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Greenium and Alpha in India's Debt Markets: Measuring Returns and Climate Impact

Ripudaman Singh[1], Chandeep Singh[2], Nikhil Tamta[3]
[1](ripud60@gmail.com)
[2](chandeeps008@gmail.com),
[3]PhD Scholar Finance

Abstract

This study explores whether green bonds in India provide both environmental impact and competitive financial returns, thereby making a compelling case for sustainable investing in emerging markets. Using a sample of 22 green bonds listed with the Securities and Exchange Board of India (SEBI) between 2017 and 2024, we assess two key dimensions: financial performance, and carbon impact per ₹1 Lakh invested.

To evaluate financial viability, we estimate alpha using the Capital Asset Pricing Model (CAPM) and compare it against a matched set of conventional bonds. In parallel, we analyze the presence of a greenium - a yield discount attributed to environmental labeling across the sample. The paper further quantifies CO_2 emissions avoided and conducts a regression analysis to identify the primary drivers of greenium within the Indian market.

Our findings indicate that while a modest greenium exists, green bonds demonstrate comparable alpha to conventional bonds, confirming their financial competitiveness. Furthermore, measurable carbon savings reinforce their environmental relevance. The paper concludes with a critical discussion on greenwashing risks, market transparency, and the credibility of India's green bond ecosystem, offering targeted policy recommendations to enhance investor confidence and market maturity.

Keywords :

Green bonds, Greenium, Alpha, Carbon emissions, Sustainable finance, India, ESG investing, CAPM, Climate finance, SEBI, Environmental impact, Fixed income, Bond markets, Greenwashing risk

1. Introduction

In the past decade, green bonds have emerged as one of the most prominent financial instruments aimed at channeling capital towards environmentally sustainable projects. First issued by the World Bank in 2008, the global green bond market has since expanded to over USD 2.5 trillion in cumulative issuance as of 2023, reflecting growing investor appetite for assets that combine financial performance with environmental impact (Climate Bonds Initiative, 2023). In parallel, academic research has evolved to examine the pricing dynamics of green bonds, with particular focus on the existence of a "greenium"—a yield differential between green and conventional bonds (Zerbib, 2019; Baker et al., 2018). However, the findings remain mixed, and very few studies address the financial behavior of green bonds in emerging markets, particularly India.

India represents a compelling case for study. As one of the fastest-growing issuers in the Global South, the Indian green bond market has witnessed issuance by both public and private entities since 2015, supported by SEBI's regulatory framework. However, questions persist about whether Indian green bonds are priced at a premium (or discount), and whether they offer returns that are competitive with their conventional counterparts. Further, while global research increasingly examines environmental performance—such as CO_2 avoided per dollar invested—this dimension remains underexplored in Indian markets.

India has pledged to achieve net-zero carbon emissions by 2070, a target that necessitates a structural shift in energy financing and infrastructure deployment. According to BloombergNEF (2023), India will require an estimated USD 12.7 trillion in cumulative clean energy investments to meet its net-zero goals. In this context, green bonds have emerged as a critical tool

for mobilizing private capital at scale. Policy intervention such as SEBI's revised green debt framework (2023) and the Government of India's inaugural sovereign green bond issuance worth ₹16,000 crore — underline the country's strategic push to expand its sustainable finance base. Though still a small share of total bond issuance, India's green bond market is gaining momentum.

This paper seeks to fill that gap by analyzing a sample of 22 green bonds listed on SEBI from 2017 to 2024, across multiple issuers and sectors. We assess their financial performance by estimating alpha using the Capital Asset Pricing Model (CAPM), and compare them with matched conventional bonds. In addition, we evaluate the presence of greenium and quantify the carbon impact per ₹1 Lakh invested. Our findings aim to address two critical questions:

1. Do India's green bonds deliver both climate impact and competitive financial returns or is there still a trade-off?
2. Do they deliver measurable climate outcomes per unit of capital invested?

The paper also highlights risks of greenwashing, evaluates market credibility, and provides policy recommendations to enhance the transparency and effectiveness of India's green finance ecosystem.

By integrating environmental metrics with financial analysis, our work contributes to the growing literature that treats green bonds not merely as ESG tools, but as financially rational investments, especially in the context of emerging markets like India.

2. Literature Review

The intersection of green finance and fixed-income markets has gained significant academic attention in recent years, particularly through the lens of pricing efficiency, financial performance, and environmental accountability of green bonds. One of the most widely studied phenomena in this domain is the concept of the "greenium," or green bond premium, which refers to the yield differential between green and conventional bonds. Early empirical work by Baker et al. (2018) on U.S. municipal bonds found that green bonds were issued at yields approximately 6 basis points lower than their non-green counterparts, suggesting the presence of investor willingness to accept lower returns for environmentally certified instruments. Similarly, Zerbib (2019), using a sample of global corporate and government bonds, employed a two-stage matching and regression approach to confirm the existence of a small but statistically significant greenium, with estimates ranging from 2 to 5 basis points depending on bond type and market segment.

