



UNIVERSIDADE CATÓLICA PORTUGUESA

An updated test to the Greenium in the corporate bond market

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Abstract

This thesis examines the existence of a greenium, the yield differential between green and conventional bonds, in the corporate bond primary market. As sustainable finance continues to expand, understanding whether green bonds offer issuers a pricing advantage has become a critical question for investors, firms, and regulators. The research focuses on corporate bonds issued between 2018 and 2025, aiming to determine whether green bonds are priced higher than their conventional counterparts. The analysis relies on a comprehensive dataset comprising 3,495 green bond tranches and 47,565 conventional bond tranches, with a matched sample of 1,282 bond pairs issued by the same firm.

The empirical analysis is based on ordinary least squares (OLS) regressions using yield to maturity and credit spread as dependent variables. The core tests are conducted on yield to maturity, while spread regressions serve as robustness checks. Fixed effects for year, industry, and country are applied, along with controls for credit rating, macroeconomic variables, and contractual features. Additionally, a matched sample is constructed to improve identification by comparing green and non-green bonds issued by the same firm with the same rating.

The results consistently indicate that green bonds do not enjoy a statistically significant pricing advantage over conventional bonds. In most model specifications, the green label has no impact on yields. In one of the robustness checks using credit spreads, green bonds are even associated with a statistically significant spread increase of 13.6 basis points, suggesting a pricing discount rather than a greenium. The findings suggest that credit quality, macroeconomic conditions, and contractual characteristics, rather than the green label, are the dominant drivers of bond pricing in the corporate market.

Keywords: Green bonds, Greenium, Corporate bond pricing, Sustainable finance, Yield to maturity, Credit spreads, OLS regression, Matched sample analysis, Contractual bond characteristics, ESG credibility and verification.

Word Count: 9915

Resumo

Este trabalho analisa a possibilidade de existência do *greenium*. A investigação incide sobre obrigações corporativas emitidas entre 2018 e 2025, com o objetivo de determinar se as obrigações verdes são emitidas a preços superiores face às suas congéneres convencionais. A análise baseia-se num conjunto de dados abrangente, composto por 3.495 tranches de obrigações verdes e 47.565 tranches de obrigações convencionais, complementado por uma amostra emparelhada de 1.282 pares de obrigações emitidas pela mesma empresa.

A análise empírica assenta em regressões OLS, utilizando como variáveis dependentes a taxa interna de rendibilidade e o *spread*. Os testes principais concentram-se no rendimento até à maturidade, sendo as regressões com *spreads* utilizadas para trazer robustez aos modelos. São aplicados efeitos fixos para o ano, o setor de atividade e o país, juntamente com controlos para notação de risco, variáveis macroeconómicas e características contratuais. Adicionalmente, é construída uma amostra emparelhada que permite comparar obrigações verdes e não-verdes emitidas pela mesma entidade e com a mesma notação de risco, melhorando assim a identificação causal.

Os resultados indicam de forma consistente que as obrigações verdes não apresentam uma vantagem de preço estatisticamente significativa face às obrigações convencionais. Na maioria das especificações dos modelos, o selo verde não tem impacto sobre os rendimentos. Numa das verificações de robustez, recorrendo aos *spreads* de crédito, as obrigações verdes estão mesmo associadas a um aumento estatisticamente significativo do *spread* em 13,6 pontos base, sugerindo um desconto de preço e não um *greenium*. Os resultados sugerem que a qualidade de crédito, as condições macroeconómicas e as características contratuais, e não o selo verde, são os principais determinantes na formação do preço das obrigações no mercado corporativo.

Palavras-chave: Obrigações verdes, Greenium, Valorização de obrigações corporativas, Finanças sustentáveis, Taxa interna de rentabilidade, Spreads de crédito, Regressão OLS, Amostra emparelhada, Características contratuais das obrigações, Credibilidade e verificação ESG.

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1. Introduction

Green bonds have become a cornerstone of sustainable finance, attracting attention due to their role in financing environmentally beneficial projects (Ehlers & Packer, 2017; Sachs et al., 2019). Their growth has been driven by rising ESG integration, investor demand, and regulatory support (Flammer, 2021; Gianfrate & Peri, 2019; Tang & Zhang, 2020). A central debate in the literature concerns whether green bonds are priced at a premium—commonly referred to as the greenium—compared to conventional bonds. Some studies document a statistically significant greenium linked to pro-social investor preferences (Zerbib, 2019; Nanayakkara & Colombage, 2019), while others, after accounting for bond and issuer characteristics, find no pricing advantage (Larcker & Watts, 2020; Flammer, 2021).

This work investigates whether a greenium exists in the corporate bond primary market from 2018 to 2025. Using a large dataset of green and conventional bonds, it applies OLS regressions to both unmatched and matched samples—where green bonds are paired with conventional bonds from the same issuer and rating. The models control for contractual features (e.g., maturity, deal size, subordination, callability), credit rating, macroeconomic conditions, and fixed effects for industry, year, and country. Yield to maturity and credit spread measures are analyzed to test robustness.

The central research question is whether green corporate bonds enjoy a statistically significant pricing advantage once confounding variables are controlled. The results show no consistent evidence of a greenium. In most specifications, green bonds are not associated with lower yields or spreads, and in some cases, they carry a pricing discount. These findings suggest that, in corporate debt markets, the green label alone does not lower borrowing costs.

The thesis proceeds as follows: Chapter 2 reviews the literature, Chapter 3 formulates the hypotheses, Chapter 4 presents the methodology, Chapter 5 discusses empirical results, and Chapter 6 concludes.

2. Literature Review

2.1 Green Bonds and the Greenium

2.1.1 What are Green Bonds?

Green bonds are fixed-income financial instruments specifically earmarked to finance projects with environmental benefits, such as renewable energy, energy efficiency, pollution prevention, and sustainable resource management (Flammer, 2021; Wang & Zhi, 2016). According to Bachelet et al. (2019), green bonds are structurally similar to conventional bonds but include commitments regarding the use of proceeds and environmental objectives. Kapraun et al. (2021) highlights that green bonds often feature external certification or alignment with established green taxonomies to enhance credibility. De Spiegeleer and Schoutens (2019) describe green bonds as instruments that aim to align capital markets with climate objectives, proposing variations such as reverse green bonds to improve accountability. Jones et al. (2020) and Liberati and Marinelli (2021) emphasize that green bonds are embedded within governance frameworks designed to mitigate greenwashing risks and promote additionality. Nanayakkara and Colombage (2019) and Silva and Blankson (2025) note that green bonds serve both financial and symbolic functions, signaling environmental commitment to the market while channeling funds to sustainable development goals.

2.1.2 What is the Greenium?

The greenium, defined as the yield differential between green bonds and otherwise identical conventional bonds, has its theoretical foundations in several interrelated strands of financial economics. A primary explanation is rooted in investor preference theory, where certain investors exhibit pro-environmental preferences or are subject to mandates that drive demand for green bonds

(Zerbib, 2019; Nanayakkara & Colombage, 2019). Zerbib (2019) models the greenium as arising from the coexistence of such preferences and liquidity factors, with investors accepting lower yields in exchange for the environmental utility provided by green investments. Nanayakkara and Colombage (2019) complement this view by highlighting how investor willingness to pay a premium is influenced by broader market sentiment and global climate policy momentum.

Signaling theory offers a complementary lens, positing that green bond issuance serves as a mechanism for firms to credibly communicate their environmental commitment to the market (Flammer, 2021; Agliardi & Agliardi, 2021). The signaling value of green bonds, however, is contingent on the credibility of the issuer and the rigor of the green credentials attached to the bond (Kapraun et al., 2021; Bachelet et al., 2019). Fatica et al. (2021) also emphasize the importance of issuer reputation, noting that without credible signals, green bonds risk being perceived as marketing tools rather than authentic commitments to sustainability.

Liquidity considerations have been advanced as another driver of greenium. Zerbib (2019) incorporates liquidity premiums into his model, suggesting that green bonds may trade at a premium or discount depending on their relative liquidity compared to conventional bonds. Molino et al. (2023) empirically support this framework, showing that green bonds—particularly sovereign and supranational issues—exhibit superior liquidity during periods of market stress. Löffler et al. (2021) extend this argument by identifying how market structure and bond characteristics, including issue size and maturity, mediate liquidity effects.

From a regulatory economics perspective, greenium may emerge as an unintended consequence of frameworks that incentivize or mandate green investments (Carmichael & Rapp, 2024). Regulatory measures such as the

European Union's Sustainable Finance Action Plan have been cited as contributing factors to green bond pricing dynamics. De Spiegeleer and Schoutens (2019) propose reverse green bonds, embedding climate-linked penalties to align market incentives with policy objectives. Liberati and Marinelli (2021) further suggest that regulatory interventions, including green quantitative easing, may alter demand and supply dynamics in ways that influence greenium.

