

Corporate Sustainable Bonds in Brazil: Market Reactions and Spillover Effects

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Abstract

This study investigates the Brazilian capital market's reaction to sustainable bond issuances by publicly traded companies on B3. Using event study methodology on 62 issuances between 2015 and 2024, we measure cumulative abnormal returns across multiple temporal windows. Results reveal a systematic pattern of negative abnormal returns, with an average cumulative abnormal return of -1.71% over 21 trading days, significant at the 5% level, contrasting with evidence from developed markets, where green bond issuances typically generate positive or neutral returns. Spillover analysis on 248 competing firm observations identifies no significant impacts, suggesting the market treats these issuances as idiosyncratic decisions. Sub-period analysis indicates possible deterioration in market perception after 2020. Findings carry implications for issuers, investors, and regulators. This study contributes to sustainable finance literature by documenting the first systematic evidence on green

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Email: profacamilaguedes@gmail.com. This work received the 20th ANBIMA Capital Markets Prize (master's dissertation category). This study was financed in part by CAPES.

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bond market reactions in Brazil, showing that developed-market patterns do not automatically generalize to emerging economies.

Keywords: Green bonds; Sustainable bonds; Event study; Spillover effect; Brazilian capital market

1 Introduction

The global financial market is undergoing a transformation in how it allocates capital. Growing concern over environmental issues and the need for sustainable development have modified investment decisions and corporate financing strategies. In this context, green bonds and other sustainable securities have emerged as instruments that allow companies to raise funds specifically directed toward projects with measurable environmental benefits.

International literature on green bonds documents positive capital market reactions to issuance announcements. Flammer (2021) found positive abnormal returns in issuing firms, particularly in debut issuances and when bonds have external certification. Tang and Zhang (2020) identified reduction in firms' cost of capital following green bond issuances. These findings suggest that investors perceive value in signaling environmental commitment and investment opportunities in sustainable projects.

BRF (merger of Sadia and Perdigão) was the first Brazilian and South American company to issue a green bond in the international market, raising 500 million euros in 2015 with maturity in 2022 and 2.75% annual interest. This operation was successful, with demand four times higher than the offered value. The context was marked by COP21 in Paris, where 195 countries signed the Paris Agreement to limit global warming, and the UN's launch of the Sustainable Development Goals (SDGs). This historic moment created strong appetite among European investors, especially pension funds, for sustainable assets. BRF allocated resources to energy efficiency projects, renewable energy, greenhouse gas emission reduction, among others. The issuance established an important precedent, positioning Brazil as a relevant market in sustainable finance and paving the way for other Brazilian companies such as Suzano, Klabin, and AES Tietê to follow the same

model of fundraising linked to environmentally responsible projects.

Since then, gradual expansion in issuance volume has been observed, following the global trend of sustainable finance growth. However, the Brazilian institutional context presents particularities that may influence the pricing of these instruments. The country has structurally high interest rates, a less developed capital market than advanced economies, and a history of investor skepticism regarding corporate responsibility initiatives.

Understanding the market effects of sustainable bond issuances in Brazil remains limited. While international studies document financial benefits for issuing firms, it is unclear whether these patterns replicate in emerging markets with distinct characteristics. Additionally, literature on spillover effects on competing firms remains scarce even in developed markets, with Li et al. (2023) being one of the few recent contributions on the topic.

This work investigates how green bonds and other sustainable bond issuances affect the market value of Brazilian issuing firms and whether they generate spillover effects on competing firms in the same sector. The methodology employs event study with market model to measure abnormal returns around issuance announcement dates. The analysis covers multiple temporal windows to capture different market reaction horizons.

The research observes the scarcity of empirical evidence on sustainable securities in the Brazilian market. Most literature focuses on developed markets, particularly the United States and Europe, where the institutional environment and investor preferences may differ substantially from the Brazilian context. Additionally, understanding spillover effects remains underdeveloped even internationally, representing a relevant contribution to sustainable finance theory.

From a practical standpoint, results can guide companies on expected economic effects when issuing sustainable bonds. Financial managers need to evaluate whether potential benefits offset additional compliance and reporting costs associated with these instruments. For investors, the work provides evidence on how the Brazilian market prices corporate sustainability initiatives, relevant information for capital allocation strategies.

Regulators and policymakers can also benefit from the findings. The development of

sustainable capital markets depends on adequate regulatory frameworks and understanding of pricing mechanisms for these instruments. Evidence on spillover effects is particularly relevant for sectoral policies incentivizing sustainability.

We investigate how green bonds and other sustainable bond issuances by Brazilian companies affect the market value of issuing firms and generate spillover effects on their competitors. The general objective was to analyze the impact of green bond and other sustainable bond issuances in Brazil on the market behavior of issuing firms and their main competitors, using event study methodology.

Specific objectives unfold into three dimensions. First, analyze the Brazilian capital market's reaction to announcements of green bond and other sustainable bond issuances, evaluating the impact on issuing firms' stock prices across multiple temporal windows. Second, investigate spillover effects on competing firms, verifying whether issuances generate significant changes in the market value of firms in the same sector. Third, identify factors in market reaction, including issuer characteristics, issuance characteristics, and market conditions.

This research adopts an exploratory approach in investigating the Brazilian market's reaction to sustainable bond issuances. The choice not to formulate directional hypotheses a priori is based on some methodological and contextual considerations.

The scarcity of previous studies on the topic in the Brazilian market makes it impossible to derive robust theoretical predictions anchored in local empirical evidence. Furthermore, direct extrapolation of results documented in developed markets to the Brazilian context may be inadequate given that institutional, regulatory, and investor base composition characteristics differ substantially between these economies. Finally, international literature on market reactions to green bond issuances presents heterogeneous results, with some studies documenting positive abnormal returns, others finding neutral effects, and still others reporting mixed results depending on specific issuance and market characteristics.

Theoretically, arguments can be constructed for predicting both positive and negative Brazilian market reactions. On one hand, signaling theory suggests that green bond issuance can credibly communicate commitment to sustainability, differentiating the company

from competitors and attracting investors with ESG preferences, generating positive reaction. On the other hand, high certification and compliance costs in an environment of structurally higher interest rates, combined with weaker regulatory enforcement and greater greenwashing risk, may generate perception of value destruction, resulting in negative reaction. The absence of a robust base of investors with explicit ESG mandates in Brazil may eliminate the demand premium for sustainable bonds.

Given this theoretical and empirical uncertainty, the research is guided by open questions instead of directional hypotheses. The central questions guiding the investigation are: How does the Brazilian capital market react to announcements of sustainable bond issuances by publicly traded companies? Is the observed reaction, if any, positive, negative, or neutral? What is the magnitude and statistical significance of cumulative abnormal returns in different temporal windows? Are there spillover effects on competing firms in the same sector? Does market reaction present temporal heterogeneity, with differences between issuances conducted in different periods?

This exploratory approach allows data to reveal emerging patterns without imposing potentially inadequate theoretical structure to the Brazilian context. The obtained results can contribute to theory construction on sustainable bond pricing in emerging markets and will inform development of directional hypotheses for future research as empirical evidence accumulates and Brazil's institutional framework matures.