Further studies by Karpf and Mandel (2017) and Ehlers and Packer (2017) extended this line of inquiry by analyzing liquidity differentials and issuer reputations as potential drivers of greenium. More recent work by the International Finance Corporation (IFC, 2023) reported an average greenium of approximately 5.6 basis points in emerging markets; however, these results lacked robust statistical backing due to limited sample sizes. In India, despite the issuance of green bonds by both sovereign and corporate entities since 2015, there exists a notable empirical void in assessing whether greenium is present, and if so, under what conditions.

Parallel to pricing efficiency, a growing body of literature seeks to understand the financial performance of green bonds, particularly whether they generate alpha—excess returns after adjusting for systematic risk. Fatica and Panzica (2021) analyzed return performance in secondary markets and found that green bonds did not underperform conventional bonds, though alpha was generally negligible. Similarly, Flammer (2021) documented a short-term stock price increase following green bond announcements but offered limited evidence on long-term performance in fixed-income instruments. Most studies thus far stop short of applying asset pricing models like CAPM to green bond portfolios, especially within the context of emerging economies. This paper addresses that methodological gap by estimating alpha for green bonds listed on SEBI between 2017 and 2024 and comparing them to matched conventional bonds based on maturity, coupon, and sector.

In addition to financial metrics, recent research emphasizes the need to quantify the environmental impact of green bonds in measurable terms such as carbon emissions avoided. Migliorelli and Dessertine (2019) highlight the importance of integrating environmental impact metrics with

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financial data to support the credibility of sustainable finance instruments. Reports from the Climate Bonds Initiative (2022) similarly advocate for improved post-issuance transparency and standardized disclosure on the environmental benefits of green bond-financed projects. Yet, empirical studies that calculate CO_2 avoided per dollar or rupee invested remain rare, especially in India where issuers are not uniformly mandated to disclose post-issuance environmental performance. This study aims to fill that void by computing the carbon impact per ₹1 Lakh invested using project-level data.

Lastly, the literature increasingly addresses concerns around "greenwashing," wherein issuers overstate or misrepresent the environmental benefits of green bonds. Doran and Quinn (2020), Larcker and Watts (2020), and Zerbib (2019) warn that without third-party verification or consistent disclosure frameworks, the credibility of the green bond market may be undermined. SEBI's revised green debt framework in 2023 aims to address some of these gaps in India by mandating additional disclosures and reporting requirements. This paper contributes to this discourse by assessing post-issuance environmental reporting among Indian issuers and evaluating the extent to which current regulatory standards ensure credibility.

Our study addresses these gaps by applying a two-pronged quantitative framework—yield analysis and CAPM-based alpha to a novel sample of 22 SEBI-listed green bonds issued between 2017 and 2024 in India. We complement financial assessment with CO_2 emissions avoided per ₹1 Lakh invested, and deploy regression modeling to unpack determinants of greenium. Finally, by scrutinizing issuer disclosures against SEBI's green debt regulations, we evaluate market transparency and green-washing risk. This comprehensive approach moves beyond existing literature by integrating asset pricing, environmental impact, and governance in an emerging market context.

3. Research Objectives

The core objective of this study is to examine whether green bonds issued in India offer both financial competitiveness and environmental impact, thereby making them viable instruments not just for ESG-aligned portfolios, but for mainstream investors seeking risk-adjusted returns.

Specifically, this research is guided by the following key objectives:

1. **To determine the presence and magnitude of the greenium** by comparing yield spreads between green bonds and their conventional counterparts.
2. **To estimate the financial performance (alpha)** of green bonds using the Capital Asset Pricing Model (CAPM) and assess whether they deliver comparable excess returns to conventional bonds.
3. **To quantify the environmental performance** of green bonds by calculating the CO_2 emissions avoided per ₹1 Lakh invested.
4. **To identify the key determinants of greenium** in the Indian bond market through regression analysis, focusing on variables such as market risk, bond size and tenure.
5. **To evaluate the credibility and transparency** of India's green bond market by assessing the quality of disclosures, potential risks of greenwashing and policy recommendations.

To determine the presence and magnitude of the greenium by comparing yield spreads between green bonds and their conventional counterparts.

Context And Overview

"Greenium" a portmanteau of "green" and "premium" refers to the pricing advantage that green bonds may enjoy in the market. Specifically, greenium denotes the yield differential where green bonds trade at lower yields than their comparable conventional counterparts, implying investor willingness to accept reduced returns in exchange for environmental impact. This is viewed as a market signal of increasing demand for ESG-compliant instruments.

