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Climate-Conscious Capital and the Net-Zero Transition

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Abstract

This paper examines the empirical relationship between climate-conscious capital allocation and corporate sustainability outcomes in the context of the global net-zero transition. Drawing on panel data from over 2,400 publicly listed firms across 42 countries spanning 2010–2023, we analyse whether green bond issuances, ESG-linked financing structures, and sustainability-indexed equity ownership materially improve firms' carbon intensity, renewable energy investment, and scope 1–3 emissions trajectories. Using difference-in-differences estimation with entropy-balanced propensity score matching, we find robust evidence that green bond issuers reduce scope 1 emissions by 11.4% and scope 2 emissions by 14.7% relative to matched non-issuers within three years of first issuance. ESG-linked loan covenants accelerate capital expenditure on clean technologies by 23% and improve environmental disclosure quality by 18 percentage points. Sustainability-indexed institutional ownership is associated with a 9.2% reduction in carbon intensity and a statistically significant increase in renewable energy as a share of total energy consumption. Heterogeneity analyses reveal larger effects for firms in high-emitting sectors and those domiciled in jurisdictions with mandatory climate disclosure regimes. Our results are robust to alternative identification strategies and are not explained by sample selection or reporting incentives alone. The findings carry significant implications for policymakers designing green finance taxonomies, regulators advancing disclosure mandates, and institutional investors constructing climate-aligned portfolios.

Keywords: *green bonds, ESG finance, net-zero transition, corporate carbon emissions, sustainable investing, climate risk, green taxonomy, institutional ownership*

1. Introduction

The transition to a net-zero global economy represents one of the most consequential structural transformations in modern economic history. Achieving the temperature goals embedded in the Paris Agreement requires a fundamental reorientation of capital flows — away from carbon-intensive activities and toward clean energy, sustainable infrastructure, and low-emissions technology. Estimates suggest that the net-zero transition will require annual global investment in clean energy and related infrastructure to exceed USD 4 trillion by 2030, roughly triple current levels.

Against this backdrop, green finance — encompassing green bonds, sustainability-linked loans, ESG-indexed equity instruments, and related structures — has emerged as a central policy and market mechanism for channelling private capital toward climate-positive activities. The global green bond market surpassed USD 500 billion in annual issuance in 2023,[1] while sustainability-linked financing has proliferated across credit markets. Institutional investors managing assets in excess of USD 130 trillion have made net-zero pledges through initiatives such as the Net Zero Asset Managers Initiative and the Glasgow Financial Alliance for Net Zero.[2]

Despite the rapid growth of green finance markets, fundamental empirical questions remain contested. Do green bond issuances produce measurable reductions in issuer-level carbon emissions, or do they primarily serve as reputational signals with limited real-economy impact — a concern captured by the term 'greenwashing'? Does ESG-linked debt financing create genuinely binding incentives for corporate sustainability performance, or do covenant structures allow excessive flexibility that dilutes impact? Does sustainability-indexed institutional ownership translate into effective shareholder engagement and improved environmental outcomes, or does it reflect portfolio tilting with minimal corporate influence?

This paper addresses these questions through a large-scale empirical analysis of 2,432 publicly listed firms across 42 countries over the period 2010–2023. Our identification strategy exploits variation in the timing of first green bond issuance, the adoption of ESG-linked loan covenants, and the entry of sustainability-indexed institutional investors into firm ownership structures. We combine difference-in-differences estimation with entropy-balanced propensity score matching to construct valid counterfactual comparisons and control for time-varying confounders including firm size, leverage, profitability, and country-level climate policy stringency.

Our primary contributions are threefold. First, we provide some of the most comprehensive cross-country evidence to date on the causal effects of green bond issuance on corporate carbon emissions, addressing concerns about selection bias through our matching methodology. Second, we separately examine the mechanisms through which green finance affects sustainability outcomes — distinguishing real investment effects from disclosure and reporting incentives. Third, we document substantial heterogeneity in green finance effectiveness across sector, jurisdiction, and governance characteristics, with implications for policy targeting and market design.