2 Literature Review

Signaling theory, initially developed by Spence (1973) in the labor market context and later applied to corporate finance by Ross (1977), establishes that firms use observable actions to communicate private information to the market when information asymmetry exists between managers and external investors. In the basic signaling model, the firm possesses superior information about its quality, risk, or future prospects, but faces the challenge of credibly communicating this information to skeptical investors. Signaling credibility depends critically on differential signaling costs between high and low-quality firms.

Myers and Majluf (1984) demonstrate how information asymmetry affects corporate financing decisions. In their model, managers possess superior information about existing asset values and investment opportunities, leading external investors to price new equity issuances at a discount. This discount can be sufficiently large that firms reject positive net present value investment projects when external financing is necessary. Theory predicts a hierarchy of financing preferences, with firms preferring internal financing, followed by debt, and finally equity issuance as last resort.

In the sustainable bonds context, signaling theory offers a framework to understand why firms choose to issue green bonds instead of conventional debt. Green bond issuance can signal genuine commitment to sustainability, differentiating the firm from competitors who merely engage in greenwashing. For this signaling to be credible, there must be associated costs that make issuance unattractive for firms without real commitment. These costs include external certification, detailed reporting requirements on resource use, and reputational risk if the firm fails to meet commitments (Flammer, 2021).

Connelly et al. (2011) review signaling theory in strategic management and finance, identifying four critical elements of effective signals. The signal must be observable by information receivers. The signal must impose costs on the signaler, preferably costs that vary with signaler quality. Receivers must have incentives to correctly interpret the signal. And market feedback must reward honest signals and penalize dishonest signals. Applying this framework to green bonds, issuances with external certification and robust disclosure better satisfy these criteria than issuances without such characteristics.

Separation between firms truly committed to sustainability and firms engaging in greenwashing constitutes a central challenge for signaling effectiveness. Delmas and Burbano (2011) analyze the greenwashing phenomenon, defined as communication of environmental performance exceeding actual performance. Greenwashing undermines credibility of all environmental signals by increasing investor skepticism. The presence of independent certification and verifiable disclosure standards can mitigate this problem by increasing greenwashing costs.

Voluntary disclosure theory examines under what conditions firms choose to disclose

private information to the market in the absence of mandatory regulatory requirements. The classical full disclosure (unraveling) model of Grossman (1981) and Milgrom (1981) establishes that, under certain conditions, firms will voluntarily disclose all private information in equilibrium. The intuition is that if only firms with good news disclose information, investors infer that non-disclosing firms have bad news, creating an incentive for all firms to disclose. This extreme result requires restrictive assumptions, including absence of disclosure costs and certainty that all firms possess information to disclose.

Verrecchia (1983) develops a more realistic voluntary disclosure model incorporating proprietary disclosure costs. Proprietary costs refer to competitive disadvantages firms may suffer when revealing sensitive information to competitors. The model predicts firms will disclose favorable information, withhold unfavorable information up to a certain threshold, and disclose even unfavorable information if sufficiently bad, as withholding would signal even worse news. This prediction of partial disclosure in equilibrium aligns better with observed corporate disclosure patterns.

Dye (1985) introduces endogenous uncertainty about whether the firm possesses information to disclose. In this model, absence of disclosure may reflect either unfavorable information or absence of information, breaking complete unraveling of the Grossman-Milgrom model. Equilibrium involves probabilistic disclosure, where firms disclose with higher probability when possessing favorable information, but even firms with unfavorable information occasionally disclose to avoid being confused with firms possessing no information.

Applying disclosure theory to sustainable bonds, firms face choices about transparency level in issuance documentation, reporting frequency on resource use, and degree of detail in environmental impact measurement. Theory predicts firms with genuinely high-quality green projects will disclose detailed information to differentiate from firms engaging in greenwashing. Conversely, firms with questionable project quality will provide minimal disclosure, creating a separating equilibrium where disclosure quality signals underlying quality of sustainable commitment (Christensen et al., 2021).

Leuz and Wysocki (2016) review economic literature on corporate disclosure and capital market regulation. The authors discuss how disclosure quality affects market

liquidity, cost of capital, and resource allocation efficiency. In the sustainability context, inadequate disclosure about green bond resource allocation and achieved environmental impacts can raise monitoring costs for investors and reduce bond demand, increasing green cost of capital.

Healy and Palepu (2001) examine the role of information intermediaries, including financial analysts, rating agencies, and auditors, in mitigating information asymmetry problems. In the sustainable bond market, external certifiers such as Climate Bonds Initiative and Second Party Opinion providers function as intermediaries who verify quality of environmental commitments. The presence of these intermediaries can increase signaling credibility and reduce information costs for investors.

The interaction between signaling theory and disclosure theory becomes evident in the green bonds context. The decision to issue a green bond constitutes high-level signaling about environmental commitment, while choices about certification, reporting standards, and disclosure granularity represent second-level signaling about commitment quality. Firms face trade-offs between transparency benefits, which include lower cost of capital and access to ESG investors, and disclosure costs, which include direct certification and reporting costs and proprietary costs of revealing strategic information.

Sustainable bonds emerged as financial instruments designed to mobilize capital for projects with measurable environmental or social benefits. Green bonds constitute the most established category of these instruments, defined as debt securities whose raised funds are exclusively directed toward green projects (Flammer, 2021). The first corporate green bond issuance occurred in 2013 by French bank Credit Agricole, marking the beginning of a market that grew exponentially in the subsequent decade (MacAskill et al., 2021).

Literature distinguishes four main categories of sustainable bonds according to International Capital Market Association taxonomy. Green bonds finance environmental projects such as renewable energy, energy efficiency, or clean transportation. Social bonds direct resources to projects with positive social impact, including affordable housing, education, or healthcare. Sustainability bonds combine environmental and social objectives. Sustainability-linked

bonds link bond financial characteristics, typically interest rate, to achievement of predefined sustainability targets (Bhutta et al., 2022).

Green bonds differ fundamentally from conventional bonds in three dimensions. First, explicit commitment to exclusive use of proceeds for environmental projects. Second, presence of external verification and certification mechanisms. Third, additional reporting obligations on resource use and achieved environmental impacts. These characteristics aim to increase transparency and credibility of environmental commitments, mitigating greenwashing risks.

The greenium, defined as yield differential between green bonds and comparable conventional bonds, has been subject of intense academic debate. Zerbib (2019) documents negative greenium of approximately 2 basis points in European and U.S. markets, indicating investors accept lower yields for green bonds. Larcker and Watts (2020) challenge this result, finding no evidence of greenium after controlling for bond and issuer characteristics. Fatica et al. (2021) identify greenium heterogeneity, with premium concentrated in bonds issued by financial institutions and supranational entities, but absent in corporate issuances.

Flammer (2021) conducts comprehensive analysis of stock market reactions to corporate green bond announcements using global sample of 1,507 issuances between 2013 and 2018. Results document positive average abnormal returns of approximately 0.89% in short windows around announcement dates. Effect is stronger for debut issuances, bonds with external certification, and issuers with strong prior environmental performance. Findings support signaling hypothesis, suggesting market interprets green bond issuances as credible commitment to environmental sustainability.