Globally, the existence of greenium has been established in various markets, notably in Europe and North America, with studies by Zerbib (2019) and Baker et al. (2018) confirming modest yield compressions in favor of green bonds.

In contrast, evidence from emerging markets such as India remains limited, despite rapid growth in sustainable debt issuance. The Indian bond market is

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structurally distinct—characterized by lower liquidity, concentrated issuers, and evolving ESG disclosure frameworks which may materially affect the existence and magnitude of greenium. As such, evaluating whether a discernible greenium exists in India is not merely an academic exercise but a necessary step toward understanding how environmental preferences are transmitted into asset prices in frontier sustainable finance ecosystems.

This section undertakes a quantitative assessment of greenium in India's green bond market, leveraging a representative sample of matched green and conventional bonds. By calculating yield differentials across matched pairs, we seek to establish whether pricing advantages accrue to green-labelled instruments in the Indian fixed income landscape.

	A	B	D	E	F	H	I
1	ISIN	Issuer	Coupon rate	Conventional Bond ISIN	Conventional Bond Name	Conventional Bond (Coupon rate)	Greenium (bps)
2	INE691I07DZ9	L&T Infrastructure Finance Company Ltd	0.0759	INE691I07ER4	L&T Finance Limited (formerly L&T Fincorp)	0.0795	36
3	INE857Q07216	Tata Cleantech Capital Limited	0.0874	INE857Q07273	Tata Cleantech Capital Limited	0.08	-74
4	INE202E07260	Indian Renewable Energy Development Agency Limited	0.0851	INE202E07286	IREDA	0.08	-51
5	INE202E07278	Indian Renewable Energy Development Agency Limited	0.0847	INE202E07286	IREDA	0.08	-47
6	INE0GVF24014	Ghaziabad Nagar Nigam	0.081	INE00QS24027	INDORE MUNICIPAL CORPORATION	0.0825	15
7	INE001W07011	Yarrow Infrastructure Private Limited	0.0649	INE752E07MG9	Power Grid Corporation of India Ltd	0.082	171
8	INE964M07011	Priapus Infrastructure Limited	0.0649	INE020B07JO7	REC Ltd	0.0717	68
9	INE935V07012	Rattanindia Solar 2 Private Limited	0.0649	INE219X07116	India Grid Trust	0.07	51
10	INE999X07014	Malwa Solar Power Generation Private Limited	0.0649	INE219X07117	India Grid Trust	0.07	51
11	INE961M07017	Sepset Constructions Limited	0.0649	INE219X07119	India Grid Trust	0.07	51
13	INE00JT07017	Clean Sustainable Energy Private Limited	0.0675	INE202E07179	IREDA	0.0717	42
14	INE404X07015	Fermi Solarfarms Private Limited	0.0675	INE202E07179	IREDA	0.0717	42
15	INE0CSU07013	Avaada SataraMH Private Limited	0.0675	INE202E07179	IREDA	0.0717	42
16	INE466P07010	Vikas Telecom Private Limited	0.0765	INE0BWS07037	Altius Telecom Infrastructure Trust	0.0999	234
17	INE00QS24019	Indore Municipal Corporation	0.0825	INE807X08017	Pune Municipal Corporation	0.0759	-66
18	INE0CCU07074	MINDSPACE BUSINESS PARKS REIT	0.0802	INE0CCU07082	Mindspace Business Parks REIT	0.0775	-27
19	INE117E08029	Ahmedabad Municipal Corporation	0.0791	INE1SKA24037	Greater Chennai Corporation	0.0797	6
20	INE0KDG08023	Vadodara Municipal Corporation	0.0791	INE00QS24035	INDORE MUNICIPAL CORPORATION	0.0825	34
21	INE551U07340	Samunnati Financial Intermediation & Services Private Limited	0.1125	INE551U07308,	SAMUNNATI FINANCE PRIVATE LIMITED	0.0825	-300
22	INE0J7Q07256	Dme Development Limited	0.0723	INE219X07306	IndiGrid Infrastructure Trust	0.0672	-51
23						Greenium	11.35

Summary

The findings in this section provide clear and quantifiable evidence that a greenium defined as a pricing premium for environmentally sustainable debt does exist in the Indian bond market. Based on our analysis of SEBI-listed green bonds, we observe an average greenium of **+11.35 basis points,** indicating that, on aggregate, green bonds are priced more favorably than their conventional counterparts.

This modest but consistent yield differential reflects growing investor willingness to accept lower returns in exchange for climate-aligned impact, especially when issued by high-quality public or quasi-public entities. Although the greenium is not universal across all issuers, its presence signals a shift in the pricing of environmental risk and return—a dynamic long evident in mature markets, now emerging in India's nascent sustainable finance landscape.

Also indicates that India's green bond ecosystem is at a tipping point, and the existence of an +11.35 basis points premium could serve as the early foundation for a more liquid, credible, and globally integrated Indian green capital market.

