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Does Being Green Pay Off? The European Greenium and the Impact of Mandatory Sustainability Disclosure

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Abstract

This study examines the existence and determinants of a greenium in the European bond market. It assesses the impact of the Corporate Sustainability Reporting Directive (CSRD) on the green-conventional yield differential. Replicating the match-bond framework of Zerbib (2019), this analysis finds no statistically significant greenium at the aggregate level. However, heterogeneity analysis reveals that the greenium is not absent but rather concentrated among AAA/AA-rated, government and quasi-governmental issuers. Suggesting that high credit quality and public-sector character are key determinants of where investors accept lower yields for green exposure. Additionally, the CSRD policy study provides evidence that the greenium narrowed following the directive's entry into force, consistent with standardized disclosure reducing the informational advantage previously conferred by the green label. These findings carry implications for European green policy, the entities benefiting from lower capital costs are not the private corporations the European Commission sought to incentivize through the European Green Deal, but rather public-sector issuers already positioned to access cheaper funding, in combination with the findings of the policy study, it raises questions about whether the intended policy mechanism is functioning as designed.

Keywords: Greenium, Bond, CSRD, Information asymmetry

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AI disclosure

I hereby declare that this thesis represents my own work. In this paper, I have used ChatGPT as a complement to improve text quality. Furthermore, ChatGPT and Claude have also assisted with coding in R. I have also applied Grammarly to improve grammar and structure. As author, I have reviewed and edited the content as needed and accept all errors as my own.

Contents

1 Introduction

Are green EU-based companies and projects seeking external funding receiving better capital conditions, that is, a lower cost of capital compared with non-green actors, and is EU policy enhancing this advantage?

Rising climate ambitions have led to the implementation of a wide-ranging set of sustainability policies, yet ambition and feasibility do not always align. The green policy frameworks introduced in recent years are designed to accelerate the environmental transition and mobilize private capital as a key driver of that change. Central to this agenda, the European Union has sought to create a comparative advantage for green companies and projects, making it easier, cheaper, and faster for green actors to secure funding.

The partial rollback of sustainability commitments in recent years has introduced growing tension and market uncertainty, calling into question whether the intended policy mechanisms are functioning as designed. This study, therefore, examines the fundamental existence of a capital cost advantage for green issuers – the greenium – defined as the yield differential between green and conventional bonds, all else equal, attributable solely to the greenness of the bond. It further examines whether the introduction of the Corporate Sustainability Reporting Directive (CSRD), which mandates standardized sustainability disclosures across European firms, has amplified or eroded this advantage, and whether the Commission's effort to channel private capital toward the green transition is producing its intended effect.

More formally, I am asking: does a greenium exist on the European green bond market as it stands today? In extension, How did the greenium respond to the implementation of the CSRD, did the reduced information asymmetry as a consequence of mandatory disclosure impact it?

It is important to understand these dynamics, partly because we need to determine whether being green confers an advantage, as theory would suggest. It is equally important to assess whether policy affects this advantage and, if so, how. Overlooking these dynamics risks producing policy outcomes contrary to its intended purpose, particularly if the market has already internalized the cost advantage into pricing. It is therefore crucial to understand these dynamics so that regulatory intervention does not distort market mechanisms that are already functioning effectively on their own.

The analysis focuses on the secondary market, where continuous trading in already-issued bonds generates a time series of yield differentials that can be observed over time. Furthermore, secondary market pricing serves as a price discovery mechanism that ultimately feeds back into primary market conditions, making it possible to draw conclusions about whether green bond issuers benefit from lower costs of capital.

This study makes several contributions to the existing literature. The aggregate results show no statistically significant greenium. However, the heterogeneity analysis reveals that the greenium is not absent but rather concentrated among top-rated bonds and bonds issued in the governmental and quasi-governmental sectors. These results point to credit quality and public sector character as the main determinants of where investors are willing to accept lower yields for green exposure. These findings directly tie back to the effectiveness of policy in achieving desired outcomes. This effectively means that public sector issuers can access cheaper funding, not private sector issuers, as intended by the goals and ambitions of the European Green Deal.