Tang and Zhang (2020) examine whether shareholders benefit from green bond issuances using sample of 151 first-time corporate issuances and document positive abnormal returns of 0.71% in short window around announcement. Additionally, they find evidence of cost of capital reduction following issuance and improved operational performance measured by return on assets. Results suggest green bond issuances generate value not only through signaling but also through access to new investor base and improved corporate reputation.

Wang et al. (2020) analyze Chinese green bond market reactions using sample of 125 corporate issuances and find positive abnormal returns concentrated in issuances with government support and external certification. The effect is stronger for state-owned enterprises and high-pollution industries. Results highlight the importance of institutional context and credibility mechanisms in emerging markets.

Literature on spillover effects of sustainable initiatives on competing firms remains scarce. Li et al. (2023) investigate how ESG performance generates spillover effects on green innovation of peer firms and find positive spillovers, with firms increasing green innovation in response to competitors' high ESG scores. The mechanism operates through information revelation about green technology viability and competitive pressure to maintain industry standards. The study does not specifically examine sustainable bond issuances but establishes theoretical foundation for sectoral spillovers of sustainability initiatives.

The Brazilian sustainable bond market began in 2015 with the first corporate green bond issuance by BRF, totaling 500 million euros directed toward renewable energy and energy efficiency projects (Valor, 2015). The market grew gradually in the subsequent decade, though remaining small relative to developed markets. Yamahaki et al. (2022) identify structural and specific barriers to Brazilian market development, including lack of official green taxonomy, high certification costs, and limited base of investors with explicit ESG mandates.

Brazil's regulatory structure for sustainable bonds developed slowly. The Securities and Exchange Commission in Brazil (CVM) published guidance on ESG information disclosure only recently, substantially after developed markets implemented similar requirements. This regulatory lag may have contributed to investor skepticism about credibility of Brazilian companies' sustainability commitments.

ANBIMA (Brazilian Financial and Capital Markets Association), on the other hand, has been developing work in the area of green bond issuances and sustainability-related securities, promoting discussions on the topic. It is expected that in the coming years Brazil will have a relevant database and set of studies on the topic.

Although the literature on green bonds in Brazil is scarce, there are studies on

the relationship between corporate sustainability and financial performance using B3's Corporate Sustainability Index (ISE). Andrade et al. (2013) investigate potential determinants of ISE adherence and relationship with firm value. They find that larger, more profitable firms with greater stock liquidity show higher probability of adherence. However, they do not document significant relationship between ISE participation and market value.

Arias et al. (2013) analyze performance of sustainable investments in the Brazilian market through ISE return analysis and find that ISE stock portfolio presented risk-adjusted return similar to Ibovespa between 2005 and 2010, suggesting no return penalty/benefit for investing in sustainable companies. They also find no return premium, contradicting hypothesis that sustainability creates shareholder value.

Freguete et al. (2015) examine relationship between corporate social responsibility and financial performance during the 2008 crisis. Using sample of Brazilian firms, they document that firms with greater social responsibility did not present superior financial performance during crisis, contradicting the hypothesis that sustainable practices reduce risk in stress periods.

2.1 Gaps in Brazilian Literature

Literature review reveals scarcity of studies on sustainable bonds in the Brazilian market. No published study examines market effects of green bond issuance announcements in Brazil using event study methodology. Existing literature focuses on descriptive market analysis or case studies of specific issuances, without quantitative analysis of price reactions.

Additionally, studies on spillover effects of sustainable bond issuances are nonexistent. This gap is particularly significant given that signaling theory predicts that information revealed by issuances should affect pricing of related firms. Spillover investigation can contribute to understanding how the market interprets environmental commitment signals.

Brazil's specific market characteristics expose a favorable scenario to this study. Structurally high interest rates, higher ownership concentration than developed markets, lower penetration of institutional investors with ESG mandates, and more recent capital market development may generate pricing patterns distinct from those documented internationally. Extrapolation

of developed market results to Brazilian context may be inadequate given fundamental institutional differences.

Literature review identifies four main findings relevant to this study. First, international evidence predominantly documents positive abnormal returns associated with green bond issuance announcements in short windows. Second, existence of greenium in secondary market remains controversial, with studies reporting conflicting results. Third, external certification and disclosure quality constitute important determinants of how market reacts to issuances. Fourth, literature on sustainable bond spillovers is practically nonexistent, representing a gap to be explored.

This study contributes to literature in different ways. First, provides first empirical evidence on market reaction to green bond issuances in Brazil, filling gap on emerging markets. Second, investigates spillover effects on competing firms, question unexplored in existing literature. Third, examines sectoral heterogeneity in effects, allowing identification of industries where sustainable bonds generate greater market impact. Fourth, uses comprehensive sample covering ten-year period, allowing analysis of temporal evolution of market reactions.

Theoretical predictions developed in developed markets may not apply directly to Brazilian context. If Brazilian investors have weaker sustainability preferences than investors in advanced markets, Pastor et al. (2021) model predicts lower or absent greenium. If skepticism about greenwashing is more evident in Brazil due to weaker regulatory enforcement, market may react negatively to issuance announcements. If compliance and certification costs are high relative to perceived benefits, issuances may signal value destruction instead of genuine commitment to sustainability.

3 Methodology

This research adopts a descriptive and explanatory approach regarding its objectives, a quantitative stance regarding methodology, and documentary and ex-post-facto procedures regarding data collection and analysis. The analysis focuses on events that had already occurred prior to the study, without any experimental manipulation of the variables of

interest.

Event study methodology is based on efficient market hypothesis in its semi-strong form, according to which asset prices instantly reflect all publicly available information. When a company announces green bond issuance, this information is incorporated into stock prices through the trading process. The speed and magnitude of this incorporation can reveal how investors evaluate the event's implications.

The observed return of a stock in a given period results from two components. The first component refers to expected return given the stock's general level of systematic risk and market conditions. The second component corresponds to abnormal return, defined as deviation between observed return and expected return. Informative events that alter expectations about future cash flows or firm risk manifest through statistically significant abnormal returns.

The methodology assumes that in the event's absence, stock return would follow predictable pattern based on its historical relationship with the market. The market model may capture this relationship through linear regression between stock returns and market index returns. Parameters estimated in the period prior to the event allow calculating expected return during event window and the difference between observed and expected return constitutes the event impact estimate.

The event of interest consists of the green bond or other sustainable bond issuance date by Brazilian company with stocks traded on B3. Event date ($t = 0$) corresponds to issuance date, identified through secondary database available in LSEG GLOB.

Event window comprises the period in which abnormal returns potentially caused by the event are measured. This study employs multiple event windows to capture different market reaction horizons. Short window of $[-1, +1]$ trading days captures immediate market reaction to event. Intermediate window of $[-3, +3]$ trading days allows identifying some anticipation or gradual information incorporation. Wide window of $[-5, +5]$ trading days and extended window of $[-10, +10]$ trading days capture longer-term effects.

Short window captures immediate market reaction to event. Presence of significant abnormal returns in this window indicates rapid information incorporation, consistent

with market efficiency. Longer windows allow identifying information leakage prior to event, manifested through abnormal returns negative at $t < 0$, or gradual information incorporation, evidenced by abnormal returns distributed over several days after event.