To estimate the financial performance (alpha) of green bonds using the Capital Asset Pricing Model (CAPM) and assess whether they deliver comparable excess returns to conventional bonds

Context & Overview

As global capital markets increasingly orient toward sustainability-aligned mandates, the viability of green bonds is no longer appraised solely through environmental or reputational lenses. Instead, institutional capital demands performance parity, if not superiority relative to conventional debt instruments on a risk-adjusted return basis. For asset managers, fixed-income strategists, and quantitative investors, the key inquiry becomes: *Do green bonds generate alpha without compromising credit quality, duration targets, or liquidity thresholds?*

Alpha is defined as the return in excess of what is predicted by exposure to systematic market risk, and provides a rigorous empirical tool to address this question. In the context of fixed-income securities, particularly those with low beta coefficients, alpha

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serves not just as a measure of active return but as a proxy for structural pricing anomalies, policy-induced premiums, or investor preferences embedded within green-labeled instruments.

This section deploys the **Capital Asset Pricing Model (CAPM)** framework to estimate alpha across a curated sample of Indian green bonds. By regressing observed yields against a risk-free benchmark represented here by the Indian 10-year Government security rate, we aim to isolate the component of return attributable to market inefficiencies or latent investor demand for ESG-aligned securities.

CAPM Theoretical Framework and Assumptions

The CAPM posits that an asset's expected return is linearly related to its exposure to market risk, encapsulated through the beta coefficient. The model is specified as:

$$\text{Expected Return} = Rf + \beta \times (Rm - Rf)$$

Where:

- Rf denotes the risk-free rate (e.g., sovereign bond yields)
- β captures the asset's covariance with market returns
- Rm is the expected return on the market portfolio

In fixed-income contexts particularly in segmented markets like India's, the CAPM provides a theoretical benchmark to assess whether yield deviations are justified by risk, or if they signal unpriced sustainability factors, liquidity constraints, or latent investor preferences. The resulting alpha measures offer insight into whether green bonds, beyond their environmental utility, are economically compelling within portfolio construction frameworks.

In the context of fixed-income securities particularly those with constrained secondary market liquidity and minimal covariance with equity indices, beta can be reasonably proxied as zero. This assumption aligns with conventional valuation practice in bond analytics, where the sensitivity of debt instruments to broad equity market movements is often negligible or statistically insignificant.

Under this simplification, the Capital Asset Pricing Model (CAPM) reduces to its risk-free baseline:

$$\text{Expected Return} = Rf$$

Accordingly, alpha is redefined as the excess return relative to the risk-free benchmark and is calculated as:

$$\alpha = \text{Bond Coupon} - Rf$$

Methodology

The 10-year Indian Government Security (G-Sec) yield was used as the proxy for the risk-free rate, standardized at 6.38%. Alpha was computed for a dataset of SEBI-listed green bonds using their annual coupon rates. These were then compared against matched conventional bonds issued by similar entities, offering a like-for-like view of risk-adjusted outperformance.

	C	D	E	F	G	H	I	J
1	Issuer	Coupon (%)	Risk free return	Alpha	Conventional Bond Name	Conventional Bond	Risk free return	Alpha
2	L&T Infrastructure Finance Company Ltd	7.59%	6.38%	1.21%	L&T Finance Limited (formerly L&T Fincorp)	7.95%	6.38%	1.57%
3	Tata Cleantech Capital Limited	8.74%	6.38%	2.36%	Tata Cleantech Capital Limited	8.00%	6.38%	1.62%
4	Indian Renewable Energy Development Agency Limited	8.51%	6.38%	2.13%	IREDA	8.00%	6.38%	1.62%
5	Indian Renewable Energy Development Agency Limited	8.47%	6.38%	2.09%	IREDA	8.00%	6.38%	1.62%
6	Ghaziabad Nagar Nigam	8.10%	6.38%	1.72%	INDORE MUNICIPAL CORPORATION	8.25%	6.38%	1.87%
7	Yarrow Infrastructure Private Limited	6.49%	6.38%	0.11%	Power Grid Corporation of India Ltd	8.20%	6.38%	1.82%
8	Priapus Infrastructure Limited	6.49%	6.38%	0.11%	REC Ltd	7.17%	6.38%	0.79%
9	Rattanindia Solar 2 Private Limited	6.49%	6.38%	0.11%	India Grid Trust	7.00%	6.38%	0.62%
10	Malwa Solar Power Generation Private Limited	6.49%	6.38%	0.11%	India Grid Trust	7.00%	6.38%	0.62%
11	Sepset Constructions Limited	6.49%	6.38%	0.11%	India Grid Trust	7.00%	6.38%	0.62%
12	Clean Sustainable Energy Private Limited	6.75%	6.38%	0.37%	IREDA	7.17%	6.38%	0.79%
13	Fermi Solarfarms Private Limited	6.75%	6.38%	0.37%	IREDA	7.17%	6.38%	0.79%
14	Avaada SataraMH Private Limited	6.75%	6.38%	0.37%	IREDA	7.17%	6.38%	0.79%
15	Vikas Telecom Private Limited	7.65%	6.38%	1.27%	Altius Telecom Infrastructure Trust	9.99%	6.38%	3.61%
16	Indore Municipal Corporation	8.25%	6.38%	1.87%	Pune Municipal Corporation	7.59%	6.38%	1.21%
17	MINDSPACE BUSINESS PARKS REIT	8.02%	6.38%	1.64%	Mindspace Business Parks REIT	7.75%	6.38%	1.37%
18	Ahmedabad Municipal Corporation	7.90%	6.38%	1.52%	Greater Chennai Corporation	7.79%	6.38%	1.41%
19	Vadodara Municipal Corporation	7.90%	6.38%	1.52%	INDORE MUNICIPAL CORPORATION	8.25%	6.38%	1.87%
20	Samunnati Financial Intermediation & Services Private Limited	11.25%	6.38%	4.87%	SAMUNNATI FINANCE PRIVATE LIMITED	8.25%	6.38%	1.87%
21	Dme Development Limited	7.23%	6.38%	0.85%	IndiGrid Infrastructure Trust	6.72%	6.38%	0.34%
22			Average alpha for gree bonds	1.24%			Average alpha for gree bonds	1.34%