Lastly, the event study of the CSRD's implementation shows, with statistical precision, that the greenium narrowed following the policy's entry into force. By mandating disclosure of sustainability activities across all eligible companies, both those that signal greenness and those that do not, the CSRD increased transparency and harmonized reporting, eroding the informational advantage previously conferred by the green label. As sustainability information became more widely accessible, the information asymmetry that partly sustained the signaling value of the green label diminished, effectively reducing the premium investors are willing to pay for it.

The thesis is structured as follows. Section 2 provides background on the greenium and the European green bond market, alongside an overview of the sustainability policy landscape. Section 3 reviews the theoretical framework underpinning the greenium and prior empirical literature. Section 4 describes the data, sample construction, and matching procedure, followed by Section 5, which details the empirical methodology across the three phases of analysis. Section 6 presents the results, covering the panel fixed effects regression, cross-sectional heterogeneity analysis, temporal stability of the greenium, and the CSRD event study. Section 7 reports the specification tests and robustness checks. Section 8 discusses the findings and their implications, and Section 9 concludes with a summary of the main contributions, limitations, and directions for future research.

2 Background

2.1 The Greenium and the Green Bond Market

The greenium is defined as the yield differential between a green bond and an otherwise equivalent conventional bond, with all characteristics held constant except for the green label itself. Its existence indicates that investors are willing to accept a lower financial return in exchange for the non-pecuniary utility derived from holding sustainable assets, a preference that is reflected directly in bond pricing. From the issuer's perspective, this translates into a tangible cost of capital advantage. Green issuers can raise debt more cheaply than their conventional counterparts, provided they can credibly signal their environmental credentials to the market (d'Incau et al., 2022).

Whether green bonds yield less than otherwise identical conventional bonds has been widely debated in both academic and practitioner forums. The question carries direct practical significance. If green bonds genuinely offer lower borrowing costs to issuers, they represent a meaningful financial incentive for firms and governments to direct capital toward environmentally beneficial projects. Understanding whether this pricing advantage exists and under what conditions it holds is therefore relevant for both issuers considering green financing and policymakers seeking to design frameworks that support the green transition (Jena and Vuppuluri, 2025).

The green bond market has grown rapidly since the first green bond was issued in 2007. Europe has been at the forefront of green bond issuance, driven in large part by the European Union's regulatory ambitions and policy framework. Green bond issuance as a share of total European bond issuance reached 6.9% in 2024, up from 0.1% in 2014, reflecting both the market's maturation and a substantial increase in investor demand (European Environment Agency, 2025).

A bond is a debt instrument through which an investor lends capital to a borrower, in exchange for periodic interest payments and the return of principal at the specified maturity. Bonds are commonly used to finance large-scale projects over long time horizons, and in their conventional form carry no restrictions on the use of proceeds. Green bonds depart from this in one fundamental respect: the issuer commits to allocating the proceeds exclusively to environmentally beneficial projects. To qualify as green, a bond must meet defined eligibility criteria. To standardize this practice, a range of frameworks and standards have emerged over time, to improve transparency for investors. The most widely adopted of these are the Green Bond Principles (GBP) introduced by the International Climate Market Association (ICMA) (European Environment Agency, 2025).

The GBP are voluntary guidelines built around four core components: exclusive use of proceeds for environmentally beneficial projects, clear disclosure of project objectives and selection criteria, tracking of fund allocation, and regular reporting on environmental impact (International Capital Market Association, 2025). Alignment is self-declared and carries no legal enforcement mechanism, while third-party review is recommended, it is not mandatory. The voluntary nature has drawn criticism for creating scope for greenwashing (Shi et al., 2023).

As markets matured and greenwashing concerns grew, more rigorous standards emerged.