Estimation period used to calculate market model parameters comprises 252 trading days prior to event window start, specifically from day -262 to day -11 relative to event date. This period provides approximately one year of data for estimation, balancing need for sufficient sample for statistical robustness with maintenance of stability of estimated parameters. Normal return represents expected stock return in the event's absence. This study employs market model for normal return estimation, specified as:

$$R_{it} = \alpha_i + \beta_i R_{mt} + \varepsilon_{it} \quad (1)$$

where R_{it} denotes logarithmic return of stock i on day t , R_{mt} represents logarithmic return of market index (Ibovespa) on day t , α_i and β_i are stock i -specific parameters, and ε_{it} is error term with $E[\varepsilon_{it}] = 0$ and $Var[\varepsilon_{it}] = \sigma_{\varepsilon_i}^2$.

Logarithmic return is calculated as:

$$R_{it} = \ln \left(\frac{P_{it}}{P_{it-1}} \right) \quad (2)$$

where P_{it} represents adjusted closing price of stock i on day t . Use of logarithmic returns presents advantages over simple returns in financial time series analyses. Logarithmic returns are additive over time, facilitating aggregation of multi-period returns. Additionally, logarithmic returns approximate normal distribution for small price variations, useful property for parametric statistical test application.

Parameters α_i and β_i are estimated by ordinary least squares using estimation period data:

$$\hat{\beta}_i = \frac{\sum_{t=-262}^{-11} (R_{it} - \bar{R}_i)(R_{mt} - \bar{R}_m)}{\sum_{t=-262}^{-11} (R_{mt} - \bar{R}_m)^2} \quad (3)$$

$$\hat{\alpha}_i = \bar{R}_i - \hat{\beta}_i \bar{R}_m \quad (4)$$

where \bar{R}_i and \bar{R}_m represent means of stock and market returns in estimation period, respectively.

Parameter β_i captures stock return sensitivity to market return, reflecting stock's systematic risk. Stocks with $\beta_i > 1$ present higher volatility than market, amplifying index movements. Stocks with $\beta_i < 1$ exhibit lower relative volatility. Parameter α_i represents average stock return not explained by market movements, frequently interpreted as idiosyncratic performance.

Error term variance is estimated as:

$$\hat{\sigma}_{\varepsilon_i}^2 = \frac{1}{L-2} \sum_{t=-262}^{-11} \hat{\varepsilon}_{it}^2 \quad (5)$$

where $L = 252$ represents number of observations in estimation period and residuals are calculated as $\hat{\varepsilon}_{it} = R_{it} - \hat{\alpha}_i - \hat{\beta}_i R_{mt}$.

Abnormal return of stock i on day t is defined as difference between observed return and expected return according to market model:

$$AR_{it} = R_{it} - E[R_{it}] = R_{it} - (\hat{\alpha}_i + \hat{\beta}_i R_{mt}) \quad (6)$$

Abnormal return represents component of observed return not explained by general market movements, capturing firm-specific effect of event.

Cumulative abnormal return (CAR) for stock i in window $[t_1, t_2]$ is sum of daily abnormal returns:

$$CAR_i(t_1, t_2) = \sum_{t=t_1}^{t_2} AR_{it} \quad (7)$$

CAR aggregates abnormal returns over multiple days, capturing cumulative event effect on stock value. For sample of N events, average cumulative abnormal return (ACAR) is:

$$ACAR(t_1, t_2) = \frac{1}{N} \sum_{i=1}^N CAR_i(t_1, t_2) \quad (8)$$

Statistical significance of abnormal returns is evaluated using parametric and non-parametric tests. Parametric test employs t-statistic calculated as:

$$t = \frac{ACAR(t_1, t_2)}{SE_{ACAR}} \quad (9)$$

where SE_{ACAR} represents standard error of average cumulative abnormal return. Under null hypothesis of no event effect, t-statistic follows Student's t-distribution with $N - 1$ degrees of freedom.

Standard error is estimated from cross-sectional variance of individual CARs:

$$SE_{ACAR} = \sqrt{\frac{1}{N(N-1)} \sum_{i=1}^N [CAR_i(t_1, t_2) - ACAR(t_1, t_2)]^2} \quad (10)$$

As a complement to the parametric test, Wilcoxon signed-rank non-parametric test is employed. This test does not require normality assumption and is robust to outliers. Null hypothesis tests whether median of abnormal returns distribution differs from zero.

To investigate spillover effects on competing firms, competing firms are identified for each issuing firm based on sectoral classification. For each issuance event, abnormal returns of competitor stocks are calculated using same market model methodology applied to issuers.

Average cumulative abnormal return of competitors is calculated as:

$$ACAR_{comp}(t_1, t_2) = \frac{1}{M} \sum_{j=1}^M CAR_j(t_1, t_2) \quad (11)$$

where M represents total number of competitor-event observations. Significance of $ACAR_{comp}$ is tested using same statistical procedures applied to issuers.

Presence of significant positive abnormal returns in competitors would indicate that market interprets issuances as positive sectoral signal, revealing information about green technology viability or anticipating favorable regulatory changes. Significant negative abnormal returns would suggest competitive disadvantage perception, with issuing firm gaining advantage over rivals. Absence of significant effects would indicate market interprets issuances as idiosyncratic decisions without sectoral implications.

3.1 Data

Identification of green bonds and other sustainable bond issuances uses multiple sources. Main base consists of LSEG Database data, accessed through LSEG Data & Analytics platform, which maintains records on sustainable bond issuances globally. This base provides information on issued volume, issuance date, classification according to international standards, and specific resource allocation. LSEG works in partnership with Climate Bonds Initiative for bond validation and categorization, promoting alignment with International Capital Markets Association principles.

Complementarily, Brazil's Securities and Exchange Commission (CVM) information system is consulted to identify public debenture offerings with sustainability characteristics in Brazilian market. B3 makes available through its fixed income platform information on listed sustainable debentures, including classification according to international standards such as green bonds, social bonds, sustainability bonds, and sustainability-linked bonds. This source allows cross-validation of information obtained from LSEG Data & Analytics Database and CVM, enhancing consistency in identification of sustainable issuances in Brazilian capital market.

Still, ANBIMA publishes periodic reports on sustainable bond market development in Brazil, including statistics on issuance volume and issuer characteristics. These reports provide context on market temporal evolution and allow verifying sample representativeness.

Daily adjusted closing prices of issuer and competitor company stocks are obtained from LSEG Data & Analytics platform (formerly Refinitiv Eikon). Prices include adjustments for distributions (dividends, interest on equity, bonuses, splits) to ensure intertemporal return comparability.

Ibovespa index, used as market return proxy, is obtained from the same source. Although Ibovespa presents limitations as market proxy due to concentration in few large-cap stocks, it constitutes the most widely used and followed index in Brazilian market, most adequately reflecting general investor perceptions. Only trading business days are included in the analysis. Stock trading suspension periods are excluded, and events involving companies with insufficient data for parameter estimation were removed

from the sample.

Information on issuing company characteristics includes activity sector and market capitalization. These variables are collected from LSEG Data & Analytics and consolidated financial statements made available by CVM.