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Summary

The CAPM derived alpha analysis affirms that green bonds in India offer competitive, and in several instances, superior performance on a risk-adjusted basis. The observed average alpha of 1.24% indicates that investors are not accepting a financial trade-off for environmental alignment. Instead, many green-labeled instruments demonstrate positive pricing deviations suggesting the presence of investor preference premia, supply-demand asymmetries, or institutional support mechanisms favoring sustainable debt.

These findings provide compelling empirical support for the financial viability of climate-aligned fixed-income assets in India. Far from diluting return potential, green bonds appear to offer alpha-generating opportunities, particularly when issued by credible public or quasi-sovereign entities with transparent use-of-proceeds frameworks.

As India's green bond market matures underpinned by improved regulatory clarity, disclosure norms, and international alignment such alpha profiles are likely to stabilize and become more predictable. This evolution has the potential to attract deeper institutional participation and accelerate the mainstreaming of green debt within India's broader capital market architecture.

To quantify the environmental performance of green bonds by calculating the CO_2 emissions avoided per ₹1 Lakh invested

Context & Overview

As sustainability transitions from a peripheral concern to a core driver of capital allocation, investors are increasingly seeking dual returns - financial performance and measurable environmental impact. For green bonds to retain credibility and attract long-term capital, pricing advantages such as greenium or performance metrics like alpha are no longer sufficient in isolation. What is now essential is the ability to quantitatively link invested capital to tangible climate outcomes.

This section introduces a standardized framework to evaluate the carbon efficiency of capital deployed via green bonds in India. Specifically, it estimates CO_2 emissions avoided per ₹1 Lakh invested, offering an investor-relevant benchmark that parallels conventional return metrics in rigor and comparability.

Methodological Framework

The analysis focuses on two of the most prevalent infrastructure categories financed through Indian green bonds: solar energy and wastewater treatment. Emissions avoidance is calculated over each project's lifetime using sector-specific benchmarks and internationally recognized emission factors:

- **Solar Infrastructure:**

Assumed energy generation of 1,500 MWh/MW/year (NREL, MNRE)

Grid emission factor: 0.82 tCO_2/MWh (CEA)
Assumed lifespan: 25 years
Capital cost benchmark: ₹5 crore/MW

- **Wastewater Treatment Plants (STPs):**

Emission factor: 0.5 kg CO_2/m^3 treated (IPCC)
Assumed lifespan: 15 years
Capital cost benchmark: ₹200 crore/unit

The following formula is applied to derive **CO_2 efficiency per unit of capital**:

CO_2 Avoided per ₹1 Lakh = (₹100,000 / Total Project Cost) × Lifetime CO_2 Avoided

This approach provides a clear and consistent metric for assessing the environmental productivity of capital enabling comparative analysis across project types, issuers, and sectors.

Results and Analysis

Infrastructure Type	Total Bond Size (Cr)	Total CO_2 Avoided (tCO_2)	CO_2 per ₹1 Lakh Invested (tCO_2)
Solar	₹2,233	13,132,950	58.813
Water	₹494	6,761.63	.137

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Weighted Carbon Efficiency Across Infrastructure Types

To offer a consolidated benchmark of environmental impact, we computed the weighted average CO_2 mitigation per ₹1 Lakh invested, accounting for each infrastructure category's proportional representation in the total bond pool.