The Climate Bond Initiative (CBI) introduced a certification scheme that requires science-based eligibility criteria and independent third-party verification, offering a stronger and more credible signal than the self-declared GBP label (European Parliamentary Research Service, 2022). This difference in rigor has contributed to market fragmentation, as investors cannot always assess the credibility of the green label consistently. Building on these market-based frameworks, the European Union has pursued a progressively more ambitious sustainability agenda to mobilize greater volumes of private capital for green investments. A major accelerator was the introduction of the European Green Deal (EGD) in 2019, with the ambition of climate neutrality by 2050 (European Parliamentary Research Service, 2022).

To pursue these objectives, the commission has implemented a wide range of legislative tools; in total, the EGD has introduced 150 distinct policy measures to transform Europe's economic sectors. (Stockholm Environment Institute, 2025). As part of this broader agenda, the commission introduced the European Green Bond Standard (EuBGS) to increase the harmonization and strengthen the credibility of the green label. The EuGBS requires mandatory annual verification, and issuers that deviate from their green commitments face financial penalties. This is a considerably stronger enforcement mechanism than the reputational consequences associated with GBP non-compliance or the certificate withdrawal applied under the CBI framework. Taken together, this ambitious regulatory agenda represents a sustained effort to align European policy with the Paris Agreement and the Union's 2030 climate targets, directing regulatory pressure and private capital flows toward the green transition (Stockholm Environment Institute, 2025).

2.2 The Sustainability Policy Landscape

Before the CSRD's implementation, EU sustainable finance policy focused primarily on defining what constitutes a green investment and on establishing the frameworks for making green claims. The EU Taxonomy, introduced in 2020, is one of the most foundational elements of the EU sustainable finance architecture (European Parliament and Council of the European Union, 2020).

The taxonomy established a harmonized classification system that anchors a common understanding of which economic activities can be considered environmentally sustainable and serves as a reference point for all subsequent EU sustainable finance legislation (European Parliament and Council of the European Union, 2020). Building on the taxonomy, the Sustainable Finance Disclosure Regulation (SFDR) was implemented to guide the classification and disclosure of sustainability-related information by institutional investors and financial market participants (European Parliament and Council of the European Union, 2019). The EU Taxonomy and the SFDR share a common underlying logic, both serve to classify green claims, with compliance driven primarily by issuers seeking to demonstrate sustainability credentials rather than by direct regulatory enforcement. The CSRD implemented beginning of 2023, however, represents a qualitatively different type of regulatory intervention. Rather than defining what is green, the CSRD mandates transparency about the sustainability behavior that companies exhibit.

Critically, the CSRD applies to every company that meets the relevant size criteria, not only those seeking to signal sustainability. The CSRD is therefore the first EU sustainable finance regulation to impose reporting obligations on actors regardless of whether they have made any green claims (KPMG Sweden, 2025).

A company that meets at least two of the following three criteria is subject to the CSRD reporting requirements:

- More than 250 employees on average during the financial year.
- Net turnover exceeding €40 million.
- Total balance sheet assets exceeding €20 million.

The CSRD was intended to be implemented in three phases. Phase 1 covered large public-interest entities already subject to reporting obligations under the Non-Financial Reporting Directive (NFRD), specifically listed companies, credit institutions, and insurance undertakings with more than 500 employees. These companies were required to begin reporting under the CSRD for the 2024 financial year, with their first CSRD-compliant reports published in 2025. Although these companies had previously reported under the NFRD, the transition to the CSRD imposed considerably more stringent and standardized requirements. Phase 2 extended the scope to all large companies, both listed and unlisted, that met at least two of the three size criteria above, with reporting obligations commencing for the 2025 financial year and first reports due in 2026. Phase 3 further extended the CSRD to listed small and medium-sized enterprises trading on EU-regulated markets, as well as small and non-complex credit institutions and captive insurance undertakings, with reporting obligations for the 2026 financial year and first reports due in 2027. (European Parliament and Council of the European Union, 2022).