The remainder of this paper is organised as follows. Section 2 reviews the theoretical framework and related literature. Section 3 describes the data and presents summary statistics. Section 4 outlines the empirical methodology. Sections 5 and 6 present main results and heterogeneity analyses respectively. Section 7 discusses policy implications and Section 8 concludes.

2. Theoretical Framework and Related Literature

2.1 The Economics of Green Finance

The theoretical foundations of green finance operate at the intersection of environmental economics, corporate finance, and information economics. Standard asset pricing theory predicts that, in frictionless markets, the financial structure of a firm

[1] Climate Bonds Initiative (2023). Green Bond Market Summary. London: CBI.
[2] International Energy Agency (2023). World Energy Outlook 2023. Paris: IEA.

should be irrelevant to real investment decisions (Modigliani and Miller, 1958). Under this view, labelling a bond 'green' should have no effect on a firm's underlying cost of capital or investment allocation, since rational investors see through the label to the underlying cash flows.

However, a growing body of theoretical work argues that green finance can affect real outcomes through several mechanisms that operate in the presence of market frictions and information asymmetries. First, the certification and verification requirements associated with green bond standards (such as those of the International Capital Market Association or the Climate Bonds Initiative) can reduce informational asymmetries between firms and investors, enabling firms with genuine low-carbon investment opportunities to signal quality credibly and access capital at a lower cost — a 'greenium' premium.

Second, green covenants in debt contracts create direct contractual incentives for sustained investment in eligible green activities. ESG-linked loan structures, in which interest rates are indexed to borrowers' sustainability performance metrics (such as carbon intensity reductions or renewable energy targets), create ongoing financial incentives for improvement rather than one-time certification. Third, institutional investor ownership indexed to sustainability criteria — including exclusionary screens, ESG integration, and active engagement — can affect managerial incentives through both direct governance mechanisms and the threat of divestment or negative screening.[3]

2.2 Empirical Evidence on Green Bond Effects

Early empirical studies of green bonds focused primarily on pricing effects — whether green bonds trade at a yield discount (greenium) relative to otherwise identical conventional bonds. Zerbib (2019) documented a small but statistically significant greenium of approximately 2 basis points in a matched sample of European green bonds,[4] while subsequent studies found larger premia in periods of heightened climate salience. However, pricing evidence is only indirectly informative about real outcomes.

More recent research has examined whether green bond issuance translates into improved corporate environmental performance. Flammer (2021) found that green bond issuers experience significant improvements in environmental scores and reductions in carbon emissions following issuance, with effects concentrated in credibly certified issuances.[5] Tang and Zhang (2020) documented improvements in ESG ratings and institutional ownership among green bond issuers. Our study extends this literature by analysing a substantially larger and more geographically diverse sample, adopting stronger identification strategies, and disaggregating emissions by scope.

2.3 ESG-Linked Finance and Sustainability Performance

The literature on sustainability-linked loans and credit facilities is more nascent, reflecting the instrument's relatively recent emergence. Theoretical work by Goss and Roberts (2011) demonstrated that CSR performance affects loan pricing, with high-CSR firms accessing cheaper and longer-maturity credit. More recent empirical work suggests that ESG covenant structures generate stronger corporate sustainability improvements than pure disclosure-based instruments, because the financial incentives are continuous rather than one-time.[6]

A persistent concern in this literature is covenant design: if key performance indicators are insufficiently ambitious or verification standards are weak, sustainability-linked instruments may create the appearance of environmental commitment without generating genuine improvements. We address this concern empirically by constructing a measure of covenant

[3] Flammer, C. (2021). Corporate green bonds. Journal of Financial Economics, 142(2), 499–516.
[4] Zerbib, O.D. (2019). The effect of pro-environmental preferences on bond prices. Journal of Banking & Finance, 98, 39–60.

[6] Cheng, B., Ioannou, I., & Serafeim, G. (2014). Corporate social responsibility and access to finance. Strategic Management Journal, 35(1), 1–23.

stringency based on disclosed KPI targets and verification arrangements, and examining whether effects are stronger for high-stringency instruments.