Bond issuance characteristics include issued volume, maturity term, interest rate, presence of external certification (Climate Bonds Certification, Second Party Opinion), bond type (green, social, sustainability, sustainability-linked), and resource allocation sector (renewable energy, energy efficiency, clean transportation, waste management, others).

The data are organized in relational data structure implemented in Python using pandas library. Main database contains information on issuance events, with fields for event unique identifier, bond ISIN code, issuing company stock ticker, event date, and issuance characteristics. Related tables store time series of daily stock and market index prices, firm characteristics over time, and identification of competition relationships between firms. Data cleaning process includes date consistency verification, identification of missing values or outliers in price series, and validation of firm identification codes. Price series with more than 20% missing observations in estimation period were excluded from analysis.

For multiple events of the same firm, interval between issuances is verified. When two issuances of the same firm occur with interval less than 60 days, only the first is included in the analysis to avoid event window overlap. Sectoral classification uses LSEG Data & Analytics sector taxonomy, which groups firms into main economic sectors. For spillover effect analysis, more granular classification is adopted when available, allowing more precise identification of direct competitors.

The empirical analysis was implemented entirely in Python. Calculation of logarithmic returns, ordinary least squares estimation of market model parameters, and abnormal returns computation use NumPy arrays for computational efficiency. Statistical significance tests employ SciPy library functions for t-statistic and p-value calculation. Wilcoxon non-parametric test is implemented through `scipy.stats.wilcoxon` function. Result aggregation across events and descriptive statistics generation use pandas groupby and aggregation

functionalities. Graphical visualizations of average cumulative abnormal returns over time are generated with matplotlib. All developed code is organized in modular scripts, with separation between data collection, processing, abnormal return calculation, statistical testing, and result generation functions.

universe of Brazilian issuers.

4 Results and Discussion

The study’s final sample comprises 62 sustainable bond issuance events by Brazilian companies with stocks traded on B3, conducted between 2015 and 2025. After applying exclusion criteria described in methodology, including removal of events with insufficient data for market model parameter estimation and elimination of same-day duplicates of same firm issuances, a sample for abnormal return analysis was obtained.

For the spillover effect analysis on competing firms, 248 competitor firm observations were processed in event window $[-3, +3]$, representing an average of approximately 4 competing firms per issuance event. Competitor identification was based on firm sectoral classification, as described in methodology, seeking comparability between firms exposed to similar market conditions and sectoral risks.

The analysis of the distribution of cumulative abnormal returns provides additional insights into the heterogeneity of market reactions. Table 1 presents detailed descriptive statistics for the reference window $[-3, +3]$.

Table 1: Descriptive Statistics of CARs - Window $[-3, +3]$

Estatística	Emissoras	Concorrentes
Mean (%)	0.04	-0.09
Median (%)	-0.29	-0.06
Standard Deviation (%)	3.00	3.49
Min (%)	-5.27	-14.13
Max (%)	10.25	14.50
Range (%)	15.52	28.63
Skewness	1.02	0.18
Kurtosis	3.87	4.32
N	62	248

The CAR distribution for issuing firms exhibits moderate positive skewness (1,02), indicating a more pronounced right tail with the presence of some events of strong positive reaction. The kurtosis of 3,87 suggests a slightly leptokurtic distribution, with heavier tails than the normal distribution, consistent with the presence of extreme events. The range of 15,52 percentage points reveals substantial heterogeneity in market reactions.

Table 2 presents average cumulative abnormal returns (CAR) of sustainable bond issuing firms for the four analyzed event windows. Results reveal systematic pattern of negative abnormal returns, with magnitude increasing as event window expands.

Table 2: Cumulative Abnormal Returns of Issuing Firms

Window	N	Mean CAR (%)	Median CAR (%)	Std Dev (%)	t-stat	p-value	Positive (%)
[-1, +1]	61	-0.07	-0.22	2.61	-0.223	0.8246	45.9
[-3, +3]	62	0.04	-0.29	3.00	0.095	0.9247	43.5
[-5, +5]	62	-0.09	0.03	3.91	-0.173	0.8633	50.0
[-10, +10]	62	-1.71	-2.12	5.90	-2.286	0.0257**	35.5

Note: ** indicates statistical significance at 5% level. Mean CAR represents average cumulative abnormal return in percentage points. T-statistic calculated using abnormal returns standard error. P-value refers to two-tailed t-test. Positive indicates proportion of positive CARs in sample.

In shortest window [-1, +1], which captures immediate market reaction to issuance event, mean CAR of -0.07% is observed, statistically indistinguishable from zero (p-value = 0.8246). Median of -0.22% suggests slight distribution asymmetry, with slightly greater concentration of negative returns. Proportion of positive CARs of 45.9% confirms approximately symmetric distribution around zero, consistent with absence of significant market reaction in very short term.

Intermediate window [-3, +3] presents mean CAR of 0.04%, also not statistically significant (p-value = 0.9247). Again, negative median of -0.29% contrasts with near-zero mean, suggesting presence of some positive outliers that elevate mean. Proportion of positive CARs reduces to 43.5%, indicating slight predominance of negative reactions when considering broader temporal horizon.

Window [-5, +5] maintains pattern of near-zero mean CAR (-0.09%), without statistical significance (p-value = 0.8633). Median becomes slightly positive (0.03%), while proportion of positive CARs reaches exactly 50%, suggesting practically symmetric distribution in

this window.

Some results emerges in extended window $[-10, +10]$, where mean CAR reaches -1.71% , statistically significant at 5% level ($p\text{-value} = 0.0257$). Wilcoxon non-parametric test confirms significance ($p\text{-value} = 0.0163$), conferring robustness to result. Median of -2.12% indicates negative effect is not driven exclusively by outliers but reflects generalized sample trend. Proportion of positive CARs reduces to 35.5% , evidencing that approximately two-thirds of issuances associate with negative abnormal returns in this temporal window.

Figure 1 illustrates graphically the evolution of cumulative abnormal returns across event windows. Clear deterioration in abnormal performance is observed as analysis horizon expands, with error bars indicating greater dispersion in longer windows.