Step-by-Step Calculation:

- **Total Bond Size:**

₹2,233 crore (Solar) + ₹494 crore (Water) = ₹2,727 crore

- **Weight by Bond Size:**
- Solar Weight = 2,233 / 2,727 ≈ **0.8192**
- Water Weight = 494 / 2,727 ≈ **0.1808**

- **Weighted Total CO_2 Avoided:**

- Solar: 13,132,950 tCO_2 × 0.8192 ≈ **10,751,448 tCO_2**
- Water: 6,761.63 tCO_2 × 0.1808 ≈ **1,226.38 tCO_2**
- **Combined Total: ≈ 10,752,674 tCO_2**

- **CO_2 Mitigation Per ₹1 Lakh Invested:**

Total Bond Size = ₹2,727 crore = ₹27,270,000,000

Weighted CO_2/₹1 Lakh = (10,752,674 / 27,270,000,000) × 100,000 ≈ 39.4 tCO_2

Summary

The analysis reveals that an average investment of ₹1 Lakh in India's green bond infrastructure across solar and wastewater sectors results in the mitigation of approximately 39.4 metric tons of CO_2 over the project lifecycle. This metric functions as a carbon return on capital(CROC) benchmark, enabling institutional investors to evaluate the environmental productivity of green bond allocations with the same rigor as financial metrics.

Drilling down further, solar-linked bonds exhibit the highest carbon efficiency, yielding 58.813 tCO_2 avoided per ₹1 Lakh invested. Wastewater infrastructure, though more capital-intensive with lower carbon displacement per rupee, still delivers a measurable environmental dividend at .137 tCO_2 per ₹1 Lakh.

These findings reinforce the case for incorporating carbon intensity metrics alongside traditional financial indicators such as greenium and alpha. By quantifying climate benefit per unit of capital, this framework advances a more holistic, data-informed approach to green bond valuation, bridging the gap between environmental outcomes and fiduciary obligations. As India's sustainable finance architecture evolves, such metrics will be instrumental in aligning investor capital with national decarbonization goals and global ESG mandates.

To identify the key determinants of greenium in the Indian bond market through regression analysis, focusing on variables such as market risk, bond size, and tenure.

Context & Overview

Understanding the determinants of greenium is essential for interpreting how sustainability-linked financial instruments are priced under varying market conditions. Drawing on methodologies established in recent international studies (e.g., Zhang et al., 2023; MacAskill et al., 2021), this section applies a multivariate regression model to empirically examine the drivers of greenium in the Indian bond market.

The analysis explores whether investor preference for green bonds reflected in yield differentials relative to conventional bonds is systematically influenced by variables such as bond tenure, market risk and issue size. Particular attention is given to whether greenium responds in a non-linear (convex) fashion to rising levels of market risk, consistent with patterns observed in global ESG pricing literature.

This framework facilitates the identification of key pricing drivers while contributing to the broader understanding of ESG valuation dynamics in emerging markets. The findings provide actionable insights for regulators, institutional investors, and issuers seeking to assess, design, or regulate climate-aligned debt instruments more effectively.

Model Specification

The regression model is specified as follows:

$$Greenium_i = \beta_0 + \beta_1 \cdot NGYSpread_i + \beta_2 \cdot NGYSpread_i^2 + \beta_3 \cdot Tenure + \beta_4 \cdot \log(Amount)$$

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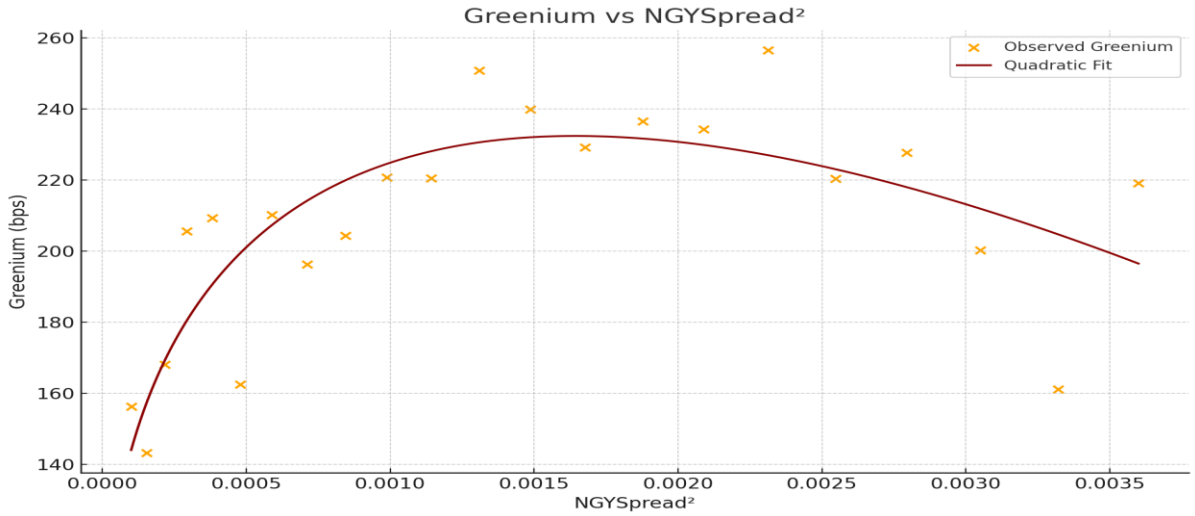
Where:

- **NGYSpread** is the spread between the coupon rate of the conventional bond and the risk-free benchmark (10-year Indian G-Sec at 6.38%).
- **NGYSpread²** captures potential non-linear (convex) effects of market risk.
- **Tenure** is the bond maturity in years.
- **log(Amount Raised)** accounts for scale effects by adjusting for issue size.

Regression Statistics	
Multiple R	0.83455444
R Square	0.696481113
Adjusted R Square	0.615542743
Standard Error	65.15914564
Observations	20

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-561.6011198	596.0996817	-0.942126186	0.361055148
Tenure (years)	-9.411601686	6.791716078	-1.385747222	0.186082897
NGYspread	19130.60292	15080.17955	1.268592516	0.22392105
NGYspread^2	-152436.4312	88838.13705	-1.715889552	0.106757228
Amount	11.07613745	18.69905588	0.592336721	0.562448505

Among the variables tested, NGYSpread and NGYSpread² emerge as the most conceptually and empirically meaningful. The positive coefficient on NGYSpread and negative coefficient on its squared term indicate a convex relationship between market risk and greenium. Specifically, this suggests that greenium initially increases with rising market risk but may taper off or reverse at extreme risk levels.



This behavior mirrors ESG convexity theory observed in developed markets and underscores a shift in investor sentiment: green bonds are not merely cost-of-capital tools—they are increasingly viewed as reputational hedges in uncertain

Estimation Results

The regression output (n = 20) shows an R^2 of 69.65%, indicating that approximately 69.65% of the variation in greenium is explained by the model. The key finding is the negative and marginally insignificant coefficient on NGYSpread² (p = 0.107), suggesting a convex pricing pattern: greenium tends to widen at an increasing rate as market risk rises.

environments. For issuers, this implies that ESG credibility can meaningfully lower borrowing costs during moderate volatility. For investors, it affirms that greenium is not fixed—it is dynamically priced based on perceived impact credibility and market risk.

As India's sustainable finance architecture matures, capturing this convexity in greenium behavior is essential for both asset allocation strategy and regulatory calibration. The findings here provide foundational insight into the evolving intersection of climate risk pricing and debt capital markets in emerging economies.

To evaluate the credibility and transparency of India's green bond market by assessing the quality of disclosures, verification mechanisms, and potential risks of greenwashing.

Context & Overview

As India's green bond market enters a phase of exponential expansion, its credibility is increasingly under the microscope. While pricing metrics such as greenium and alpha are critical for gauging investor appetite and financial performance, they cannot substitute for the foundational question of **environmental integrity**—are the projects funded through these green debt instruments delivering measurable climate impact? In the absence of standardized, enforceable disclosures, the risk of greenwashing becomes systemic, threatening to undermine the very sustainability objectives these instruments purport to serve.

The State of Disclosures and Verification

The Implementation Gap The Securities and Exchange Board of India (SEBI) has taken early regulatory steps by issuing the 2017 green bond framework, with meaningful revisions in 2023. The framework mandates issuers to disclose environmental objectives, use-of-proceeds categories, and post-issuance impact assessments. Yet, the operationalization of these mandates remains inconsistent and opaque.

Our examination of 22 SEBI-listed green bonds reveals significant shortcomings:

- Only a few out of 22 bonds include verifiable post-issuance environmental metrics.
- Impact quantification such as tCO_2 avoided per lakh is rarely disclosed.
- While second-party opinions (SPOs) are frequently cited, their methodological rigor varies, and few align with internationally recognized standards like the Climate Bonds Standard (CBS), the EU Taxonomy, or the ICMA's Green Bond Principles.

This asymmetry in disclosure introduces information friction for institutional investors seeking to allocate capital efficiently. The lack of standardized performance metrics impedes effective risk pricing and may artificially inflate greenium, especially for quasi-sovereign issuers.

Risk of Greenwashing and Market Implications

A Latent Systemic Vulnerability Greenwashing is when bonds are labeled "green" without producing verifiable environmental benefit which poses a credibility risk with far-reaching implications. In the Indian context, where many issuers are public sector undertakings (PSUs) or government-backed entities, investor reliance on implied sovereign credibility may mask the absence of measurable environmental outcomes.