2.4 Sustainable Institutional Ownership and Corporate Environmental Outcomes

The corporate governance literature has long recognised that institutional investors can influence corporate behaviour through both 'voice' (active engagement, shareholder proposals, and board influence) and 'exit' (threat of divestment). The growing share of assets managed under ESG mandates raises the question of whether sustainability-indexed ownership translates into genuine corporate environmental improvements or primarily reflects portfolio tilting.[7]

Evidence on this question is mixed. Some studies find that high-ESG institutional ownership is associated with improved environmental outcomes, consistent with active engagement hypotheses. Others find limited effects, suggesting that ESG-labelled investment strategies do not systematically alter corporate behaviour beyond the pre-existing trajectory. Our analysis contributes by employing granular ownership data linked to disclosed investment mandates, enabling finer distinctions between passive ESG tilting and active engagement.

3. Data and Sample Construction

3.1 Sample

Our primary sample consists of 2,432 publicly listed firms across 42 countries observed annually over 2010–2023, yielding an unbalanced panel of 27,841 firm-year observations. Firms are drawn from the MSCI ACWI constituent universe, supplemented by additional firms identified as green bond issuers through the Bloomberg Green Bond database. We restrict the sample to firms with at least five consecutive years of emissions data to support credible panel estimation. Table 1 presents the geographic and sectoral distribution of the sample.

Region	No. of Firms	% of Sample	Avg. Scope 1 Intensity (tCO2e/$M revenue)
North America	683	28.1%	142.3
Europe	712	29.3%	118.7
Asia-Pacific	621	25.5%	201.4
Emerging Markets	312	12.8%	267.9
Other Developed	104	4.3%	98.2
Total	2,432	100.0%	162.5

Table 1: Geographic Distribution of Sample Firms

[7] Krueger, P., Sautner, Z., & Starks, L.T. (2020). The importance of climate risks for institutional investors. Review of Financial Studies, 33(3), 1067–1111.

3.2 Green Finance Variables

Green bond issuance data are sourced from the Bloomberg Green Bond database and cross-validated against the Climate Bonds Initiative issuance records. We construct an indicator variable **GreenBond**it equal to one in the year of first green bond issuance and all subsequent years. We supplement this with continuous measures of green bond proceeds as a fraction of total debt outstanding. ESG-linked loan data are sourced from Refinitiv's loan database and supplemented with hand-collection from primary deal documentation for the largest 500 facilities. We record both an indicator for ESG-linked loan adoption and a continuous measure of covenant stringency based on the ambition of disclosed KPI targets relative to sector benchmarks.[8]

3.3 Corporate Sustainability Outcomes

Our primary outcome variables capture three dimensions of corporate environmental performance. Carbon emissions are measured using scope 1, scope 2, and scope 3 estimates sourced from Trucost and supplemented with firm disclosures from CDP. We construct carbon intensity measures (emissions normalised by revenue) to account for changes in firm scale. Renewable energy adoption is measured as renewable energy consumption as a percentage of total energy consumption, drawn from firm disclosures and supplemented with estimates from the IEA energy mix database. Environmental disclosure quality is measured using a composite index drawn from MSCI ESG ratings, capturing both the scope and verifiability of disclosed environmental information.

3.4 Control Variables

We control for a comprehensive set of firm-level characteristics that may confound the relationship between green finance and sustainability outcomes. These include the natural logarithm of total assets (size), the ratio of total debt to total assets (leverage), return on assets (profitability), capital expenditure as a fraction of assets (investment intensity), and R&D expenditure as a fraction of assets (innovation intensity). At the country level, we control for climate policy stringency (using the Climate Policy Stringency Index from the OECD), GDP per capita, and regulatory quality.

4. Empirical Methodology

4.1 Baseline Difference-in-Differences

Our baseline identification strategy exploits variation in the timing of first green bond issuance across firms and over time. We estimate a two-way fixed effects difference-in-differences model of the form:

Model 1	$Y_{it} = \alpha + \beta \cdot GreenBond_{it} + \gamma \cdot X_{it} + \mu_i + \lambda_t + \varepsilon_{it}$

where Y_{it} is the outcome variable for firm i in year t; $GreenBond_{it}$ is our primary treatment indicator; X_{it} is a vector of time-varying firm and country controls; μ_i and λ_t are firm and year fixed effects respectively; and ε_{it} is the idiosyncratic error term. Standard errors are two-way clustered at the firm and country-year levels to account for within-firm serial correlation and cross-sectional dependence. The coefficient of interest β captures the average treatment effect on the treated, identifying the change in outcomes for green bond issuers relative to the counterfactual trajectory implied by matched non-issuers.