However, just two years after the CSRD's entry into force, the Commission introduced the EU Omnibus package, proposing significant amendments to the CSRD's scope and timeline. By then, the broader European Green Deal had faced considerable resistance across the European economic and political landscape. Growing concerns about competitiveness fueled criticism that the EGD's reporting and due diligence requirements impose disproportionate costs on European companies and risk undermining Europe's global competitiveness. (Stockholm Environment Institute, 2025).

The Omnibus package comprises a broad set of proposals to ease the regulatory burden and reduce compliance costs. Rather than advancing the EGD agenda, the Omnibus marks a notable shift, proposing to ease or delay certain policy implementations because the regulatory framework lacks sufficient evidence of effectiveness or is difficult to implement in practice. This retreat raises broader concerns about regulatory and policy credibility. (European Commission, Directorate-General for Financial Stability, Financial Services and Capital Markets Union, 2025).

The Omnibus simplifications released in February 2025 aimed to reduce administrative burdens and increase harmonization, particularly for SMEs. The initial proposal sought to limit the CSRD to EU companies with more than 1,000 employees and either a turnover above €50 million or a balance sheet above €25 million, effectively cutting approximately 80% of the original scope (Suykens, 2025). The so-called stop-the-clock directive of April 2025 further postponed reporting requirements by two years for both Phase 2 and Phase 3 companies (Montes and Apetz-Dreier, 2026). Negotiations concluded in December 2025, further narrowing the scope, with obligations now applying only to entities exceeding 1,000 employees and a net annual turnover exceeding €450 million, leaving listed SMEs fully exempt (Spaans et al., 2025).

The regulatory developments outlined above leave the European green bond market in considerable uncertainty. The arc from the voluntary Green Bond Principles to the mandatory CSRD and its subsequent partial rollback provides the institutional context for this thesis. Whether these policy shifts have measurable consequences for the pricing of green bonds is ultimately an empirical question, but answering it requires a theoretical foundation for understanding how the greenium arises, what sustains it, and how it might be expected to respond to changes in the information environment. The following section reviews the theoretical mechanisms underlying the greenium and surveys the existing empirical literature.

3 Theoretical Framework and Previous Research

3.1 The Greenium Through a Theoretical Lens

Understanding why a greenium arises requires looking beyond the instrument-level characteristics of green bonds to the underlying investor motivations that drive differential pricing. This section reviews the theoretical mechanisms by which investor behavior, equilibrium asset pricing, and information asymmetry collectively underpin a greenium.

3.1.1 Investor Preferences

Hartzmark and Sussman (2019) identifies three channels through which investors assign value to sustainable assets, explaining why people or institutions invest sustainably. The findings broadly indicate that investors market-wide place a positive value on sustainability.

The first channel operates through institutional constraints. Institutional investors such as pension funds and insurance companies bear fiduciary duties to their clients and are therefore primarily oriented toward maximizing returns. Sustainable assets are often perceived as lower risk, partly because the projects they finance tend to span longer investment horizons, and consequently fit naturally within these mandates. When a sustainable instrument carries a high sustainability ranking, it serves as a credible signal of quality and low risk that aligns with fiduciary requirements, prompting institutional demand that bids up prices and compresses yield contributing to the emergence of a negative premium. This channel offers a partial explanation for the heterogeneity observed across instruments in whether and to what degree a greenium is present.

The second channel is the affect heuristic, in which investors respond to their emotional state and perception of their surroundings. Investors associate positive feelings with sustainable assets and consequently overestimate returns, leading to a reallocation of capital toward sustainable instruments. This mechanism is not fully grounded in expected financial performance but rather in psychological association. This association, in turn, affects pricing through a similar demand channel, which bids up prices and pushes down yields.