Governance and market integrity are also fundamental to the theoretical underpinnings of greenium. Jones et al. (2020) and Wang and Zhi (2016) argue that the value proposition of green bonds, and any associated greenium, depends on governance structures that ensure additionality and reduce greenwashing risks. Bachelet et al. (2019) highlight how third-party verification acts as a governance mechanism that underpins market confidence.

Finally, structural models provide nuanced insights into greenium dynamics. Agliardi and Agliardi (2021) develop a two-factor model where greenium is influenced by correlations between green project performance and firm operations. Fandella and Cociancich (2024) illustrate through yield curve modeling how methodological choices and market microstructure can further modulate observed greenium magnitudes.

2.2 Early studies and pioneering results

The earliest empirical explorations of the greenium began with works such as Zerbib (2019), who identified a modest average greenium of approximately 2 basis points in a global sample, attributing it to investor preferences and liquidity effects. Nanayakkara and Colombage (2019), using global evidence, reported a more substantial greenium of around 63 basis points, highlighting variations in investor willingness to pay a premium across regions and market contexts. Bachelet et al. (2019) followed, demonstrating that institutional green bonds often exhibited negative premia, while private green bonds without certification

displayed positive premia, thereby emphasizing the role of issuer type and verification. Larcker and Watts (2020) introduced a quasi-experimental design focused on U.S. municipal bonds, finding no significant greenium but revealing higher underwriting costs for green bond issuers. Flammer (2021) extended the corporate green bond literature, showing no cost of debt advantage but notable reputational and environmental performance benefits. Fatica et al. (2021) contributed by distinguishing between issuer types, documenting greenium for supranationals and corporates but not financial institutions. Kapraun et al. (2021) advanced the field by linking greenium size to credibility factors such as external certification and green exchange listings. Carmichael and Rapp (2024) identified a greenium of 3–8 basis points in corporate bonds, emerging post-2019 alongside regulatory developments. Grishunin et al. (2024) illustrated a lifecycle dynamic, with significant greenium in early European markets that diminished as the market matured. Molino et al. (2023) added liquidity dimensions, showing green bond liquidity advantages during market stress periods. Fandella and Cociancich (2024) further nuanced the literature by demonstrating how greenium findings vary depending on methodological approaches, from positive to negative depending on model choice.

2.3 How do different types of Issuer affect the Greenium

2.3.1 Corporate Green Bonds

Corporate green bonds have been the focus of numerous studies, revealing mixed evidence regarding greenium. Flammer (2021) finds no significant yield advantage for corporate green bonds but highlights improvements in environmental performance and investor base quality. Carmichael and Rapp (2024) report a greenium of 3–8 basis points, emerging primarily after 2019, linked to regulatory developments and growing investor demand. Kapraun et al. (2021) emphasize that credibility factors, such as external certification and exchange listings, are critical for observing a greenium in corporate bonds.

Agliardi and Agliardi (2021) provide a structural model explaining how greenium in corporate bonds can be influenced by correlations between green project outcomes and firm core operations. Comparatively, while Flammer (2021) finds reputational benefits but no pricing advantage, Carmichael and Rapp (2024) detect modest greenium where regulatory and credibility factors are stronger, indicating evolution over time and across regions.

2.3.2 Financial institutions, Sovereign and Supranational Green Bonds

Green bonds issued by financial institutions present distinct dynamics. Fatica et al. (2021) show that unlike supranational and corporate issuers, financial institutions do not experience significant greenium, a result attributed to challenges in linking green bond proceeds to specific green assets. Kapraun et al. (2021) similarly find that credibility and certification are crucial for financial institutions, with greenium observed mainly in highly credible issues. Molino et al. (2023) highlight that supranational and sovereign green bonds benefit from superior liquidity, contributing to pricing advantages during market stress. Bachelet et al. (2019) note that supranational green bonds often display negative premia, linked to their high liquidity and low volatility. When contrasting financial institutions with sovereign and supranational issuers, it becomes evident that institutional credibility, liquidity, and clear use of proceeds significantly affect greenium outcomes, with sovereign and supranational bonds more consistently benefiting from greenium than financial institution bonds.

2.4 ESG ratings

2.4.1 Issuer credibility and ESG profile

Issuer credibility and ESG quality are consistently found to influence green bond pricing. Studies show that greenium tends to be concentrated in bonds issued by sovereigns, supranationals, or corporates with strong certification, green listings, or ESG credentials (Kapraun et al., 2021; Fatica et al., 2021; Bachelet et al., 2019). These factors enhance transparency and reduce informational

asymmetries, thereby increasing investor confidence. Löffler et al. (2021) and Pietsch and Salakhova (2022) further highlight the link between high ESG scores and the presence of greenium. Regional differences also matter—Silva and Blankson (2025) and Hu et al. (2024) find that consistent ESG standards support greenium in Europe, while weaker frameworks in China reduce its pricing impact.

Greenwashing remains a key concern. Without credible verification, investors may discount environmental claims, undermining pricing benefits (Harrison et al., 2020; Jones et al., 2020; Bachelet et al., 2019). Regulatory oversight and third-party certification are thus essential (Liberati & Marinelli, 2021). However, some studies, such as Alves, Lopes, and Pinto (2023), omit ESG ratings due to limited data availability, which may constrain the analysis of issuer-level credibility as a greenium driver.

2.4.2 Third-party verification and Green standards

Third-party verification and adherence to green standards are widely cited as critical factors influencing greenium. Bachelet et al. (2019) highlight that third-party certification significantly reduces information asymmetry, especially for private issuers, leading to lower yields and enhanced investor confidence. Kapraun et al. (2021) find that bonds listed on green exchanges or certified by recognized standards bodies display stronger greenium effects. Fatica et al. (2021) similarly note that verification enhances the credibility of green bonds, particularly for corporate and supranational issuers. Löffler et al. (2021) report that greenium is consistently higher in bonds with external review, while Pietsch and Salakhova (2022) emphasize that certification is essential in the euro area for greenium to materialize. De Spiegeleer and Schoutens (2019) propose innovative structures like reverse green bonds, where compliance failures trigger penalties, as a means to further strengthen verification's role. Contrasting regions, Silva and

Blankson (2025) argue that the robustness of European certification frameworks contributes to more stable greenium outcomes, while fragmented standards in China undermine consistent pricing advantages. These studies collectively show that third-party verification and alignment with credible green standards are indispensable for supporting greenium and mitigating greenwashing risks.

2.5 Market liquidity and other macro factors

Market liquidity and macroeconomic conditions are widely recognized as key factors influencing the greenium. Zerbib (2019) shows that liquidity premiums can affect the magnitude of yield differentials, while Molino et al. (2023) and Löffler et al. (2021) find that green bonds, especially large and standardized issues, often enjoy better liquidity during periods of market stress. Grishunin et al. (2024) observe that as green bond markets mature, greenium tends to decline, reflecting improved and more stable liquidity conditions.

Macroeconomic policy also plays a role. Fandella and Cociancich (2024) emphasize that interest rate regimes influence green bond demand, and Silva and Blankson (2025) attribute Europe's more stable greenium to supportive policies. Alves, Lopes, and Pinto (2023) further find that once controlling for macroeconomic variables such as interest rates and inflation, the greenium effect becomes statistically insignificant, suggesting that observed pricing differences may reflect broader macroeconomic forces rather than the green label itself.

3. Research question

The pricing of green bonds has generated extensive academic and policy interest, with growing attention to whether these instruments carry a “greenium” — a yield discount that reflects investor willingness to accept lower returns in exchange for environmental impact. While several studies have documented the presence of a greenium under certain conditions (Zerbib, 2019; Bachelet et al., 2019; Fatica et al., 2021), the evidence remains heterogeneous and often contradictory. Differences in bond type, market maturity, certification practices, and issuer characteristics have made generalizations difficult, particularly in the corporate bond segment where green finance is still evolving.

The central research question of this thesis is whether corporate green bonds are priced at a statistically significant premium compared to conventional corporate bonds, once key bond-specific, issuer-level, and macroeconomic variables are controlled for. To address this question, the analysis tests the following hypotheses:

- H₁: Corporate green bonds are priced higher than conventional corporate bonds (i.e., they offer lower yields, consistent with the existence of a greenium).
- H₂: Corporate green bonds are equally priced to conventional corporate bonds (i.e., there is no statistically significant difference in yields).

The research question responds to several gaps identified in the literature. First, while earlier studies (e.g., Flammer, 2021; Larcker & Watts, 2020) have examined firm-level reputational and secondary market effects, fewer works provide rigorous tests of primary market pricing using large-scale bond-level datasets with issuer-matched samples. Second, existing findings often lack consistency regarding whether the greenium is robust to the inclusion of controls for liquidity, macroeconomic risk, or issuer credibility — factors that are especially relevant in corporate bond pricing. Third, many studies rely solely on

yield-to-maturity or spread metrics without comparing the results across alternative specifications or subsamples.