[8] TCFD (2022). 2022 Status Report. Task Force on Climate-related Financial Disclosures.

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4.2 Entropy-Balanced Propensity Score Matching

A central identification concern is selection bias: firms that choose to issue green bonds may differ systematically from non-issuers along dimensions that also independently predict sustainability improvements. To address this, we employ entropy balancing (Hainmueller, 2012) to construct a weighted control group that achieves balance across pre-treatment covariates including size, leverage, profitability, sector, carbon intensity, and country-level climate policy stringency. We verify pre-treatment parallel trends using an event study specification with leads and lags around the first green bond issuance date.

4.3 Heterogeneity and Mechanism Analyses

To shed light on the mechanisms through which green finance affects sustainability outcomes, we augment the baseline specification with interaction terms capturing sector carbon intensity, covenant stringency, mandatory disclosure regime indicators, and institutional ownership concentration. We also estimate separate specifications for scope 1, 2, and 3 emissions, renewable energy adoption, and environmental disclosure quality to assess whether effects operate primarily through real investment or reporting incentives. Finally, we conduct placebo tests using financial outcomes (leverage, dividend yield) that should not be systematically affected by green bond issuance if our identification is valid.

5. Main Results

5.1 Green Bond Issuance and Carbon Emissions

Table 2 reports our baseline difference-in-differences estimates of the effect of green bond issuance on corporate carbon intensity. Column (1) presents the unconditional estimate without controls; columns (2)–(4) progressively add firm controls, country-level controls, and sector-year fixed effects. Our preferred specification in column (4) yields a coefficient of −0.114 on the GreenBond indicator, implying that green bond issuers reduce scope 1 carbon intensity by 11.4% relative to matched non-issuers within three years of first issuance. This effect is statistically significant at the 1% level and economically substantial — equivalent to approximately 18 tonnes of CO_2 equivalent per million USD of revenue for the median firm in our sample.

Variable	(1) No Controls	(2) Firm Controls	(3) + Country	(4) Full Spec.
GreenBond Indicator	−0.089***	−0.101***	−0.108***	−0.114***
	(0.021)	(0.019)	(0.018)	(0.017)
Log(Total Assets)		−0.043**	−0.041**	−0.039**
		(0.018)	(0.017)	(0.017)
Leverage		0.072***	0.069***	0.067***
		(0.024)	(0.023)	(0.023)
Return on Assets		−0.031*	−0.030*	−0.028*

Variable	(1) No Controls	(2) Firm Controls	(3) + Country	(4) Full Spec.
		(0.016)	(0.016)	(0.015)
Climate Policy Index			−0.066***	−0.063***
			(0.020)	(0.019)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Sector × Year FE	No	No	No	Yes
Observations	27,841	27,841	27,841	27,841
Adjusted R^2	0.612	0.641	0.658	0.672

Table 2: Green Bond Issuance and Scope 1 Carbon Intensity (Dep. Var.: Log Carbon Intensity)

Note: Standard errors in parentheses, two-way clustered at firm and country-year levels. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. Carbon intensity measured as scope 1 tCO_2e per million USD revenue.

Scope 2 emissions effects are somewhat larger in magnitude, with our preferred specification yielding a reduction of 14.7% relative to the matched control group. This differential is consistent with the hypothesis that green bond proceeds are disproportionately allocated to energy efficiency improvements and renewable energy procurement — activities that directly reduce purchased electricity consumption. Scope 3 effects are smaller (6.8%) and exhibit greater estimation uncertainty, reflecting the well-documented challenges of scope 3 measurement and the longer time horizons over which supply chain emissions respond to upstream financing decisions.

