1233

Appendix C

Study 3. Distribution of firm-year observations by country

Countries	Green bond issuer	Non-green bond issuer
	Firm-year observations	Firm-year observations
Australia	137	821
Austria	9	34
Belgium	13	77
Brazil	8	16
Canada	173	936
Chile	10	42
China	463	2565
Denmark	10	17
Finland	17	98
France	103	644
Germany	87	561
Chinese Hong Kong	33	184
Iceland	8	18
India	103	604
Indonesia	30	157
Ireland	27	137
Italy	33	184
Japan	793	4852
Luxembourg	7	25
Mexico	40	218
Netherlands	37	204
New Zealand	53	284
Norway	17	89
Portugal	9	28
Singapore	13	76
South Africa	17	89
South Korea	10	56
Spain	53	331
Sweden	33	184
Switzerland	53	250
Thailand	17	92
United Arab Emirates	17	95
United Kingdom	173	1171
United States	1447	8219

Appendix D

Study 3. Panel C Variable Descriptions and Measurement Units

This panel defines all variables used in the analysis and their respective units of measurement. Variables include green bond issuance (dummy variable), firm characteristics (e.g., total assets, leverage, tangibility, profitability), governance metrics (e.g., independent board members, management stock ownership), and additional control variables (e.g., environmental and social pillar scores, bid-ask spread, and market competition indices).

Variable	Definition	Unit Measurement
Waste	Disposal and treatment of waste generated in the reporting company's operations in the reporting year (in facilities not owned or controlled by the reporting company).	Number
Composite Emissions Intensity	A composite measure of key atmospheric emissions, comprising (a) total carbon dioxide (CO_2) emissions, (b) nitrogen oxide (NOx) emissions, and (c) sulphur oxide (SOx) emissions. The measure follows relevant international reporting protocols and is scaled by firm revenue to control for size.	Number
Water pollutant	Total weight of water pollutant emissions in tonnes. The substances discharged into water system like PRTR (pollutant release and transfer registers) and substances, BOD (biochemical oxygen demand), COD (chemical oxygen demand) and TSS (total suspended solids) are included.	Number
Waste recycled	Total recycled and reused waste produced in tonnes. The waste used through incineration to generate energy, and waste used for composting is also considered as waste recycled. And wastes recycled include both hazardous and non-hazardous waste.	Number
VOC Emissions Intensity	Total emissions of volatile organic compounds (excluding methane and ethane), scaled by firm revenue. This metric captures emissions of non-methane hydrocarbons, which are precursors to ground-level ozone and smog.	Number
Water purchased	Total volume of water discharged in cubic meters. Water discharged for which there is no further use by the company is considered wastewater and treated wastewater and discharged information is also in scope.	Number
Green Bond Issuance	Binary variable (1 for firms with green bond issuance and years afterward, 0 otherwise).	Dummy Variable
Total Asset	Logarithmic total book assets in millions of USD.	Number
Cash Flow Volatility	Standard deviation of yearly cash flows from operations divided by total assets over the past two calendar years.	Percentage
Leverage	(Debt in current liabilities + total long-term debt) divided by total assets.	Percentage
Tangibility	Net property, plant, and equipment divided by total assets.	Percentage
Profitability	EBITDA divided by total assets.	Percentage
Market-to-Book Ratio	(Debt in current liabilities + total long-term debt + preferred stock carrying value, deferred taxes and investment tax credit + stock price at the end of the quarter * common shares outstanding) divided by total assets.	Percentage
Audit Committee Independence	Percentage of independent members in firms' audit committees.	Percentage
Independent Board Member	Percentage of independent members in firms' boards.	Percentage

Management Stock Ownership	Percentage of shares held by insiders.	Percentage
Environment Pillar Score	Weighted average relative rating based on reported environmental information.	Percentage
Social Pillar Score	Weighted average relative rating based on reported social information.	Percentage
Governance Pillar Score	Weighted average relative rating based on reported governance information.	Percentage
ESG Controversy Score	Measures a company's exposure to environmental, social, and governance controversies and negative events reflected in global media.	Percentage
ESG Score	Logarithmic score based on environmental, social, and governance pillar scores.	Percentage
Bid-Ask Spread	Ratio of difference between bid and ask prices divided by the mid-point of the bid-ask price.	Percentage
Abnormal Earnings	Disparity between last year's earnings per share forecasts and this year's actual earnings per share, scaled by the calendar year-end stock price.	Percentage
Dividend Report Frequency	Logarithmic measure of the number of months firms take to disclose a dividend report.	Number
Earnings Report Frequency	Logarithmic measure of the number of months firms take to disclose an earnings report.	Number
CEO Duality	Binary variable (1 if the Chief Executive Officer is a Chairman of the Board, 0 otherwise).	Dummy Variable
Climate Change Positive Sentiment	Percentage derived from climate change bigrams and keywords within firms' earnings call transcripts.	Percentage
Climate Change Negative Sentiment	Percentage derived from climate change bigrams and keywords within firms' earnings call transcripts.	Percentage
Climate Change Performance	Instrument to enable transparency in national and international climate politics.	Percentage
Economic Policy Uncertainty	Percentage reflecting the relative frequency of own-country newspaper articles discussing economic policy uncertainty.	Percentage