To address these limitations, this thesis applies both YTM and credit spread regressions to a matched sample of green and conventional bonds issued by the same corporate entities. The analysis incorporates fixed effects for rating, year, industry, and country, and controls for key bond characteristics including maturity, size, subordination, callability, and currency risk. Macroeconomic conditions, such as volatility and sovereign risk, are also accounted for.

By narrowing the empirical scope to corporate bonds and employing a robust methodological framework, the research question is designed to test whether a statistically and economically meaningful greenium exists once appropriate controls are applied. The findings derived from this approach aim to clarify the empirical ambiguity surrounding green bond pricing and to contribute to the growing body of literature assessing the financial consequences of sustainability-linked investment.

4. Methodology

4.1 Previous methodology approaches

The greenium literature employs a diverse range of methodological approaches, each contributing unique insights but also complicating comparability across studies. Matched pair analyses, as employed by Larcker and Watts (2020), provide a quasi-experimental framework to control for bond-specific characteristics, revealing no significant greenium in U.S. municipal bonds. OLS regression models are common in studies such as Flammer (2021), where firm-level controls and event study techniques are used to isolate green bond effects, finding reputational but not pricing benefits. Yield curve modeling, as demonstrated by Fandella and Cociancich (2024), illustrates that greenium estimates are sensitive to model specifications, with results ranging from positive to negative depending on the approach. Simulation models, including Traore (2024), provide theoretical explorations of how investor preferences and regulatory risks interact to shape greenium under various scenarios. Panel regressions, as in Molino et al. (2023), help to capture dynamic liquidity effects and macroeconomic interactions.

Cheong and Choi (2020) and Kedia and Joshipura (2023) critique the heterogeneity of methods in the literature, emphasizing that differences in matching criteria, control variables, and sample construction can lead to divergent findings. Kapraun et al. (2021) and Löffler et al. (2021) highlight the importance of incorporating credibility and verification factors into methodological designs to accurately capture greenium effects. Alves, Lopes, and Pinto (2023) underscore the significance of controlling for macroeconomic variables to avoid attributing yield differentials solely to green labels. Collectively, these studies underline that while methodological diversity enriches the field, it also necessitates caution in comparing results and calls for greater harmonization in future research.

4.2 Research design

This thesis employs a two-pronged empirical strategy to evaluate the existence and magnitude of greenium in bond markets. The research design integrates a matched pairs approach with multivariate regression analysis, enabling robust testing of the yield differentials between green and conventional bonds while controlling for confounding factors.

First, the matched pairs methodology ensures direct comparability between green bonds and their conventional counterparts. Each green bond in the sample is paired with a conventional bond issued by the same issuer, thereby controlling issuer-specific characteristics that could influence bond pricing. Matching is conducted at the issuer level, and pairs are further refined using propensity score matching (PSM). The PSM process incorporates bond characteristics such as deal size, maturity, and rating to create statistically comparable pairs, minimizing selection bias (Rosenbaum & Rubin, 1983).

Second, the thesis applies multivariate ordinary least squares (OLS) regression techniques to model the yield to maturity (YTM)

$$YTM_{\{i,t\}} = \alpha + \beta_1 Green_{\{i\}} + \beta_2 \log_deal_size_{\{i,t\}} + \beta_3 \log_maturity_{\{i,t\}} + \beta_4 num_tranches_{\{i,t\}} + \delta' X_{\{i,t\}} + \theta_1 VIX_t + \theta_2 CountryRisk_{\{i,t\}} + \theta_3 RiskFree_t + \mu_{\{rating\}} + \mu_{\{industry\}} + \mu_{\{country\}} + \mu_{\{year\}} + \mu_{\{firm\}} + \epsilon_{\{i,t\}}$$

Afterwards a similar regression was employed to test for the spread as a robustness check for the previous model varying for the difference in needed controls.

$$Spread_{\{i,t\}} = \alpha + \beta_1 Green_{\{i\}} + \beta_2 callable_{\{i,t\}} + \beta_3 \log_deal_size_{\{i,t\}} + \beta_4 \log_maturity_{\{i,t\}} + \beta_5 num_tranches_{\{i,t\}} + \beta_6 subordination_{\{i,t\}} + \delta' X_{\{i,t\}} + \theta_1 VIX_t + \theta_2 CountryRisk_{\{i,t\}} + \mu_{\{useofproceeds\}} + \mu_{\{industry\}} + \mu_{\{year\}} + \epsilon_{\{i,t\}}$$

The regression models incrementally introduce controls for bond-specific attributes, market variables, and fixed effects to isolate the greenium effect.

Clustered standard errors at the country-year level are used to correct for potential intra-cluster correlation in residuals, enhancing the validity of statistical inference.

This dual approach addresses key limitations in the existing literature, such as omitted variable bias, and enhances the reliability of conclusions drawn about the presence and determinants of greenium.

4.3 Sample construction

The empirical analysis draws on bond-level data from DCM Analytics, a platform widely used in green bond research for its comprehensive coverage (e.g., Flammer, 2021; Kapraun et al., 2021). The dataset comprises tranches of euro-denominated corporate bonds—both green and conventional—issued across various industries between January 2, 2018 and January 6, 2025. Sovereign and supranational issuers are excluded, focusing the analysis solely on corporate bonds.

Two dependent variables are analyzed: yield to maturity (YTM) and spread to benchmark, both in basis points. The primary explanatory variable is a green bond dummy. Additional controls include bond-specific features (maturity, issuance size, callability, subordination, credit rating, tranche structure, currency), as well as macroeconomic indicators (VIX, country risk premium, and the risk-free rate), consistent with prior literature (Zerbib, 2019; Bachelet et al., 2019; Fatica et al., 2021).

To ensure comparability, each green bond is matched to a conventional bond issued by the same firm, following Larcker and Watts (2020). This is refined with propensity score matching on maturity, size, and rating, as in Kapraun et al. (2021), to improve internal validity.

Observations with missing data or rare fixed effects categories are excluded. The final sample offers a rigorous basis to test whether a greenium exists in corporate bond pricing.

4.5 Spread determinants

4.5.1 Credit rating

Credit rating plays a central role in the determination of bond yields, reflecting the issuer's default risk and its capacity to meet debt obligations under varying economic conditions. In the corporate bond market, credit spreads — the yield premium above a risk-free benchmark — are strongly influenced by the issuer's rating. Empirical research consistently finds that lower-rated bonds command higher credit spreads to compensate investors for increased credit risk (Elton et al., 2001; Gabbi & Sironi, 2005; Flannery et al., 2012). This relationship is well-documented across market cycles and rating agencies and is often non-linear, with spread sensitivity increasing sharply for bonds rated below investment grade (Campbell & Taksler, 2003).

Credit rating affects not only the level of spreads but also their sensitivity to other determinants. For instance, maturity risk premia are more pronounced for lower-rated bonds, as long-term uncertainty compounds credit concerns (Sarig & Warga, 1989). Similarly, the importance of structural features such as subordination, callability, or tranche complexity is amplified in lower credit grades, where investors rely more heavily on protective covenants and pricing premiums to mitigate default exposure (Vink & Thibeault, 2008; Fabozzi & Vink, 2012). Therefore, the role of credit rating is both direct, through its impact on spread levels, and indirect, by conditioning how other contractual or firm-specific factors affect bond pricing.

In the context of green bond pricing, the inclusion of credit rating as a control variable is essential to distinguish pricing effects attributable to environmental labeling from those arising due to credit risk. Green bonds may be disproportionately issued by higher-rated firms — particularly in Europe and the

supranational space — leading to spurious greenium findings if credit quality is not properly accounted for (Zerbib, 2019; Bachelet et al., 2019). Kapraun et al. (2021) show that once credit risk is controlled, the greenium often shrinks or disappears, suggesting that market pricing primarily reflects issuer fundamentals rather than environmental signaling. Similarly, Silva and Blankson (2025) emphasize that robust greenium estimation must explicitly separate environmental preferences from baseline creditworthiness.

4.5.2 Contractual characteristics

Beyond credit rating, bond-specific contractual characteristics play a crucial role in determining issuance yields and credit spreads. These features encode both structural risk and marketability dimensions, and their inclusion in greenium analysis is essential to ensure that observed yield differentials are not driven by bond design rather than environmental labeling (Elton et al., 2001; Gabbi & Sironi, 2005; Vink & Thibeault, 2008).

Callability is one of the most widely studied contractual features in bond pricing. Callable bonds grant the issuer the right to redeem the bond before maturity, typically when interest rates fall, which introduces reinvestment risk for investors. As a result, callable bonds generally carry higher yields than their non-callable counterparts to compensate for this embedded option (Chambers & Charnes, 2009; Fabozzi & Vink, 2012). In the context of green bonds, callability may interact with investor preferences — green bonds with callable features might be perceived as less stable long-term sustainability investments, potentially impacting investor demand and pricing.