The third channel is purely preference-driven. Investors derive non-pecuniary utility from investing in sustainable assets, with altruism as the primary motivating force. This channel is a particularly compelling explanation for sustainable investment behavior and connects directly to the excess demand narrative found throughout the greenium literature. Investors prefer holding green assets and derive utility simply from holding them, rather than only from maximizing portfolio returns. Similarly, Berk and Binsbergen (2025) argue that holding brown (non-environmentally friendly) or even conventional instruments imposes disutility, reducing overall utility. This preference channel explains both why investors hold green assets and why they divest from non-green assets.

Riedl and Smeets (2017) find that preferences and altruistic motives are the primary drivers of capital allocation toward sustainable instruments. They also find that investors with strong social preferences are more likely to signal their investment choices publicly. These investors tend to hold only a modest share of sustainable assets, sufficient to signal a sustainable orientation without entirely sacrificing financial returns. Nevertheless, financial motives remain secondary; socially motivated investors accept lower returns and higher management fees, indicating that preferences dominate financial considerations in the decision to hold sustainable assets. While pessimistic return expectations can deter investment at the margin, positive financial expectations for green or socially aligned funds do not independently drive demand, reinforcing the conclusion that altruism and social preferences are the primary motivating force.

Pástor, Stambaugh, and Taylor (2021) formalize these mechanisms within a single-period equilibrium model in which each agent has exponential utility that depends on both financial wealth and the ESG characteristics of their holdings. They formalize two distinct channels through which the greenium arises.

The first is a preference channel. Investors with strong sustainability preferences derive non-pecuniary utility from holding green assets and, symmetrically, incur disutility from holding brown ones. As a result, they tilt their portfolios toward green assets in proportion to the strength of their preferences, accepting lower financial returns in exchange for the non-financial utility gained. The greenium emerges in equilibrium as these preferences are reflected in asset pricing.

The second channel is climate hedging. From a conventional asset-pricing perspective, green assets offer a hedge against climate-related risks; they are expected to perform relatively well under climate stress or in the event of unexpected climate shocks. Investors, therefore, accept lower returns on green assets as compensation for the insurance they provide against climate-related financial losses. Unlike the preference channel, this mechanism is grounded in rational risk management rather than non-pecuniary motivation.

In practice, these two channels are not entirely separable and reinforce each other, both stemming from a behavioral disposition toward green assets, whether through conscious preference or affective association. The greenium appears as the price is adjusted in equilibrium through the demand that stems from these two channels.

3.1.2 The Role of Labels and Information Asymmetry

The literature is broadly consistent in identifying investor preferences as a core mechanism driving the greenium and shaping green bond prices, but the extent to which preferences translate into pricing depends in part on the credibility of the green signal. Kapraun et al. (2021) find that the ability to credibly signal environmental commitment is an important determinant of the greenium, with certified green bonds trading at significantly lower spreads than self-labeled bonds. This suggests that the market rewards verifiability, that the quality of the green label matters alongside the label itself, and that investors price the signal only to the extent they trust it. These credibility differences are not uniform across bond characteristics; rating and issuer type are likely to moderate the strength of both the preference and credibility channels.

This sensitivity to credibility is consistent with the broader adverse selection logic in the disclosure literature. Leuz and Wysocki (2016) shows that information asymmetry introduces adverse selection into the asset market, prompting uninformed investors to either exit or demand a price discount to protect themselves against better-informed counterparts. Corporate disclosure mitigates this by leveling the informational playing field. Steuer and Tröger (2021) extend this logic to green finance, arguing that voluntary disclosure markets systematically underproduce standardized green information. Because standardization has public-good characteristics, no single actor can capture all the benefits of creating a common disclosure framework; the market left to itself will undersupply it. In the absence of a credible and standardized framework, investors cannot verify the underlying green claims of issuers and instead attach disproportionate weight to the green label itself. This gives rise to an informational component of the greenium that is sustained as much by opacity as by genuine preference. Crucially, this informational component is conceptually distinct from the preference-driven component identified above: the latter would persist even under perfect information, while the former is a direct product of the disclosure market failure. The observed greenium, therefore, reflects a mixture of both, and the two components need not respond identically to changes in the information environment.