Appendix E

Study 3. Panel H Correlation matrix for waste

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1) WAS	1.000										
(2) GBI	-0.355***	1.000									
	(0.004)										
(3) lg_ta_m	0.345***	0.141***	1.000								
	(0.000)	(0.000)									
(4) profit	0.043***	0.021***	0.296***	1.000							
	(0.000)	(0.000)	(0.000)								
(5) lever	0.087***	0.076***	0.301***	0.007***	1.000						
	(0.000)	(0.000)	(0.000)	(0.000)							
(6) mbratio	-0.013	-0.011***	0.037***	-0.074***	0.136***	1.000					
	(0.014)	(0.000)	(0.000)	(0.000)	(0.000)						
(7) cash_ta	-0.019***	-0.027***	0.006***	0.044***	-0.010***	0.000	1.000				
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.827)					
(8) esgscore	0.305***	0.163***	0.543***	0.107***	0.130***	-0.035***	-0.037***	1.000			
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)				
(9) environmentalp~c	0.029***	0.003	0.031***	-0.032***	-0.041***	-0.007	-0.100***	-0.003	1.000		
	(0.000)	(0.441)	(0.000)	(0.000)	(0.000)	(0.125)	(0.000)	(0.561)			
(10) economicspoli~y	0.016***	0.012***	0.039***	-0.050***	-0.057***	-0.077***	0.077***	-0.055***	0.824***	1.000	
	(0.002)	(0.003)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)		
(11) gdppercapitag~l	-0.014***	-0.024***	0.022***	0.093***	0.002	0.059***	-0.003	-0.004	-0.338***	-0.284***	1.000
	(0.006)	(0.000)	(0.000)	(0.000)	(0.629)	(0.000)	(0.452)	(0.404)	(0.000)	(0.000)	

Study 3. Panel I Correlation matrix for water pollutant

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1) WATPOL	1.000										
(2) GBI	-0.522***	1.000									
	(0.003)										
(3) lg_ta_m	0.109***	0.141***	1.000								
	(0.000)	(0.000)									
(4) profit	0.010	0.021***	0.296***	1.000							
	(0.055)	(0.000)	(0.000)								
(5) lever	-0.007	0.076***	0.301***	0.007***	1.000						
	(0.152)	(0.000)	(0.000)	(0.000)							
(6) mbratio	-0.015***	-0.011***	0.037***	-0.074***	0.136***	1.000					
	(0.003)	(0.000)	(0.000)	(0.000)	(0.000)						
(7) cash_ta	-0.014***	-0.027***	0.006***	0.044***	-0.010***	0.000	1.000				
	(0.005)	(0.000)	(0.000)	(0.000)	(0.000)	(0.827)					
(8) esgscore	0.074***	0.163***	0.543***	0.107***	0.130***	-0.035***	-0.037***	1.000			
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)				
(9) environmentalp~c	0.003	0.003	0.031***	-0.032***	-0.041***	-0.007	-0.100***	-0.003	1.000		
	(0.579)	(0.441)	(0.000)	(0.000)	(0.000)	(0.125)	(0.000)	(0.561)			
(10) economicspoli~y	0.001	0.012***	0.039***	-0.050***	-0.057***	-0.077***	0.077***	-0.055***	0.824***	1.000	
	(0.802)	(0.003)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)		
(11) gdppercapitag~l	0.000	-0.024***	0.022***	0.093***	0.002	0.059***	-0.003	-0.004	-0.338***	-0.284***	1.000
	(0.986)	(0.000)	(0.000)	(0.000)	(0.629)	(0.000)	(0.452)	(0.404)	(0.000)	(0.000)	

Study 3. Panel J Correlation matrix for CEI

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1) CEI	1.000										
(2) GBI	-0.118***	1.000									
	(0.007)										
(3) lg_ta_m	0.227***	0.141***	1.000								
	(0.000)	(0.000)									
(4) profit	-0.013***	0.021***	0.296***	1.000							
	(0.006)	(0.000)	(0.000)								
(5) lever	0.068***	0.076***	0.301***	0.007***	1.000						
	(0.000)	(0.000)	(0.000)	(0.000)							
(6) mbratio	-0.069***	-0.011***	0.037***	-0.074***	0.136***	1.000					
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)						
(7) cash_ta	-0.043***	-0.027***	0.006***	0.044***	-0.010***	0.000	1.000				
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.827)					
(8) esgscore	0.141***	0.163***	0.543***	0.107***	0.130***	-0.035***	-0.037***	1.000			
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)				
(9) environmentalp~c	-0.028***	0.003	0.031***	-0.032***	-0.041***	-0.007	-0.100***	-0.003	1.000		
	(0.000)	(0.441)	(0.000)	(0.000)	(0.000)	(0.125)	(0.000)	(0.561)			
(10) economicspoli~y	-0.015***	0.012***	0.039***	-0.050***	-0.057***	-0.077***	0.077***	-0.055***	0.824***	1.000	
	(0.003)	(0.003)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)		
(11) gdppercapitag~l	0.015***	-0.024***	0.022***	0.093***	0.002	0.059***	-0.003	-0.004	-0.338***	-0.284***	1.000
	(0.002)	(0.000)	(0.000)	(0.000)	(0.629)	(0.000)	(0.452)	(0.404)	(0.000)	(0.000)	

Appendix F

Study 3. Subsample test for firm level

Table B1 Firm Level Subsample Analysis

Each panel includes separate regressions for subsamples split by firm level governance or risk characteristics. Chow test statistics evaluate the significance of differences in coefficients across subsamples.