Deal size (or total transaction size) also influences spreads, primarily through its relationship with market liquidity. Larger issues tend to benefit from higher secondary market liquidity, more efficient price discovery, and lower transaction costs, all of which contribute to lower yields at issuance (Chen et al., 2007;

Mayberger, 2014). This is particularly relevant for green bonds, which are often issued in smaller sizes relative to conventional bonds, especially by first-time or emerging market issuers (Nanayakkara & Colombage, 2019). Controlling for deal size is therefore critical to avoid attributing yield differences to greenness when they may instead reflect liquidity premia.

The number of tranches serves as a proxy for structural complexity and investor segmentation. Multi-tranche issues are typically employed to tailor risk and maturity profiles to different classes of investors, and may be associated with lower costs of capital due to enhanced diversification and optimized pricing (Vink & Thibault, 2008; Fabozzi & Vink, 2012). However, complexity can also introduce opacity and valuation uncertainty, particularly in the absence of clear documentation or third-party verification, potentially increasing spreads. For green bonds, multiple tranches may reflect strategic structuring to align with specific environmental use-of-proceeds categories or regulatory thresholds.

Subordination defines the bond's position in the capital structure, with subordinated bonds ranking behind senior debt in the event of default. These bonds inherently carry higher credit risk and are thus priced with a spread premium (Gabbi & Sironi, 2005; Pinto & Marques, 2020). Subordination is particularly relevant in green finance, where issuers may choose to fund riskier, long-horizon environmental projects using subordinated debt to avoid senior balance sheet exposure. Consequently, failing to control for subordination would bias greenium estimates, as higher spreads could be mistakenly attributed to the green label rather than risk tier.

4.5.3 Macroeconomic factors

Macroeconomic factors are essential in determining bond yields and must be controlled for when testing for greenium. As emphasized by Zerbib (2019), failing to account for general market conditions can bias estimates of the green

label's effect. To capture baseline borrowing costs, the model includes the 3-month U.S. Treasury bill rate and the term spread (UST5Y – UST3M), reflecting monetary policy stance and yield curve dynamics.

Country-level institutional quality is addressed using creditor rights and legal enforcement indices (La Porta et al., 1998; Hainz & Kleimeier, 2012; Subramanian & Tung, 2016), accounting for cross-country variation in investor protection and legal systems. Country risk scores are also included.

To reflect market sentiment, the VIX is used as a proxy for global volatility (Chen et al., 2007; Mayberger, 2014), while year and industry fixed effects control for macro and sector-specific shocks (Riachi & Schwienbacher, 2015; Pinto & Marques, 2020; Navi, 2020). These controls enhance causal interpretation by ensuring that observed pricing effects are not driven by broader risk factors.

4.6 Matched sample

To complement the regression analysis and enhance causal inference, a matched sample framework is employed. Matching methods are widely used in the green bond literature to estimate the greenium under controlled conditions (Larcker & Watts, 2020; Kapraun et al., 2021; Cheong & Choi, 2020).

The approach follows a two-step design. First, each green bond is paired one-to-one with a conventional bond issued by the same corporate entity, thereby eliminating issuer-specific differences in governance, credit quality, or market visibility. This exact-issuer matching approach is also used by Larcker and Watts (2020) in their municipal bond study.

Second, propensity score matching (PSM) is applied based on time to maturity, deal size, and retained credit rating—variables shown to influence bond pricing and selection into green labelling (Fatica et al., 2021; Zerbib, 2019). Propensity scores are estimated via logistic regression, and nearest-neighbor matching without replacement is used to construct the sample.

The greenium is then estimated using paired t-tests on the yield spread differential between each matched pair, following similar procedures used in Kapraun et al. (2021) and Bachelet et al. (2019). The focus is on the spread to benchmark, though robustness checks using YTM are also conducted. Because matching occurs at the issuer level, unobservable firm-specific attributes are held constant, enhancing the internal validity of the estimates.

Following the matching procedure, Model 5 YTM and Model 5 Spread were re-estimated using only the matched sample, allowing for direct comparability of regression results under controlled issuer-level conditions. This step is consistent with approaches adopted by Flammer (2021) and Kapraun et al. (2021), who similarly re-ran core regressions on balanced or subsampled datasets to test the stability of their findings.

This matched sample analysis complements the multivariate regressions by offering a quasi-experimental test of the greenium hypothesis under tightly controlled conditions. Its consistency with the regression-based results reinforces the robustness of the findings and aligns with best practices in empirical finance.

5. Green bond pricing dynamics

5.1 Univariate analysis

This section presents a univariate analysis of the key features of green and conventional bonds in the sample. The comparison covers sectoral and geographic issuance patterns, issuer concentration, and financial characteristics at the bond level. This preliminary assessment provides essential context for interpreting the multivariate results presented in subsequent sections.

Table 1 Bond issuance distribution per industry

5.1.1 Panel A: Industrial distribution						
Industrial category of issuer	Conventional bonds			Green bonds		
	Number of tranches	Total value [€ Million]	Percent of total value	Number of tranches	Total value [€ Million]	Percent of total value
<i>Machinery</i>	666,00	421 677	1,4%	40	11 562	0,9%
Oil & Gas	1 857	1 949 214	6,5%	32	8 268	0,7%
Computers & Electronics	2 286	3 695 310	12,3%	96	56 662	4,5%
Real Estate/Property	8 321	1 977 739	6,6%	907	200 450	15,9%
Auto/Truck	1 321	1 202 917	4,0%	91	78 482	6,2%
Utility & Energy	6 376	2 891 665	9,7%	1 230	561 407	44,6%
Holding Companies	1 360	396 333	1,3%	31	5 940	0,5%
Transportation	4 006	1 835 306	6,1%	335	83 682	6,6%
Chemicals	1 525	817 828	2,7%	85	33 745	2,7%
Metal & Steel	1 535	418 463	1,4%	75	22 464	1,8%
Construction/Building	8 202	1 491 248	5,0%	294	45 976	3,7%
Forestry & Paper	232	91 237	0,3%	45	27 280	2,2%
Retail	932	1 318 173	4,4%	29	11 293	0,9%
Telecommunications	1 455	2 228 879	7,4%	52	39 750	3,2%
Food & Beverage	1 409	1 506 882	5,0%	29	14 626	1,2%
Leisure & Recreation	581	714 420	2,4%	10	298	0,0%
<i>Healthcare</i>	1 968	4 489 297	15,0%	12	9 811	0,8%
<i>Professional Services</i>	1 160	559 435	1,9%	35	32 785	2,6%
<i>Mining</i>	981	342 890	1,1%	23	3 936	0,3%
<i>Textile</i>	133	20 835	0,1%	4	176	0,0%
<i>Consumer Products</i>	802	807 280	2,7%	22	8 144	0,6%
<i>Aerospace</i>	272	764 194	2,6%	4	878	0,1%
<i>Agribusiness</i>	185	22 597	0,1%	14	1 404	0,1%
Total	47 565	29 963 817	100,0%	3 495	1 259 019	1,00

This table displays the industrial distribution of corporate green and conventional bonds issued between 2018 and 2025. It reports the number of tranches, total issuance volume (in € million), and share of total value by industrial category. The sample includes 47,565 conventional and 3,495 green bond tranches. Data is sourced from DCM Analytics. Industry classification is based on the issuer's primary sector. Percentages reflect the proportion of each industry in total issuance value within each bond type.

Panel A presents the industrial distribution of both green and conventional bond issuances across 24 distinct industry categories. The sample comprises 47,565 tranches of conventional bonds with a cumulative issuance value of €29.96 trillion, and 3,495 green bond tranches totaling €1.26 trillion. The breakdown reveals stark differences in industry participation, both in absolute terms and relative proportions.

The Utility & Energy sector dominates green bond issuance, accounting for 44.6% of the total green issuance volume with €561.41 billion across 1,230 tranches. In contrast, its share among conventional bonds is markedly lower, at 9.7%. This overrepresentation reflects the strong alignment between energy transition objectives and green financing frameworks, as also observed in prior studies (e.g., Flammer, 2021; Fatica et al., 2021).

Real Estate/Property follows with a substantial 15.9% share of green bond value (€200.45 billion), a notable increase compared to its 6.6% share of conventional bonds. The sector's increased role may be driven by the expansion of green building certifications and the financing of energy-efficient infrastructure, consistent with trends documented by Zerbib (2019).

Transportation and Auto/Truck sectors also display proportional increases in green financing, representing 6.6% and 6.2% of green bond volumes, respectively, versus 6.1% and 4.0% in the conventional bond market. These patterns underscore a growing emphasis on decarbonizing mobility and electrification initiatives (Kapraun et al., 2021).

Conversely, several sectors are markedly underrepresented in the green bond market. Notably, Healthcare accounts for 15.0% of conventional bond issuance by value, but only 0.8% of green bonds. A similar pattern is observed in

Computers & Electronics (12.3% conventional vs. 4.5% green), Telecommunications (7.4% vs. 3.2%), and Oil & Gas (6.5% vs. 0.7%). The limited green bond activity in these sectors likely reflects lower compatibility with green bond use-of-proceeds criteria and the risk of perceived greenwashing (Bachelet et al., 2019).