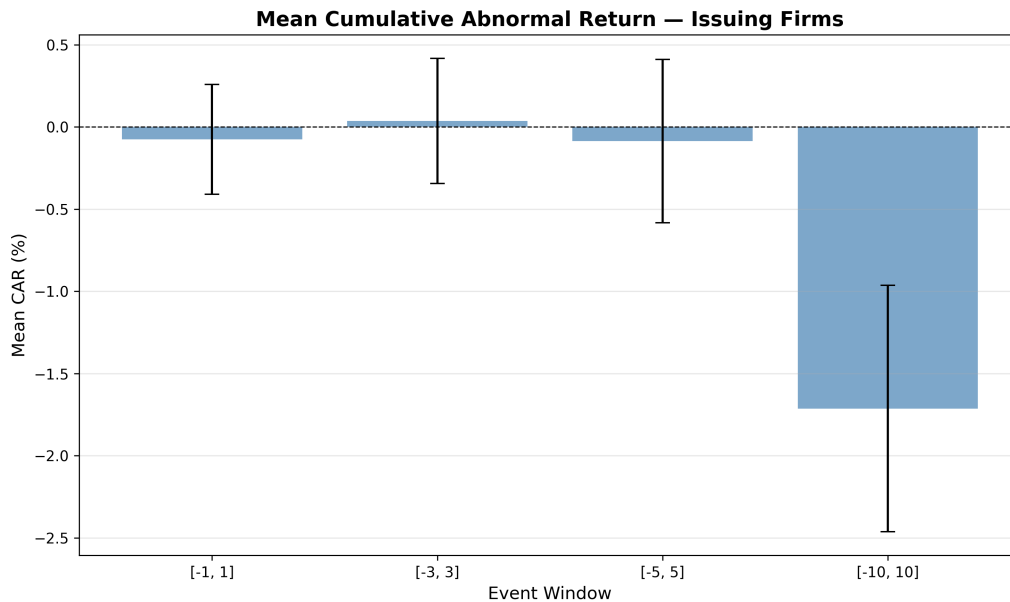


Figure 1: Average Cumulative Abnormal Returns of Issuing Firms by Event Window

The analysis of cumulative abnormal returns distribution provides additional insights into market reaction heterogeneity. Descriptive statistics reveal substantial dispersion in individual CARs, with standard deviations ranging from 2.61% in shortest window to 5.90% in extended window. This dispersion reflects heterogeneity in market perceptions of different issuances, possibly related to issuer characteristics, issuance characteristics, or market conditions at event time.

Also, distributions presents positive skewness in most windows, indicating the presence of extreme positive values that elevate mean relative to median. Excess kurtosis suggests

distribution with heavier tails than normal distribution, evidencing greater frequency of extreme values than predicted by normal distribution. These characteristics may justify use of non-parametric tests as robustness complement to parametric tests.

Figure 2 presents the distribution of cumulative abnormal returns in the $[-3, +3]$ window. The distribution shows concentration around zero with slight negative bias, confirming the pattern observed in descriptive statistics. The vertical line indicates mean CAR of 0.04%, very close to zero.

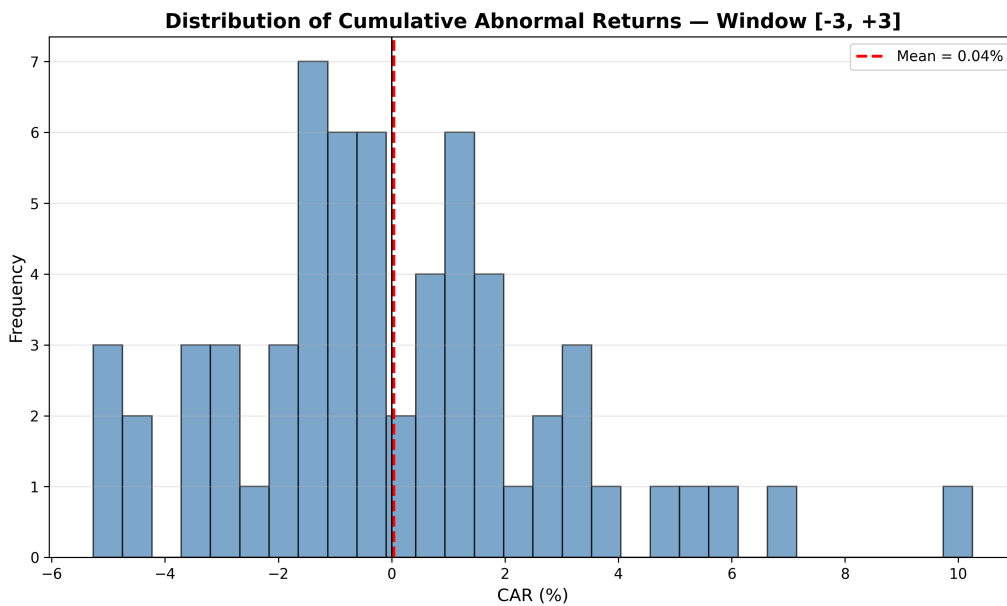


Figure 2: Distribution of Cumulative Abnormal Returns - Window $[-3, +3]$

Figure 3 presents boxplots comparing CAR distributions between issuing firms and competing firms in window $[-3, +3]$. Visual comparison reinforces similarity in distributions, with both groups presenting median close to zero and comparable dispersion. This visual representation corroborates absence of significant differences between groups documented in statistical tests.

To investigate whether market perception of sustainable bond issuances evolved over time, the sample is divided into two sub-periods: issuances conducted until December 31, 2019 (Before 2020) and issuances from January 1, 2020 (After 2020). This division captures potential changes in market perception following COVID-19 pandemic and the intensification of ESG debate globally.

Results suggest temporal heterogeneity. Issuances before 2020 present mean CARs

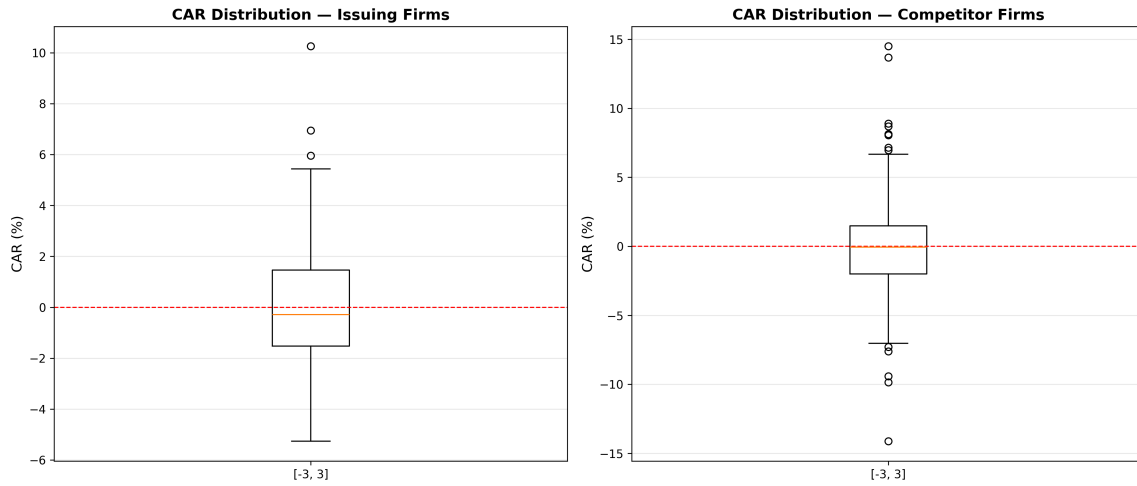


Figure 3: CAR Distribution Comparison - Issuers vs. Competitors

Table 3: Sub-period Analysis - Before and After 2020

Event Window	Mean CAR		N		p-value difference
	Before 2020 (%)	After 2020 (%)	Before	After	
[-1, +1]	0.18	-0.21	23	38	0.6234
[-3, +3]	0.42	-0.16	23	39	0.5187
[-5, +5]	0.29	-0.31	23	39	0.5891
[-10, +10]	-0.95	-2.18	23	39	0.3842

Note: Sample division into issuances conducted until 12/31/2019 (Before 2020) and from 01/01/2020 (After 2020). P-value refers to t-test for mean difference between sub-periods.

near zero or slightly positive in short windows, becoming negative only in window [-10, +10] (-0.95%). Issuances after 2020 exhibit consistently negative CARs in all windows, with greater magnitude in window [-10, +10] (-2.18%).