	1	**2**	**3**	**4**	**5**	**6**
	Higher audit committee independence	Lower audit committee independence	Higher audit committee independence	Lower audit committee independence	Higher audit committee independence	Lower audit committee independence
	waste_kt_1	waste_kt_1	Water pollutant	Water pollutant	CEI_kt_1	CEI_kt_1
Green bond issuance	0.044	-0.012***	0.485	-1.062***	0.080	-2.357***
	(0.046)	(0.003)	(0.446)	(0.082)	(0.237)	(0.180)
All control variables						
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R2	0.9678	0.9559	0.9145	0.8128	0.9499	0.9595
Observation	11224	12074	11224	12074	12874	12906
Chow test		99.35***		131.16***		59.47***
Test statistic		(0.0000)		(0.0000)		(0.0000)

Study 3. Table B2 Firm Level Subsample Analysis

Table B1 Firm Level Subsample Analysis

Each panel includes separate regressions for subsamples split by firm level governance or risk characteristics. Chow test statistics evaluate the significance of differences in coefficients across subsamples.

	1	**2**	**3**	**4**	**5**	**6**
	Higher independent board member	Lower independent board member	Higher independent board member	Lower independent board member	Higher independent board member	Lower independent board member
	waste_kt_1	waste_kt_1	Water pollutant	Water pollutant	CEI_kt_1	CEI_kt_1
Green bond issuance	-0.072	-0.091***	0.570	-0.961***	0.012	-2.109***
	(0.075)	(0.027)	(0.737)	(0.128)	(0.251)	(0.153)
All control variables						
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R2	0.3114	0.2738	0.9187	0.8169	0.9472	0.9619
Observation	20947	3963	20697	3915	15447	11732
Chow test Test statistic		105.80*** (0.0000)		82.47*** (0.0000)		84.31*** (0.0000)

Study 3. Table B2 Firm Level Subsample Analysis

Table B1 Firm Level Subsample Analysis

Each panel includes separate regressions for subsamples split by firm level governance or risk characteristics. Chow test statistics evaluate the significance of differences in coefficients across subsamples.

	1	**2**	**3**	**4**	**5**	**6**
	Higher Management stock ownership	Lower Management stock ownership	Higher management stock ownership	Lower management stock ownership	Higher management stock ownership	Lower management stock ownership
	waste_kt_1	waste_kt_1	Water pollutant	Water pollutant	CEI_kt_1	CEI_kt_1
Green bond issuance	-0.103***	0.002	-0.615***	0.426	-1.681***	-0.277
	(0.022)	(0.088)	(0.057)	(0.410)	(0.167)	(0.245)
All control variables						
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R2	0.3452	0.3137	0.8311	0.9174	0.9391	0.9679
Observation	16845	8065	16570	8045	14350	12829
Chow test Test statistic		178.13*** (0.0000)		219.20*** (0.0000)		51.69*** (0.0000)

Table B1 Firm Level Subsample Analysis
Each panel includes separate regressions for subsamples split by firm level governance or risk characteristics. Chow test statistics evaluate the significance of differences in coefficients across subsamples.

	1	**2**	**3**	**4**	**5**	**6**
	CEO duality	Non-CEO duality	CEO duality	Non-CEO duality	CEO duality	Non-CEO duality
	waste_kt_1	waste_kt_1	Water pollutant	Water pollutant	CEI_kt_1	CEI_kt_1
Green bond issuance	-0.110	-0.088***	-0.575**	0.014	-1.940***	-0.254
	(0.086)	(0.018)	(0.229)	(0.087)	(0.199)	(0.176)
All control variables						
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R2	0.3246	0.2997	0.9237	0.8442	0.9609	0.9459
Observation	11053	13857	10898	13627	11696	15392
Chow test		291.10***		240.59***		134.37***
Test statistic		(0.0000)		(0.0000)		(0.0000)

Appendix G

This table presents the differences in all variables between the control and treated groups in the post-match PSM results. The differences for all the matching variables are insignificant.

Study 3: Comparison of control and treated groups

Average	Control	Treated	%bias	t
Total asset	9.772	9.841	4.6	0.60
Leverage	0.489	0.498	5.3	0.74
Profitability	0.067	0.070	5.8	0.72
Market-to-book ratio	0.777	0.842	5.9	1.32
Cash	0.180	0.180	-0.1	-0.01