Several smaller industries display interesting relative shifts. Forestry & Paper, for example, represents only 0.3% of conventional issuance but accounts for 2.2% of green bond volume. Professional Services and Chemicals also see moderate increases in relative green bond issuance. On the other hand, Mining, Aerospace, and Textile sectors remain marginal in both markets, with negligible green bond participation, likely due to the difficulty of aligning these sectors with environmentally sustainable objectives.

Overall, the industrial composition of green bonds is skewed toward infrastructure-heavy and capital-intensive sectors that lend themselves well to environmental projects and verifiable impact metrics. This pattern is broadly consistent with the literature, which notes that eligibility for green certification and alignment with climate policy frameworks are key drivers of sectoral green bond participation (Löffler et al., 2021).

Table 2 Bond Issuance distribution by geography

5.1.2 Panel B: Geographic distribution						
Geographic location of issuer	Conventional bonds			Green bonds		
	Number of tranches	Total value [€ Million]	Percent of total value	Number of tranches	Total value [€ Million]	Percent of total value
Europe	7 077	6 321 523	20386,91	1 206	597 541	47,45
European Union	0	0	0,00	0	0	0,00
United Kingdom	1 580	1 191 893	3,98	73	52 434	4,16
Eastern Europe	50	22 372	0,07	14	6 250	0,50
Northern Europe	1 489	384 216	1,28	598	97 882	7,77
Western Europe	3 958	4 723 042	15,76	521	440 975	35,02
America	11 329	17 235 383	55584,10	450	252 867	6752,32
United States	9 831	16 290 173	54,37	335	216 031	17,15
Canada	1 167	745 539	2,49	85	25 073	1,99
Caribbean	0	0	0,00	0	0	0,00
Latin America	331	199 672	0,67	30	11 762	0,93
Asia	28 503	6 073 331	20,27	1 813	396 309	10582,67
China	22 534	3 934 169	13,13	1 117	181 717	14,43
East Asia	5 708	2 030 091	6,78	660	199 146	15,81
South Asia	0	0	0,00	0	0	0,00
Southeast Asia	154	31 008	0,10	20	3 745	0,30
Western Asia	107	78 063	0,26	16	11 702	0,93
Australia/New Zealand	593	291 495	0,97	23	12 287	0,98
Africa	63	42 085	0,14	5	333	0,03
Total	47 565	29 963 817	100,00	3 497	1 259 336	100,00

This table presents the geographic distribution of green and conventional corporate bonds issued between 2018 and 2025. It reports the number of tranches, total issuance volume (in € million), and percentage share by issuer region. The sample includes 47,565 conventional and 3,497 green bond tranches. Geographic classification follows issuer domicile. Data is sourced from DCM Analytics. Percentages reflect each region's share of total issuance value within each bond category.

Panel B illustrates the geographic distribution of green and conventional bond issuers. While some of the largest issuers in both markets remain consistent, key differences emerge in the relative importance of regions, driven by distinct regulatory environments, investor bases, and institutional capacities.

Europe stands out as the global center for green bond issuance, contributing 47.45% of the total green bond market by value, a striking contrast to its 21.09% share of conventional issuance. This overrepresentation is particularly concentrated in Western Europe, which alone accounts for 35.02% of green issuance, and Northern Europe, contributing 7.77%. These figures reaffirm the central role played by Europe's regulatory infrastructure, including the EU taxonomy and disclosure frameworks, which have fostered investor confidence and deepened market penetration (Carmichael & Rapp, 2024).

In contrast, the Americas, particularly the United States, dominate the conventional bond landscape (54.37% of total volume) but are comparatively underrepresented in green finance, issuing only 17.15% of green bonds. While the U.S. remains a major player by volume (€216.03 billion), the relative scale indicates a lag in adoption of green debt instruments. This discrepancy likely stems from the absence of cohesive federal sustainability regulation, coupled with more limited third-party verification practices (Kapraun et al., 2021).

Asia has emerged as the second-largest region for green bond issuance, contributing 31.46% of green volume, slightly above its 20.27% share in the conventional bond market. China leads this segment with €181.72 billion (14.43%), followed by East Asia (€199.15 billion, 15.81%). These figures suggest robust public sector engagement and growing institutional interest in green finance, supported by national policy agendas and central bank initiatives (Hu et al., 2024; Zenno & Aruga, 2022). Notably, East Asia's performance nearly doubles its share in conventional markets, indicating accelerated growth in green issuance.

Regions such as Australia/New Zealand, Western Asia, and Latin America exhibit relatively balanced shares between green and conventional bond markets, each contributing around 0.9%. While these regions remain small in absolute terms, their proportional alignment may reflect an initial but stable integration of green finance principles.

Conversely, Africa contributes only 0.03% of green bond volume, a significant underrepresentation compared to its already limited 0.14% share in conventional bonds. This reflects persistent structural barriers such as low issuer scale, weak investor ecosystems, and high transaction costs — all well-documented impediments to green capital access in lower-income markets (Liberati & Marinelli, 2021).

South Asia and Caribbean markets record no green or conventional bond issuances in this dataset, highlighting either data exclusions or complete market inactivity, and pointing to untapped potential in these regions.

In sum, the data reflects a geographic skew in favor of Europe and increasingly Asia within the green bond market, while the dominance of North America in conventional debt is not mirrored in sustainable finance. These observations underscore the importance of regulatory support and institutional credibility in driving regional green bond participation.

Table 3 Top issuers by deal value

Panel C: Top issuers					
Conventional bonds			Green bonds		
Firm	By value of deals	By number of deals	Firm	By value of deals	By number of deals
Comcast Corp	1,36%	0,10%	TenneT Holding BV	3,67%	0,23%
CVS Health Corp	1,35%	0,08%	ENGIE SA	3,09%	0,24%
AbbVie Inc	1,31%	0,05%	NTT Finance Corp	2,42%	0,17%
UnitedHealth Group Inc	1,14%	0,11%	E.ON SE	1,90%	0,16%
Bristol-Myers Squibb Co	1,12%	0,07%	EDF Electricite de France SA	1,73%	0,14%
Boeing Co	1,05%	0,09%	Orsted A/S	1,72%	0,16%
Verizon Communications Inc	1,02%	0,34%	Volkswagen International Finance NV	1,71%	0,11%
Magallanes Inc	1,01%	0,02%	China Three Gorges Corp	1,30%	0,46%
Amazon.com Inc	0,94%	0,05%	Iberdrola Finanzas SAU	1,00%	0,16%
Oracle Corp	0,84%	0,05%	Suez SA	0,98%	0,07%

This table organizes the dataset into the top 10 issuers by value of deals for both green and conventional bonds

Panel C outlines the top 10 issuers by value and number of deals in both bond markets. The conventional bond segment is dominated by large U.S. corporates, particularly from the healthcare, technology, and telecommunications sectors. Comcast Corp leads with 1.36% of total issuance by value, while Verizon Communications Inc ranks highest by deal count (0.34%), suggesting a more frequent issuance strategy.

In contrast, green bond issuance is led by European and Asian firms operating in energy, utilities, and infrastructure. TenneT Holding BV (3.67%), ENGIE SA (3.09%), and NTT Finance Corp (2.42%) are among the largest contributors by issuance value. China Three Gorges Corp stands out with the highest number of deals (0.46%), reflecting an active and repeated presence in the green debt market.

Notably, there is no overlap between the top issuers across the two markets. This underscores that green bond issuance is not merely a function of firm size or activity in conventional markets, but instead reflects alignment with green investment strategies and eligibility under sustainable finance criteria (Flammer, 2021; Bachelet et al., 2019).

Table 4 Descriptive statistics for the continuous variables of the matched sample

5.1.4 Matched sample – continuous variables

Variable of interest	Conventional bonds	Sustainable bonds
		Green bonds
<i>Univariate analysis -</i>		
<i>continuous variables</i>		
Credit spread (bps)		
Number	1 282	1 282
Mean	80,2	82,7
Median	55,2	73,0
Rating [1-20 weak]		
Number	1 282	0
Mean	7,3	7,3
Median	7	7
Number of tranches		
Number	1 282	1 282
Mean	1,6	1,6
Median	1	1
Transaction size (€ Million)		
Number	1 282	1 282
Mean	566 228 384,0	599 236 264
Median	372 084 581	408 747 189,9

This table summarizes the number of tranches, total issuance value (in € million), credit rating and spread for green bonds and conventional corporate bonds issued between 2018 and 2025. Data is sourced from DCM Analytics. Bond ratings are converted into a numerical scale (AAA/Aaa = 1 to D = 22).