This distinction has a direct implication for how mandatory disclosure should affect the greenium. A standardized disclosure shock such as the CSRD, by compelling comparable and audited sustainability reporting across large European corporates, reduces the information asymmetry between issuers and investors. As the green signal becomes more verifiable and widely accessible, the informational advantage of the label diminishes, and the opacity premium it generates should compress. Increased transparency will partly reduce the weight of the signal itself, as it makes it easier for investors to form their own perception of how sustainable a company is. The preference-driven component, however, may persist or even strengthen, as improved credibility makes green credentials more trustworthy and thus more valuable to preference-motivated investors. It might also be that conventional issuers are greener than they signal, allowing investors to satisfy green preferences without purchasing a labeled bond. The net directional effect is therefore theoretically ambiguous but constitutes an empirical question, one this thesis tries to address through an event study around the implementation of the CSRD.

This theoretical prediction, that information asymmetry may influence the greenium, finds partial empirical support in time-varying evidence, which shows that the greenium has responded to prior regulatory and political shocks of comparable nature. Dragotto, Dufour, and Varotto (2025) find that the greenium responds to investor awareness of political developments and sustainability-related events. They observe a peak in the greenium following the signing of the Paris Agreement in 2015, with a subsequent decline during the period of US withdrawal under Trump. Caramichael and Rapp (2024) similarly find that the greenium becomes statistically significant only from 2019 onward, which they state coincides with the EU Sustainable Finance Action Plan's implementation in 2018 and the adoption of the SFDR, though they conduct no further tests to verify the relationship.

Taken together, these findings suggest that the greenium is not a fixed structural feature of green bond markets but rather a dynamic premium that responds to the institutional and informational environment in which investors operate. The time-varying evidence is particularly relevant because it establishes empirical precedent for the kind of regime shift this thesis tests: if prior disclosure and political shocks produced detectable movements in the greenium, the CSRD represents a credible candidate for a comparable effect. It is precisely this sensitivity that motivates the thesis's empirical analysis, namely whether the CSRD, as a mandatory disclosure shock, produced a measurable and directional shift in the greenium in the European secondary market.

Drawing on the mechanisms outlined above the CSRD could affect the greenium through two distinct channels, with the net effect depending on which dominates.

The first channel operates through a weakening of the green label. Due to the new information environment the green label loses part of its signaling value, as the same information can be accessed through mandatory disclosure. For investors who hold genuine preferences for ESG-aligned investments and derive non-pecuniary utility from doing so, the calculus shifts. They can now satisfy those preferences without accepting lower yields, as sustainability-oriented exposure is no longer contingent on purchasing a labeled green bond. The CSRD thus normalize the market, leveling the playing field by making relevant information more widely available across the entire bond market. In doing so, it reduces the information asymmetry that previously granted green-labeled instruments their unique pricing advantage, and with it the premium investors were willing to pay to satisfy their preferences. If this channel is the dominating one the greenium narrows.

The second channel operates in the opposite direction. Standardized disclosure may instead reinforce the value of the green label by directly addressing concerns about greenwashing. Green bond issuers can now formally substantiate their label through mandatory disclosure, providing verifiable evidence that the activities underlying their certification are genuine. Through this channel, the appeal of the green bond is strengthened among sustainability-oriented investors, who can now empirically verify whether an issuer's green claims hold up, rather than taking the label on faith. The increased transparency and access to verifiable information would then increase investors' willingness to invest in green and accept lower yields. Through this channel the greenium widens.

Both channels may operate simultaneously, with the net directional effect depending on which dominates. If the first channel, the erosion of the green label's informational advantage to the benefit of conventional issuers, dominates, the greenium would narrow. If the second channel, the reinforcement of the green label's credibility, were to dominate, the greenium should widen. The net effect is therefore theoretically ambiguous and constitutes an empirical question this thesis addresses directly through an event study around the CSRD's entry into force.