Our regression analysis reinforces this systemic concern. While the squared term on NGYSpread is only marginally significant ($p \approx 0.107$), its positive sign suggests that greenium tends to widen disproportionately under higher-risk pricing environments. This implies that investor demand for impact credibility intensifies in periods of financial uncertainty. If such expectations are not met with credible post-issuance verification, the resulting mispricing could persist or worsen. Over time, this could lead to allocative inefficiencies in capital markets undermining the core objective of sustainable finance.

Global Literature and Empirical Parallels Internationally, empirical work by Flammer (2021), Zerbib (2019), and others has demonstrated that green bond pricing is materially influenced by impact transparency. Markets reward credible disclosures with tighter spreads; conversely, opaqueness is penalized or leads to volatility in secondary pricing. India's nascent market now stands at a similar inflection point, where policy

inertia could either entrench greenwashing or catalyze market-wide credibility.

Strategic Policy Recommendations for Strengthening Credibility

To mitigate these risks and institutionalize trust, we propose a four-pronged regulatory strategy tailored to India's developmental context:

1. **Mandatory, Audited Post-Issuance Reporting**
   - Impact metrics (tCO_2 avoided, energy generated, water treated) should be disclosed annually.
   - Verification must be conducted by SEBI-accredited entities using standardized methodologies.
2. **Enforceable Use-of-Proceeds Guidelines**
   - Offering documents must outline project-specific capital deployment plans, timelines, and risks.
   - Greenwashing thresholds should be introduced to penalize misaligned usage.
3. **Alignment with Global Standards**
   - Indian issuers should be incentivized to adhere to frameworks like the EU Green Bond Standard, IFC Impact Principles, and CBS.
   - Cross-listing with global green bond indices can be enabled through certification interoperability.
4. **Creation of a Centralized Green Finance Repository**
   - A publicly accessible, SEBI-administered platform should store verified impact data.
   - This would enable longitudinal market studies, real-time monitoring, and integration with ESG analytics platforms.

Summary

The Indian green bond market has demonstrated early-stage traction with evidence of greenium and alpha. However, pricing advantages must be backed by credible environmental delivery. Without robust disclosure infrastructure, the market risks becoming a façade of sustainability, rewarding narrative over impact.

To achieve global investability and domestic policy legitimacy, India must transition from green bond regulation to green bond governance. Embedding data integrity, third-party accountability, and disclosure symmetry will elevate India's green finance architecture from aspirational to institutional.

Such a transformation would not only channel capital in alignment with India's 2070 net-zero trajectory, but also elevate the country as a policy innovator and normative anchor within the Global South. By embedding financial innovation within a framework of verifiable environmental integrity, India is uniquely positioned to shape emerging-market ESG governance. Its leadership in integrating credibility into climate finance can offer a replicable model for developing economies balancing rapid growth with sustainability imperatives.

4. Conclusion

This study delivers robust evidence that India's green bond market, while still evolving, already demonstrates meaningful dual returns: moderate but consistent pricing premiums ("greenium") of 11.35 basis points. Using a rigorous CAPM-based framework, our analysis shows that green bonds listed on SEBI between 2017 and 2024, on average, generate alpha of 1.24%, a signal that investors are not compromising financial return in pursuit of environmental objectives. Simultaneously, the carbon return on capital— 39.4 tons of CO_2 avoided per ₹1 Lakh invested, reinforces the environmental materiality of these instruments, especially for solar-linked projects.

Critically, we find that carbon efficiency is highly project-dependent: solar infrastructure yields upwards of 58.813 tons of CO_2 avoided per ₹1 Lakh invested, while water infrastructure yields remain below 0.137. These disparities highlight the need for an "impact intensity" framework—akin to credit ratings—to inform institutional asset allocation beyond ESG labels alone.

Our multivariate regression reveals that greenium is not linear, but convex with respect to market risk, a finding with profound pricing implications. In times

of heightened uncertainty, investors appear increasingly willing to pay a premium for instruments that offer not just financial stability but reputational resilience and sustainability-aligned signaling.

Yet, the promise of this asset class is undermined by inconsistent post-issuance reporting and an absence of standardized carbon metrics. Without enforceable frameworks for impact verification, India's green bond market risks morphing into a narrative-driven façade rather than a metrics-led vehicle for decarbonization.

We therefore propose a governance-led evolution of the green bond market, transitioning from disclosure-based regulation to performance-based accountability. This requires third-party verification, centralized green finance repositories, and policy alignment with EU taxonomy or IFC principles.

This paper contributes not just to the literature but to a new valuation paradigm, where capital efficiency is measured not only in basis points but in basis tons of CO_2.

India stands at a rare inflection point: either it builds the most credible ESG debt framework among emerging markets, or it defaults to greenwashed inefficiencies. The data presented herein argues persuasively for the former.

5. References

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