The average credit spread is slightly higher for green bonds (82.7 bps) than for conventional bonds (80.2 bps), yet the median spread is notably higher for green bonds (73.0 bps vs. 55.2 bps). This suggests a skewed distribution, possibly influenced by a cluster of green bonds with relatively tight spreads. The finding contrasts with prior studies reporting a negative greenium (Zerbib, 2019; Fatica et al., 2021), and may reflect sample-specific dynamics or temporal variation.

The credit rating, reported on a 1–20 scale where higher values denote weaker ratings, is identical across both groups with a mean of 7.3 and a median of 7, implying comparable credit quality. However, the absence of observations for

green bond ratings in this table indicates that this variable may have been excluded in that subset, possibly due to data limitations.

Both categories exhibit the same average number of tranches per issuance (1.6), with a median of 1, indicating a predominantly single-tranche structure.

In terms of transaction size, green bonds appear slightly larger on average, with a mean issuance of €599.24 million versus €566.23 million for conventional bonds. The median also supports this trend, at €408.75 million for green bonds and €372.08 million for conventional ones. This suggests that green bonds in the sample tend to be modestly larger, which may relate to economies of scale in verification costs or issuer signaling strategies (Kapraun et al., 2021; Flammer, 2021).

Overall, the descriptive statistics reveal broad comparability between the two categories, with some differences in yield distribution and deal size that warrant further exploration through multivariate analysis.

Table 5 Continuation of table 4

Variable of interest	Conventional bonds	Sustainable bonds
		Green bonds
Tranche size (€ Million)		
Number	1 282	1 282
Mean	351 140 934,4	370 951 417
Median		316 349 323
Country risk		
Number	1 282	1 282
Mean	3,3	3,3
Median	3	3
Maturity (years)		
Number	1 282	1 282
Mean	6,5	6,9
Median	4	4

This table reports summary statistics for tranche size (in € million), country risk, and maturity (in years) for green and conventional corporate bonds issued between 2018 and 2025. Tranche size and maturity data are sourced from DCM Analytics. Country risk scores are based on Moody's database and are converted into a numerical scale following the same methodology used for credit ratings (AAA/Aaa = 1 to D = 22)

This panel presents further descriptive statistics on bond characteristics relevant to issuance structure and sovereign risk exposure.

The mean tranche size is slightly higher for green bonds (€370.95 million) than for conventional bonds (€351.14 million), a trend also reflected in the median values (€316.35 million for green vs. €316.35 million for conventional). This modest difference suggests that green bond issuances tend to be marginally larger, which could reflect cost-efficiency in external certification processes or a preference for larger projects with identifiable environmental benefits (Flammer, 2021; Bachelet et al., 2019).

Country risk, measured on a 1–21 scale, shows no difference across the two groups, with both samples recording an identical mean of 3.3 and median of 3. This confirms that both bond types are drawn from broadly similar sovereign risk environments, supporting the validity of direct yield comparisons without significant bias from geographic credit risk.

In terms of maturity, green bonds are marginally longer-dated on average (6.9 years) than their conventional counterparts (6.5 years), while both have a median of 4 years. The slightly longer tenor in green bonds may reflect investor demand for stable, long-horizon environmental investments, or issuer alignment with infrastructure-focused green projects (Kapraun et al., 2021).

Overall, these statistics suggest that the green and conventional bonds in the sample are well-matched along structural and sovereign risk dimensions, allowing for credible estimation of yield differentials in multivariate analysis.

Table 6 Descriptive statistics for the dummy variables of the matched sample model

<i>Univariate analysis - dummy variables</i>		
Subordinated		
Nr. of tranches	1 282	1 282
Nr. of tranches with d=1	1 270	1264
% of total	99,1%	98,6%
Currency risk		
Nr. of tranches	1 282	1 282
Nr. of tranches with d=1	298	329
% of total	23,2%	25,7%
Callable		
Nr. of tranches	1 282	1 282
Nr. of tranches with d=1	626	657
% of total	48,8%	51,2%

This table presents summary statistics for the subordinated, callable, and currency risk dummy variables for green and conventional corporate bonds issued between 2018 and 2025. All variables are binary, taking the value of 1 when the corresponding feature is present. Subordination and callable status are obtained from DCM Analytics. Currency risk is based on the mismatch between bond currency and issuer's country of risk, with classifications derived from Moody's database.

Nearly all bonds in both categories are subordinated, with 99.1% of conventional and 98.6% of green tranches flagged as such. The near-total prevalence suggests that subordination is structurally embedded in the sample, leaving limited variation for explanatory analysis.

Currency risk is present in 23.2% of conventional and 25.7% of green bonds, a small but notable difference. While the levels are broadly similar, green bonds appear slightly more likely to expose investors to currency mismatches. This

could reflect international issuance aimed at accessing ESG-sensitive capital pools (Kapraun et al., 2021).

Regarding callability, 51.2% of green bonds are callable, compared to 48.8% of conventional bonds. The difference is marginal but suggests green bonds are not systematically structured to reduce optionality, even though callability introduces reinvestment risk for investors. These values imply broad comparability in contractual flexibility between the two samples.

Together, these descriptive statistics confirm that the green and conventional bonds in the matched sample are similar in key binary features, supporting the reliability of subsequent regression analysis.

5.2 Regression results

This section investigates whether green bonds are priced at a premium relative to conventional bonds by analyzing yield to maturity (YTM) at issuance. The coefficient on the Green dummy in Table 7 measures the marginal effect of the green label on YTM, after controlling for a series of factors that could otherwise confound bond pricing.

Table 7 Regression results of the yield to maturity model

Dependent variable:						
YTM (bps)		[1]	[2]	[3]	[4]	[5]
Green	Coef.	-0.17	0.01	0.04	0.04	0.17
	t-stat	(-0.41)	(0.02)	(0.11)	(0.11)	(1.16)
Deal size (Log)	Coef.		0.02	0.10	0.10	0.58***
	t-stat		(0.08)	(0.47)	(0.47)	(4.41)
Maturity (Log)	Coef.		-0.01	-0.02	-0.02	0.25***
	t-stat		(-0.06)	(-0.11)	(-0.11)	(4.15)
# Tranches	Coef.			-0.20**	-0.20**	-0.32**
	t-stat			(-2.57)	(-2.57)	(-2.43)
AAA	Coef.		-0.93*	-0.63	-0.63	-0.56
	t-stat		(-1.77)	(-1.06)	(-1.06)	(-0.70)
AA+	Coef.		38.79	38.81	38.81	-0.94*
	t-stat		(1.00)	(1.00)	(1.00)	(-1.65)
AA	Coef.		-0.52	-0.25	-0.25	-0.38
	t-stat		(-1.17)	(-0.55)	(-0.55)	(-0.76)
AA-	Coef.		-0.08	0.07	0.07	-0.37
	t-stat		(-0.14)	(0.11)	(0.11)	(-0.65)
A+	Coef.		-0.54**	-0.54**	-0.54**	-0.30
	t-stat		(-2.12)	(-2.14)	(-2.14)	(-0.58)
A	Coef.		-0.59*	-0.63*	-0.63*	-0.22
	t-stat		(-1.73)	(-1.84)	(-1.84)	(-0.41)
A-	Coef.		-0.45	-0.46	-0.46	-0.02
	t-stat		(-1.53)	(-1.52)	(-1.52)	(-0.04)
BBB+	Coef.		-0.38	-0.39	-0.39	0.35
	t-stat		(-1.21)	(-1.23)	(-1.23)	(0.61)
BBB	Coef.		1.21	1.14	1.14	0.35
	t-stat		(1.24)	(1.21)	(1.21)	(0.61)
BBB-	Coef.		0.37	0.28	0.28	0.60
	t-stat		(1.35)	(1.05)	(1.05)	(1.05)
BB+	Coef.		0.89***	0.73**	0.73**	1.45**
	t-stat		(2.80)	(2.19)	(2.19)	(2.26)
BB	Coef.		1.73***	1.54***	1.54***	2.60***
	t-stat		(5.92)	(5.12)	(5.12)	(3.88)

BB-	Coef.	2.36***	2.16***	2.16***	3.38***
	t-stat	(7.46)	(6.52)	(6.52)	(2.95)
B+	Coef.	2.56***	2.33***	2.33***	6.34***
	t-stat	(8.16)	(6.99)	(6.99)	(6.22)
B	Coef.	3.49***	3.31***	3.31***	5.90***
	t-stat	(13.21)	(11.03)	(11.03)	(4.70)
B-	Coef.	4.84***	4.63***	4.63***	9.38***
	t-stat	(8.98)	(8.17)	(8.17)	(7.94)
CCC+	Coef.	3.68***	3.42***	3.42***	
	t-stat	(6.36)	(5.93)	(5.93)	
CCC	Coef.	4.04***	3.92***	3.92***	
	t-stat	(8.11)	(8.26)	(8.26)	
CCC-	Coef.	5.79***	5.65***	5.65***	
	t-stat	(7.95)	(8.06)	(8.06)	
CC	Coef.	3.32***	3.23***	3.23***	
	t-stat	(5.78)	(5.82)	(5.82)	
SD	Coef.	5.70***	5.59***	5.59***	
	t-stat	(4.76)	(4.69)	(4.69)	
Country risk	Coef.		0.93*	0.93*	-0.06
	t-stat		(1.83)	(1.83)	(-0.23)
Risk free	Coef.		0.38**	0.38**	0.37***
	t-stat		(2.04)	(2.04)	(3.30)
VIX	Coef.		0.00	0.00	0.02***
	t-stat		(0.45)	(0.45)	(2.81)
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Country fixed effects	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes
Rating fixed effects	No	Yes	Yes	Yes	Yes
Firm fixed effects	No	No	No	Yes	Yes
Observations	50909	50909	50909	50909	2563
R ²	0,003	0,007	0,007	0,007	0,5
Adj. R ²	0,001	0,005	0,005	0,005	0,484
Clusters	236	236	236	236	186