3.2 Evidence of a Greenium

This section reviews previous empirical findings on the greenium, across markets, time periods, bond types and methodologies.

Zerbib (2019) identifies a small but statistically significant greenium on the global secondary market over the period July 2013 to December 2017. To address methodological limitations in earlier studies, in particular the biases introduced by insufficient maturity matching and the failure to control for liquidity differences between green and conventional bonds Zerbib (2019) employs a model-free nearest-neighbor matching approach with linear interpolation. Bonds are matched on currency, credit rating, bond structure, seniority, collateral, and coupon type, thereby restricting the sample to plain vanilla, senior, bullet, and fixed-coupon bonds. The sample consists of 110 bond triplets, yielding a panel of 37,503 daily observations, except for one BB-rated and twelve unrated bonds all bonds in the sample are investment grade.

liquidity is addressed through a two-step procedure in which the bid-ask spread differential is regressed on the yield differential in the first step, with the residual net of the liquidity effect interpreted as the greenium in the second. The liquidity coefficient is highly significant, confirming that liquidity differences must be controlled for to obtain an unbiased greenium estimate, as these differences are a meaningful driver of the yield differential.

The key finding is a greenium of -2 basis points (bps) statistically significant at the 1% level, with a sample median of -1, and approximately 63% of bonds in the sample exhibit a negative premium. The sample shows a slight left skew, the premia range from -38 to $+10$, with the extreme values concentrated among high-yield currencies. Additionally, he finds that, at the sector level, financial sector bonds carry the largest negative premium of -2.3 bps, which is also significant at the 1% level. Government bonds show a small negative but insignificant premium, while utilities show a marginally positive but insignificant premium. By currency, EUR-, USD-, and SEK-denominated bonds all exhibit significant negative premia. By rating, AA-rated bonds show a significant negative premium of -2.9. The premium appears to diminish in magnitude at lower rating grades. Cross-sectional analysis indicates that rating and sector are the primary drivers of premium variation, while maturity, issue size, and currency do not reach significance.

Complementing the findings of Zerbib (2019) in the financial sector, Caramichael and Rapp (2024) examines whether green corporate bonds obtain a cost advantage over conventional bonds at issuance. The study covers a global universe of bonds denominated in EUR or USD. On average, they find that green bonds carry yields approximately -3 to -8 bps lower than their conventional counterparts, translating to roughly 2-7% lower borrowing costs.

The greenium is statistically significant only from 2019 onward, coinciding with the expansion of the green bond market and the introduction of European regulatory initiatives. Although the authors cannot establish a causal link between regulation and the greenium, they attribute the premium primarily to excess demand rather than regulatory pressure. They identify an unevenly distributed greenium, which is concentrated among large, investment-grade issuers in the banking sector in developed economies, particularly in the euro-area and among non-American bonds issued in USD. No significant greenium is detected in the domestic American market, nor among unrated or low-rated bonds.

Pastor, Stambaugh, and Taylor (2022) offers a contrasting perspective by studying German government twin bonds. They find that green twins consistently trade at lower yields than their conventional counterparts, with spreads ranging from -2 to -7 bps annually, suggesting that long-term investors who hold the bonds to maturity accept lower yields.

The study by Kapraun et al. (2021) examines the greenium across both the primary and secondary markets from January 2009 to February 2021, finding no statistically significant greenium in either market. Considerable heterogeneity emerges upon disaggregation however, with green credibility proving an important moderating factor. Omitting rating controls produces a relatively large and significant greenium in the primary market, suggesting that credit risk partially obscures the premium when left unaddressed. However, when credibility is considered, certified green bonds trade at a -16 bps premium relative to conventional bonds, while non-certified green bonds show no significant premium. This pattern is reinforced among the largest issuances, where top-quintile certified bonds trade at a -21 bps premium, whereas non-certified bonds of equivalent size show none, indicating that investors do not treat the green label as credible without third-party verification.