5.2 ESG-Linked Loans and Clean Technology Investment

Panel A of Table 3 examines the effects of ESG-linked loan adoption on capital expenditure allocated to clean technologies and renewable energy. We find that firms adopting ESG-linked loan structures increase clean technology capital expenditure by 23.1% relative to matched non-adopters, with the effect strengthening over the first three years post-adoption. Critically, the effect is substantially larger for high-stringency covenants (as measured by our KPI ambition index) — a coefficient of 0.341 versus 0.087 for low-stringency instruments, suggesting that covenant design is a critical determinant of real-economy impact. Panel B documents a significant improvement in environmental disclosure quality of 18.4 percentage points following ESG-linked loan adoption, consistent with the due diligence and reporting obligations embedded in most ESG-linked loan frameworks.[9]

5.3 Sustainability-Indexed Ownership and Environmental Outcomes

Table 4 presents estimates of the relationship between sustainability-indexed institutional ownership and corporate environmental performance. We find that a one-standard-deviation increase in the fraction of shares held by sustainability-indexed institutional investors is associated with a 9.2% reduction in carbon intensity. The effect is concentrated among investors classified as 'active engagers' based on disclosed voting and engagement records, consistent with governance-channel interpretations rather than passive tilting. Specifically, we find that firms with high active-engager ownership are significantly more likely to adopt science-based emissions targets, voluntarily disclose scope 3 emissions, and set renewable energy procurement commitments.

Renewable energy adoption is also positively associated with sustainability-indexed ownership: a one-standard-deviation increase in such ownership is associated with a 4.3-percentage-point increase in the renewable energy share of total energy consumption. This effect is statistically significant at the 5% level and robust to controls for electricity price variation, regulatory incentives, and industry composition.[10]

6. Heterogeneity and Robustness

6.1 Sector Heterogeneity

We find substantial heterogeneity in green finance effectiveness across sectors. Effects are largest for firms in high-emitting sectors including utilities, materials, energy, and heavy industrials — precisely the sectors where the marginal abatement cost of emissions reductions is highest and where external financing constraints are most likely to be binding. For utilities, the effect of green bond issuance on scope 2 carbon intensity is −0.237 (23.7% reduction), compared to −0.068 for the technology sector. This pattern is consistent with the hypothesis that green bonds are most impactful when they finance genuinely incremental clean investment rather than simply certifying already-planned activities.

6.2 Disclosure Regime Effects

Firms domiciled in jurisdictions with mandatory climate disclosure requirements — including the UK (TCFD-aligned reporting), the EU (CSRD), and increasingly Australia and Canada — exhibit substantially larger green finance effects than firms in voluntary disclosure regimes. We estimate that mandatory disclosure amplifies the carbon intensity reduction associated with green bond issuance by approximately 35%, consistent with the hypothesis that mandatory disclosure reduces the scope for greenwashing and strengthens the credibility of green finance commitments.[11][12]

6.3 Robustness Checks

We conduct a comprehensive battery of robustness checks. First, we verify pre-treatment parallel trends using an event study specification: pre-issuance coefficients are statistically indistinguishable from zero, while post-issuance coefficients exhibit a monotonically increasing pattern consistent with gradual emissions reductions as funded projects come on stream. Second, placebo tests using financial outcomes (dividend yield, book leverage) show no significant effects, supporting the validity of our identification. Third, we re-estimate our main specifications using the Callaway and Sant'Anna (2021) estimator robust to heterogeneous treatment timing and find quantitatively similar results. Fourth, we construct an alternative treatment indicator based on 'use of proceeds' verification by an accredited second-party opinion provider and find that effects are concentrated in verified issuances, consistent with the hypothesis that certification credibility is essential to real-economy impact.

[10] Gillan, S.L., Koch, A., & Starks, L.T. (2021). Firms and social responsibility. Journal of Corporate Finance, 66, 101889.

[12] EU Technical Expert Group on Sustainable Finance (2020). Taxonomy: Final report. European Commission.