This table presents the results of OLS regressions estimating the determinants of bond yield to maturity (in basis points) for a sample of green and conventional corporate bonds issued between 2018 and 2025. The dependent variable is YTM at issuance. The main explanatory variable of interest is a green bond dummy. Control variables include bond-specific contractual characteristics (deal size, maturity, number of tranches), credit rating dummies (converted from AAA/Aaa = 1 to D = 22), and macroeconomic factors (country risk, risk-free rate, and VIX index). Fixed effects for year, country, industry, rating, and firm are included depending on the specification. Column [5] represents the results from the matched sample. Clustered standard errors are reported at the country-year level. Statistical significance is denoted as follows: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Across the full sample, Models 1 through 4 show consistent evidence of no statistically significant pricing differential between green and non-green bonds. In the most basic specification (Model 1), the Green dummy is associated with a -0.17 basis point difference in YTM, with a t -statistic of -0.41 . This result persists in both magnitude and insignificance in Model 2, where fixed effects for bond ratings are added. The inclusion of contractual characteristics in Model 3 (e.g., log maturity, log deal size, number of tranches) does not materially affect the result, nor does the inclusion of issuer-level fixed effects in Model 4. The adjusted R^2 remains low in all specifications (ranging from 0.001 to 0.005), suggesting that little variation in YTM is captured by the green label or included controls in the full sample.

However, a different pattern emerges in Model 5, which restricts the sample to matched pairs of bonds issued by the same firm, thereby reducing unobservable heterogeneity. In this more tightly controlled setting, the coefficient on the Green dummy increases to 0.17 basis points and the t -statistic rises to 1.16. Although this effect is still statistically insignificant at conventional levels, the direction of the coefficient points toward a slight yield disadvantage for green bonds, contradicting the hypothesis of a greenium. The adjusted R^2 improves dramatically to 0.484, indicating that matching greatly enhances model fit by holding constant unobservable issuer characteristics.

These results stand in contrast with early evidence from studies such as Zerbib (2019) and Fatica et al. (2021), which find small but significant green premia. Instead, the findings here are more closely aligned with the null results reported by Larcker and Watts (2020) and the conditional effects identified by Flammer (2021), suggesting that green bond pricing may be sensitive to issuer-specific factors, regulatory context, or investor segmentation. In this sample, there is no robust evidence of a greenium in primary market pricing when using YTM as the dependent variable.

This section presents a complementary set of results using credit spreads as the dependent variable to assess whether green bonds exhibit systematically different pricing at issuance compared to their conventional counterparts. These regressions, reported in Table 8, function as a robustness check to the previous yield-to-maturity (YTM) analysis and are structured across five models, including a matched sample regression.

Table 8 Regression results for the spread model

Dependent variable:		[1]	[2]	[3]	[4]	[5]
Credit spread (bps)		Conventional Bonds	Green Bonds	All Bonds	All Bonds	Matched Sample
Green	Coef.			4.52	13.61***	1.85
	t-stat			(1.13)	(3.44)	(0.52)
Callable	Coef.	97.83***	131.25** *	108.01** *	100.62** *	70.31***
	t-stat	(11.12)	(10.15)	(11.42)	(11.73)	(9.45)
Deal size (Log)	Coef.	7.63***	2.09	9.52***	7.08***	19.80***
	t-stat	(3.46)	(0.70)	(4.79)	(3.23)	(5.99)
Maturity (Log)	Coef.	1.57	-2.41	-0.39	1.25	5.55***
	t-stat	(0.87)	(-0.81)	(-0.17)	(0.71)	(2.65)
# Tranches	Coef.	-7.08***	-7.08***	-5.79***	-6.30***	-9.29**
	t-stat	(-7.43)	(-7.43)	(-5.76)	(-7.02)	(-2.46)
Subordination	Coef.	-54.86***	39.49	-25.46	46.89***	-75.81**
	t-stat	(-3.55)	(0.94)	(-1.50)	(-3.01)	(-2.38)
AAA	Coef.	-70.58***	117.50** *	-	-	-0.12
	t-stat	(-4.53)	(-4.85)	(-6.99)	(-4.91)	(-0.01)
AA+	Coef.	-51.18***	124.02** *	-	-	29.36*
	t-stat	(-5.43)	(-4.14)	(-6.44)	(-5.44)	(1.92)
AA	Coef.	-44.69***	-8.02	38.31***	39.01***	5.24
	t-stat	(-5.75)	(-0.56)	(-5.05)	(-4.75)	(0.50)
AA-	Coef.	-46.93***	34.61***	50.67***	46.12***	13.75
	t-stat	(-6.29)	(-3.37)	(-6.60)	(-6.59)	(1.05)
A+	Coef.	-27.21***	35.29***	26.80***	28.15***	19.09
	t-stat	(-5.38)	(-2.93)	(-4.67)	(-5.70)	(1.47)
A	Coef.	-32.14***	32.25***	34.21***	32.48***	15.01
	t-stat	(-5.11)	(-3.72)	(-4.90)	(-5.20)	(1.16)
A-	Coef.	-27.94***	42.32***	30.22***	28.94***	37.39***
	t-stat	(-6.20)	(-4.35)	(-5.29)	(-6.34)	(3.08)
BBB+	Coef.	-22.91***	27.54***	28.05***	23.02***	65.87***
	t-stat	(-4.48)	(-3.05)	(-4.58)	(-4.38)	(5.14)
BBB	Coef.	-10.83***	-3.10	-11.12**	-9.87**	84.12***
	t-stat	(-2.85)	(-0.32)	(-2.38)	(-2.56)	(5.85)
BBB-	Coef.	12.87**	-1.06	11.11	12.55**	104.34** *
	t-stat	(2.06)	(-0.09)	(1.56)	(1.99)	(5.33)

BB+	Coef.	49.77***	-14.87	52.20***	48.01***	78.87***
	t-stat	(3.59)	(-0.86)	(4.03)	(3.66)	(2.59)
BB	Coef.	78.40***	106.43**	86.68***	80.31***	9.20
	t-stat	(5.02)	(6.09)	(5.61)	(5.37)	(0.30)
BB-	Coef.	102.58***	66.05	113.80**	101.58**	9.34
	t-stat	(3.95)	(1.00)	(4.18)	(3.91)	(0.20)
B+	Coef.	110.78***	57.95	127.99**	109.68**	40.88
	t-stat	(4.33)	(1.05)	(4.67)	(4.30)	(0.74)
B	Coef.	129.04***	-96.08*	146.03**	124.18**	42.28
	t-stat	(3.69)	(-1.95)	(4.07)	(3.52)	(0.75)
B-	Coef.	129.31***	-24.88	152.63**	126.87**	
	t-stat	(3.14)	(-0.17)	(3.33)	(3.03)	
CCC+	Coef.	212.98***	104.03**	249.20**	205.17**	
	t-stat	(7.50)	(2.83)	(9.78)	(7.43)	
CCC	Coef.	108.13*	-15.13	120.73**	105.47*	
	t-stat	(1.96)	(-0.15)	(2.08)	(1.92)	
CCC-	Coef.	67.84	167.95**	38.04	39.16	
	t-stat	(1.11)	(-7.69)	(0.62)	(0.71)	
CC	Coef.	-19.43	111.10**	-39.43	-31.39	
	t-stat	(-0.55)	(-3.93)	(-1.34)	(-1.09)	
SD	Coef.	-34.13	-36.77	-40.12*	-34.33	
	t-stat	(-1.36)	(-0.37)	(-1.72)	(-1.45)	
Country risk	Coef.	-10.14***	-4.05**	10.09***	-9.72***	-2.74**
	t-stat	(-5.20)	(-2.21)	(-4.98)	(-5.21)	(-2.04)
Currency risk	Coef.	-7.30	5.24	-9.60	-7.81	3.71
	t-stat	(-0.91)	(0.57)	(-1.02)	(-1.02)	(0.61)
VIX	Coef.	0.85**	0.94***	0.92	0.84**	0.33
	t-stat	(2.06)	(2.70)	(1.60)	(2.08)	(0.62)
Use of proceeds fixed effects	Yes	Yes	No	Yes	Yes	
Industry fixed effects	Yes	Yes	No	Yes	Yes	
Year fixed effects	Yes	Yes	No	Yes	Yes	
Observations		47538	3371	50909	50909	2563
R ²		0,432	0,423	0,381	0,426	0,51
Adj. R ²		0,43	0,401	0,381	0,424	0,49
Clusters		230	194	236	236	186

This table reports OLS regression estimates for the determinants of credit spreads (in basis points) at issuance, using a sample of green and conventional corporate bonds issued between 2018 and 2025. The dependent variable is the option-adjusted spread (OAS) relative to a risk-free benchmark. The key independent variable is a green bond dummy. Control variables include contractual features, as well as macroeconomic variables. Fixed effects for use of proceeds, industry, and year are applied as indicated.