This difference, though not statistically significant given reduced sample size in each sub-period, suggests possible deterioration in market perception of sustainable bond issuances over time. Market expansion after 2020 may have been accompanied by growing skepticism about effectiveness and authenticity of sustainable commitments, or by adverse selection where firms with less genuine commitment began issuing sustainable bonds predominantly for marketing reasons.

Analysis of spillover effects on competing firms, based on 248 competitor firm-event observations, does not identify statistically significant impacts in any temporal window. Mean cumulative abnormal returns of competitors remain near zero and not significant even in longest windows.

Table 4: Cumulative Abnormal Returns of Competing Firms

Window	N	Mean CAR (%)	Median CAR (%)	Std Dev (%)	t-stat	p-value	Positive (%)
[-1, +1]	248	-0.24	-0.03	3.16	-1.202	0.2303	44.8
[-3, +3]	248	-0.09	-0.06	3.49	-0.413	0.6799	45.6
[-5, +5]	248	-0.08	-0.07	4.20	-0.306	0.7598	49.2
[-10, +10]	248	-0.45	-0.30	6.08	-1.171	0.2425	46.0

Note: Sample of 248 competitor firm observations across 62 issuance events. Statistics calculated analogously to issuing firms.

Absence of significant spillover effects suggests Brazilian market interprets sustainable bond issuances as idiosyncratic decisions with limited sectoral implications. This differs from theoretical predictions that issuances should generate informational spillovers about green project viability or sectoral regulatory changes.

Figure 4 presents comparison between average cumulative abnormal returns of issuing firms and competing firms across different event windows. Visual analysis confirms absence of significant spillover effects, with competitors' CARs remaining close to zero across all windows while issuers show negative pattern in extended window.

A possible explanation for the absence of spillovers relates to the perceived credibility of sustainable commitments. If market participants interpret most issuances as primarily

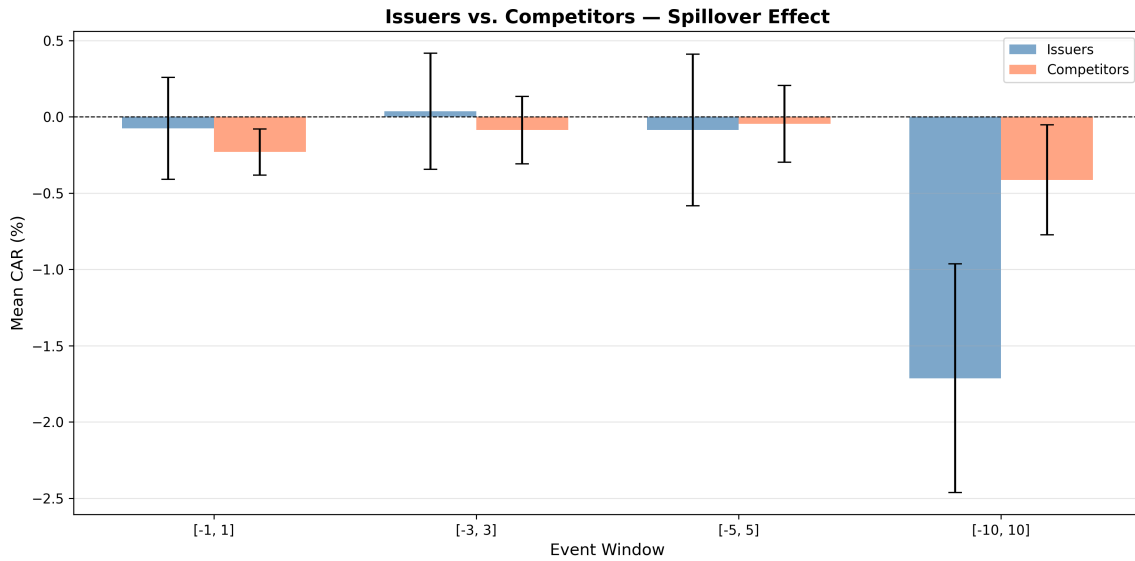


Figure 4: Comparison: Issuers vs. Competitors (Spillover Effect)

marketing exercises without substantive environmental commitment, information revealed would be specific to issuing firm and would not generalize to all the sector. Alternatively, if sustainable bond market in Brazil is perceived as incipient and heterogeneous, with substantial variation in quality and authenticity of commitments, signal extracted from one issuance would have little relevance for evaluating other firms.

The results contrast markedly with predominant (but not absolute) body of empirical evidence on market reactions to green bond issuances in developed economies. Flammer (2021) documents positive average abnormal returns of approximately 0.89% in short windows. Tang and Zhang (2020) report similar results with positive abnormal returns.

The present study, in contrast, documents cumulative abnormal returns of -1.71% in window [-10, +10] for the Brazilian market, statistically significant at 5% level. This divergence demands careful investigation of underlying mechanisms and Brazilian market contextual factors.

Various contextual factors may contribute to the negative reaction observed in Brazilian market. Institutional development of sustainable bond market in Brazil remains incipient when compared to developed markets. The absence of a specific regulatory framework during most of sample period, with clear definitions and enforcement of certification standards and resource allocation, can fuel perception of greenwashing risk.

Also, ownership structure and corporate governance of Brazilian firms may affect the credibility of sustainable commitments. Firms with concentrated control structures and less pressure from institutional investors with ESG mandates may face greater skepticism when announcing sustainable initiatives, particularly if not accompanied by substantive changes in governance and transparency. Brazilian cost of capital, substantially higher than developed economies, may alter cost-benefit calculation of sustainable bond issuances in investor perception. Additional certification, monitoring, and reporting costs may represent proportionally greater burden in high interest rate environment, without corresponding liquidity premium or funding cost reduction justifying these expenditures.

Finally, the composition of corporate debt security investor base in Brazil, with predominance of domestic investors and less participation of foreign investors specialized in ESG, may result in lower demand for sustainable bonds and absence of price premium. Without differentiated demand, incremental costs of sustainable bond issuance convert to value destruction.

To verify the robustness of the results to the choice of the estimation period, a sensitivity analysis was conducted using an alternative window of 180 trading days (approximately 9 months) instead of the standard 252 days. Table 5 presents a comparison of the results.

Table 5: Sensitivity Analysis - Alternative Estimation Period

Window Event	Mean CAR 252 days (%)	Mean CAR 180 days (%)	Diff (%)	p-value
[-1, +1]	-0.07	-0.11	-0.04	0.8921
[-3, +3]	0.04	0.01	-0.03	0.9356
[-5, +5]	-0.09	-0.13	-0.04	0.9178
[-10, +10]	-1.71	-1.68	0.03	0.9628

The results are stable to the alternative specification, with minimal differences in average CARs and no statistically significant differences. The CAR in the [-10, +10] window remains statistically significant and negative (-1.68% with a 180-day window versus -1.71% with 252 days), confirming the robustness of the main conclusion.