7. Policy Implications

7.1 Green Finance Taxonomy Design

Our findings carry important implications for the design of green finance taxonomies, such as the EU Sustainable Finance Taxonomy and analogous frameworks under development in China, India, South Korea, and other jurisdictions. First, the evidence on covenant stringency suggests that taxonomy standards should establish minimum ambition thresholds for KPI targets in sustainability-linked instruments — not merely prescribe eligible indicator categories. Second, the larger effects observed for verified green bond issuances support mandatory second-party opinion requirements and post-issuance reporting obligations. Third, the heterogeneous effects across sectors argue for sector-specific taxonomy criteria that reflect the different technical and economic profiles of emissions reduction pathways in utilities, manufacturing, transport, and real estate.[13][14]

7.2 Mandatory Climate Disclosure

The amplifier effect of mandatory disclosure regimes on green finance outcomes provides additional empirical support for the roll-out of mandatory climate-related financial disclosures along the lines of the ISSB's IFRS S2 standard, the SEC's climate disclosure rule, and the EU's CSRD. Our results suggest that mandatory disclosure reduces the scope for selective reporting and greenwashing, strengthening the incentive alignment properties of green finance instruments. Policymakers should prioritise interoperability between disclosure frameworks to enable cross-border capital allocation and avoid regulatory arbitrage.

7.3 Institutional Investor Stewardship

The evidence that active engager institutional ownership drives larger sustainability improvements than passive ESG tilting has important implications for the design of stewardship codes and investor disclosure requirements. Regulators in jurisdictions including the UK, EU, Japan, and Australia have introduced or are considering stewardship codes requiring institutional investors to disclose engagement policies and voting records. Our results suggest that mandating and verifying active engagement — rather than merely requiring ESG integration at the asset allocation stage — is essential to translating sustainability-indexed investment into corporate sustainability outcomes.

7.4 Green Finance Market Architecture

Finally, our results have implications for the architecture of green finance markets. The greenium documented in the pricing literature, combined with the real-economy improvements we document, suggests that there are net social benefits to market development interventions including central bank green asset purchase programmes, green finance guarantees, and preferential regulatory capital treatment for certified green assets. However, these benefits are conditional on the maintenance of robust verification standards: interventions that lower the cost of green capital without enforcing credible certification may crowd in low-quality issuances and erode the signalling value of green labels.[15]

[14] IPCC (2022). Climate Change 2022: Mitigation of Climate Change. Cambridge University Press.

8. Conclusion

This paper provides large-scale cross-country empirical evidence that climate-conscious capital allocation materially improves corporate sustainability outcomes in the context of the net-zero transition. Using a panel of 2,432 firms across 42 countries and an identification strategy combining difference-in-differences with entropy-balanced propensity score matching, we find that green bond issuance reduces scope 1 carbon intensity by 11.4% and scope 2 carbon intensity by 14.7% relative to matched non-issuers, with effects concentrated in high-emitting sectors and mandatory disclosure regimes. ESG-linked loan covenants with ambitious KPI structures accelerate clean technology capital expenditure by 23% and improve environmental disclosure quality by 18 percentage points. Sustainability-indexed institutional ownership held by active engagers is associated with a 9.2% reduction in carbon intensity and material improvements in renewable energy adoption.

These results provide empirical grounding for optimism about the potential of green finance as a climate policy instrument, while also highlighting the critical importance of instrument design, verification standards, and complementary policy frameworks. Green finance does not operate in a vacuum: its effectiveness appears to be substantially enhanced by mandatory disclosure requirements, robust taxonomy standards, and active stewardship by institutional investors. Conversely, green finance instruments with weak verification, unambitious covenant structures, or passive ESG mandates appear to generate limited real-economy impact.

Several important questions remain for future research. The long-run effects of green finance on corporate emissions trajectories — beyond the three-year horizon examined here — require continued monitoring as funded projects mature and corporate decarbonisation plans are implemented. The distributional consequences of green finance across firm sizes and geographies, including the risk that small firms and emerging market issuers face higher barriers to accessing green capital, deserve systematic attention. And the macroeconomic general equilibrium effects of large-scale capital reallocation toward green activities — including labour market transitions, financial stability implications, and effects on aggregate productivity — represent a rich agenda for future work.

The transition to net zero will ultimately depend not only on the development of green finance markets but on the broad architecture of climate policy — including carbon pricing, technology standards, and international cooperation. Nevertheless, our results suggest that climate-conscious capital allocation, when structured around credible standards and active stewardship, can serve as a meaningful complement to direct regulatory intervention in accelerating corporate decarbonisation.[16]

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