Bond ratings are included as dummy variables (AAA/Aaa = 1 to D= 22). Column [5] presents results from a matched sample of green and conventional bonds issued by the same firm and with the same credit rating. Standard errors are clustered at the country-year level. Statistical significance is denoted as follows: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

The coefficient on the Green dummy is statistically insignificant in Models 3 and 5, and only becomes significant in Model 4, where a green bond is associated with a 13.61 basis point higher credit spread ($t = 3.44$). Notably, this positive and significant coefficient contradicts the expected direction of a greenium and suggests the presence of pricing penalties rather than premiums, although the result is sensitive to model specification. When controlling for issuer identity through matched sampling in Model 5, the coefficient falls back to 1.85 basis points and is statistically insignificant ($t = 0.52$), mirroring the YTM-based results. This indicates that the observed premium in Model 4 may stem from unobserved issuer-level heterogeneity not fully accounted for by the control variables.

These findings align more closely with studies such as Larcker and Watts (2020), who find no evidence of a greenium in municipal bonds, and contrast with others such as Zerbib (2019) and Bachelet et al. (2019), who report modest yield differentials in favor of green bonds. The robustness of the null result in the matched sample underscores the importance of controlling for issuer characteristics when evaluating greenium effects.

The regression outputs also reinforce several expected relationships among control variables. Callable bonds consistently exhibit statistically significant higher spreads—ranging from 70.31 to 131.25 basis points across models—with all coefficients significant at the 1% level. This pattern is consistent with the pricing of embedded options and reflects investor demand for compensation against early redemption risk.

Additionally, deal size is positively associated with credit spreads in nearly all specifications, especially in the matched sample (coef. = 19.80, $t = 5.99$). This result, while contrary to some liquidity-premia narratives, may reflect that larger

issues are often tied to more complex or opaque funding structures. Meanwhile, number of tranches shows a consistent negative relationship with spreads, with significant coefficients in all models. This is consistent with the idea that higher tranche counts could reflect structured deals designed to improve risk distribution, thereby lowering risk premia.

Among the macroeconomic variables, country risk remains significantly negative across most specifications, suggesting that higher sovereign creditworthiness contributes to tighter spreads. By contrast, currency risk and VIX are largely insignificant, except in Model 2, where VIX reaches significance ($t = 2.70$), perhaps reflecting heightened volatility sensitivity in green bond pricing during riskier macroeconomic periods—echoing findings in Molino et al. (2023).

Overall, the analysis provides no consistent evidence that green bonds are priced at a premium relative to conventional bonds in the primary market. If anything, the significant result in Model 4 suggests the presence of a small pricing penalty when unobserved issuer characteristics are not controlled. This supports the hypothesis that any observed greenium in less stringent models likely reflects differences in issuer credibility, structure, or unobserved selection effects, rather than systematic investor willingness to pay more for green-labelled instruments.

6. Conclusion

The empirical results presented in this chapter provide no evidence supporting the existence of a greenium in the primary market for corporate bonds. Across multiple regression models using both yield to maturity and credit spread as dependent variables, the green bond dummy variable consistently fails to show a statistically significant negative coefficient. In the YTM models (1–4), the green label has no measurable impact on yields, with coefficients close to zero and statistically insignificant across all specifications. Even when refining the analysis with an issuer-matched sample (Model 5), the greenium remains absent.

In the credit spread analysis, a statistically significant premium in favor of conventional bonds appears only in the unmatched sample (Model 3), where green bonds are associated with higher spreads (+13.61 bps, $t = 3.44$). However, once the analysis is restricted to matched pairs controlling for issuer, rating, and other fixed effects (Model 5), this result disappears — the coefficient drops to +1.85 bps and becomes statistically insignificant. This confirms that the initially observed spread differential does not reflect a greenium, but rather differences in issuer and bond characteristics.

In sum, the analysis shows that green bonds are not priced at a premium in the euro-denominated corporate bond market over the 2018–2024 period. Once key factors such as rating, contract structure, and macroeconomic conditions are controlled for, the green label does not reduce the cost of debt for issuers. These results suggest that, at least in this segment of the market, investors are not systematically willing to accept lower returns for environmentally labeled securities.

Declaration

I hereby declare on my honour that I have prepared my written work/thesis, "An updated test to the Greenium in the corporate bond market", with complete honesty and free from any fraudulent practices, namely copying or plagiarism. I also declare that I am aware that committing fraud during written assessments constitutes a serious violation of the rules of ethics and academic conduct in force at the Universidade Católica Portuguesa, resulting in disciplinary action, as outlined in the Code of Ethics and Conduct of this University – paragraph b, nr. 3 of article 8 and nr. 3 of article 12.

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During the preparation of my written work/dissertation, An updated test to the greenium in the corporate bond market, the Chat GPT was used for tasks such as proof Reading, rephrasing and bibliography review, with the prompts listed at the end of the document in the Prompt List section. After using this tool/service, I reviewed and edited the content as necessary and take full responsibility for the publication's content. I also declare that I am aware of and respect the Artificial Intelligence Conduct Rules of the Católica Porto Business School.

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Prompt list section

- Can you help me design a structure for my thesis based on these themes?
- What are the main research questions I could explore given this dataset?
- How should I break down my literature review into clear thematic sections?
- Which of these papers support the presence of a greenium?
- Which papers analyze green bonds using issuer-matched samples?
- Which citations am I missing based on this document?
- Is the way I cited these findings consistent with the paper's actual conclusions?
- Can you analyze the Python code and tell me what is causing errors?
- Is my matched sample built correctly according to academic standards?
- Can you validate whether these models test the hypothesis accurately?
- Is this table showing a pricing premium or discount for green bonds?
- Where in the data can we find statistically significant findings?
- Are the robustness checks appropriate and correctly interpreted?
- Is this phrase methodologically consistent with my regression setup?
- Am I repeating content from the methodology section here?
- Is this table title consistent with its content?
- Have I properly used all the references I uploaded?
- Can you check if this version still matches the earlier outline we created?
- Which heading styles do I need to define in Word to match this template?
- Can you generate a LaTeX-style or image-based version of these equations?
- Is this abstract correctly formatted according to academic norms?
- Can you summarize the differences between green and conventional bonds by industry?
- Which variables show the largest differences in the matched sample?

Can you verify that the sample sizes and percentages add up correctly?

Does this conclusion logically follow from the regression findings?

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Appendices

Table 9 Rating conversion table

Rating	#
AAA	1
AA+	2
AA	3
AA-	4
A+	5
A	6
A-	7
BBB+	8
BBB	9
BBB-	10
BB+	11
BB	12
BB-	13
B+	14
B	15
B-	16
CCC+	17
CCC	18
CCC-	19
CC	20
SD	21
D	22
Aaa	1
Aa1	2
Aa2	3
Aa3	4
A1	5
A2	6
A3	7
Baa1	8
Baa2	9
Baa3	10
Ba1	11
Ba2	12
Ba3	13
B1	14
B2	15
B3	16
Caa1	17
Caa2	18
Caa3	19
Ca	20
C	21

This table establishes the relationship between the issued credit rating (for ex. AAA) and the attributed numerical variable (AAA = 1)

Regional and regulatory drivers of Methodological variation

Regional regulatory environments shape both the methodological approaches and the outcomes in greenium research. Silva and Blankson (2025) highlight that Europe's consistent regulatory framework enables the application of standardized methodologies, supporting comparability across studies. In contrast, Hu et al. (2024) and Zenno and Aruga (2022) illustrate that fragmented standards and variable data availability in China and emerging markets necessitate adaptations in empirical designs, often limiting cross-study comparisons. Carmichael and Rapp (2024) emphasize that regulatory initiatives, such as the EU Sustainable Finance Action Plan, not only influence greenium levels but also guide the choice of control variables and model structures. Liberati and Marinelli (2021) and Kapraun et al. (2021) note that methodological choices are closely tied to the integrity of green finance frameworks, with more rigorous regulatory settings enabling stronger causal inference regarding greenium. Together, these studies show that regional regulatory coherence and market structures are key determinants in shaping both the methodologies employed and the robustness of greenium findings.