Documented results have direct implications for corporate financing decisions. Brazilian firms contemplating sustainable bond issuance should carefully consider cost-benefit relationship of this strategy. In the absence of market premium and facing evidence of negative

reaction, justification for green bond issuance should be based on other benefits not captured by short-term abnormal returns. These benefits may include access to differentiated investor base, improvement in corporate reputation with non-financial stakeholders, fulfillment of controlling shareholders' sustainability mandates, or strategic positioning for future environmental regulations.

Firms should explicitly communicate these justifications to market participants, avoiding expectations of immediate positive stock price reaction. Additionally, results suggest the importance of credible signaling of sustainable commitment. Firms issuing sustainable bonds should consider robust external certifications, detailed disclosure of resource allocation, and establishment of measurable environmental impact targets. The absence of these signals may intensify greenwashing perceptions and amplify negative market reactions.

These findings evidence a need for institutional development of Brazilian sustainable bond market. CVM and ANBIMA can play central role in establishing clear certification standards, green activity taxonomy, and disclosure requirements for sustainable bond issuers.

Overall, empirical analysis of abnormal returns associated with sustainable bond issuances in Brazilian market reveals negative market reaction pattern, with average cumulative abnormal return of -1.71% in window [-10, +10], statistically significant at 5% level. This result fundamentally contrasts with predominant evidence from developed markets, where green bond issuances typically generate positive or neutral abnormal returns.

The absence of significant reaction in short windows suggests Brazilian market does not interpret sustainable bond issuances as immediate signaling of quality or environmental commitment. Negative effect emerging in longer horizon indicates possible growing skepticism or gradual incorporation of perception that associated costs exceed benefits in absence of differentiated demand or financing premium.

Spillover effect analysis does not identify significant impacts on competing firms, suggesting sustainable bond issuances are perceived as idiosyncratic decisions with limited sectoral implications. This absence of informational externalities contrasts with international

evidence of positive spillovers.

These results have implications that may be relevant for companies, investors, regulators, and policymakers, evidencing the need for institutional development of Brazilian sustainable bond market and credible signaling of environmental commitments for building credibility and market trust.

5 Conclusions

This work investigated Brazilian capital market reaction to sustainable bond issuances by companies with stocks traded on B3. Using event study methodology applied to a sample of 62 issuances conducted between 2015 and 2024, this research documents systematic evidence of negative abnormal returns associated with these events. Main results reveal average cumulative abnormal return of -1.71% in a 21-trading-day window around issuance date, statistically significant at 5% level according to parametric t-test and confirmed by Wilcoxon non-parametric test. This finding contrasts with the predominant body of empirical evidence documented in developed markets, where studies in United States, Europe, and China report positive or neutral abnormal returns associated with corporate green bond issuances.

The absence of significant reaction in short windows of one and three days suggests Brazilian market does not immediately incorporate information about sustainable bond issuances as positive signaling of quality or environmental commitment. Negative effect emerges only in longer 21-day horizon indicating gradual information incorporation process or growing skepticism as investors analyze issuance implications. The proportion of only 35.5% positive abnormal returns in extended window reinforces the systematic nature of negative effect, evidencing that approximately two-thirds of issuances associate with shareholder value destruction in short term.

Spillover effect analysis on competing firms, based on 248 competitor firm-event observations, does not identify statistically significant impacts in any temporal window. Mean cumulative abnormal returns of competitors remain near zero and not significant even in longest window. This result contrasts with theoretical predictions that green bond issuances

should generate informational spillovers about sustainable project viability or sectoral regulatory changes. The absence of spillover suggests market interprets issuances as idiosyncratic decisions with limited implications for related firm valuation, differently from patterns observed in developed markets where environmental commitment signals generate positive informational externalities for entire sector.

Brazilian market negative reaction admits multiple complementary interpretations anchored in specific characteristics of institutional context. First, institutional development of sustainable bond market in Brazil remains incipient relative to developed markets. The absence of official green taxonomy during most of the sample period, combined with less rigorous certification standards and weaker regulatory enforcement, fuels a perception of high greenwashing risk. Skeptical investors about effective resource allocation to sustainable projects may interpret issuances as marketing exercises without substantive commitment. Second, cost-benefit structure of sustainable issuances differs substantially between Brazil and developed markets. External certification costs, detailed tracking and reporting system implementation, and compliance with international standards represent proportionally greater burden in structurally high interest rate environment. In the absence of differentiated demand or price premium for sustainable bonds, these incremental costs convert to value destruction. Third, Brazilian investor base composition, with less participation of foreign institutional investors with explicit ESG mandates, limits specific demand for sustainable bonds. Without differentiated investor pool willing to accept lower returns in exchange for sustainability attributes, issuances do not generate pricing benefits.

Sub-period analysis reveals possible temporal deterioration in market perception, with more negative abnormal returns for post-2020 issuances (-2.18%) compared to prior issuances (-0.95%). This trend may reflect market expansion accompanied by adverse selection, where firms with less genuine commitment begin issuing sustainable bonds predominantly for image reasons, or may capture market learning about green bond framework limitations in generating measurable environmental improvements.

Documented results have direct implications for multiple stakeholders. For companies

considering sustainable bond issuance, evidence of negative abnormal returns demands careful reassessment of cost-benefit relationship of this financing strategy. In the absence of short-term market premium, justification should be based on benefits not captured by immediate abnormal returns, including access to differentiated long-term investor base, improvement in corporate reputation with non-financial stakeholders, or strategic positioning anticipating future environmental regulations. Firms choosing to issue should invest in credible signaling through robust external certifications, detailed resource allocation disclosure, and establishment of measurable environmental impact targets. For investors, particularly those with ESG mandates, the findings evidence a need for in-depth due diligence when evaluating issuances, verifying not only certification presence but also the history of environmental commitment fulfillment and robustness of governance systems for resource allocation.

For regulators and policymakers, especially Brazil's Securities and Exchange Commission (CVM) and Brazilian Financial and Capital Markets Association (ANBIMA), the findings evidence urgent need for institutional development of Brazilian sustainable bond market. CVM can play a central role in establishing clear and enforceable disclosure standards for sustainable bond issuers, including precise definitions of eligible projects, external certification requirements, and mandatory periodic reporting on resource use and achieved impacts.

Fiscal incentive policies or partial government guarantees for certified sustainable bonds, similar to programs implemented in other jurisdictions, could assist in transaction cost reduction and market building in initial stages. Such interventions should be carefully designed to avoid adverse selection where only lower quality firms seek subsidies, and should include robust conditionalities on certification, disclosure, and impact verification. International experience demonstrates that effective sustainable bond markets require coordination between regulators, self-regulators, issuers, investors, and certifiers.

The contrast between Brazilian and international results evidences that robust institutional development constitutes a prerequisite for effective functioning of sustainable bond markets. Building institutional credibility requires not only regulatory and self-regulatory changes,

but also cultural changes in perceptions about sustainability value. As climate risks materialize more frequently and pressures for sustainable practices intensify, perceptions may gradually align with developed economies, but this process demands time, consistent enforcement, and repeated demonstration that environmental commitments generate real measurable value.

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