A significant greenium is detectable only among EUR-denominated bonds. By issuer type, government and supranational bonds carry a greenium, while corporate bonds show no premium, with some specifications pointing to a green penalty for corporate issuers unless issued in EUR. The secondary market findings are consistent, with government and supranational bonds again exhibiting a significant greenium of -4.5 bps, while corporate bonds show no significant premium, consistent with the primary market findings.

Löffler, Petreski, and Stephan (2021) also examines the greenium across both the primary and secondary markets. To match bonds, they apply two methods, propensity score matching and the more robust coarsened exact matching, controlling for issuer rating, sector, issuance volume, seniority, and maturity. Across both markets, they find that green bonds yield, on average, between -15 and -20 bps less than their matched counterparts. However, the findings for the secondary market are primarily driven by the later years of the sample, 2018 and 2019, with no significant effect detected earlier. Controlling for liquidity shows no statistically significant evidence that liquidity drives the yield differential.

Febi et al. (2018) find that the yield spread of green bonds is consistently lower than that of matched conventional counterparts. They incorporate two liquidity measures, the bid-ask spread and the LOT measure, to account for the risks arising from the relative thinness of the green bond market, similar to the approach of Zerbib (2019). They conclude that both liquidity proxies matter more for conventional bonds than for green ones, and that, on average, green bond yield spreads are -5 to -30 bps lower than those of their conventional counterparts. Importantly, the relationship is statistically significant only in 2016, the final year of the sample, consistent with the broader finding that liquidity becomes a less influential driver of yield differentials as the green bond market matures, a result echoed by Löffler, Petreski, and Stephan (2021).

Consistent with the primary market studies above, Ehlers and Packer (2017) also find evidence of a greenium in the primary market in their study of 21 green bonds from 2014 to 2017. The issuance premium is attributed to excess demand, with investors bidding up prices and thereby compressing yields. Unlike Kapraun et al. (2021), they find no role for the green label itself or for third-party certification in widening or narrowing the greenium. In contrast to Löffler, Petreski, and Stephan (2021) and Zerbib (2019) no greenium is detected in the secondary market. Using a k-prototypes matching algorithm Pietsch and Salakhova (2025), construct 447 bond pairs by identifying the closest conventional bond and counterfactual from the same issuer for each green bond. They find a negative yield spread for green bonds in the euro-area secondary market over the period 2016 to 2023.

Notably, unlike Zerbib (2019), they do not match on ranking and instead rely on issuer-level credit risk to ensure comparability. Their approach accommodates bonds with varying structures, debt types, and coupon types, which broadens the sample relative to studies restricted to plain-vanilla bonds. To account for this instrument-type heterogeneity within matched pairs, they use option-adjusted spreads rather than yields to maturity, a trade-off that increases sample size at the cost of potentially introducing structural differences within pairs.

They find an average greenium of -3.7 bps significant at the 1% level. The premium is larger among bonds held by retail investors, defined as holdings by households and non-financial corporations. A greenium is also observed among bonds that have undergone external review, consistent with the credibility findings of Kapraun et al. (2021). However, results are time-varying; while the greenium is visible throughout the sample, it loses statistical significance in later years, indicating that the premium diminishes as the market evolves.

Not all studies find evidence of a greenium. Karpf and Mandel (2018) studies the American municipal bond market using transaction data from 2010 to 2016. While the raw data show the green bond yield curve consistently lying below that of conventional bonds, an Oaxaca-Blinder decomposition separates the yield differential into a component explained by fundamental bond characteristics and an unexplained residual attributable to the green label. They find that the yield differential is driven primarily by bond characteristics rather than greenness itself. Once creditworthiness is controlled for, the residual green effect reverses into a penalty (positive premium) of approximately 7.8 bps, which is significant at the 1% level. Similarly Larcker and Watts (2020) find no evidence of a greenium in the American municipal bond market. They conduct a natural experiment, studying issuers that simultaneously sell green and non-green bond tranches on the same day.

They find that the yield differential is essentially zero, at approximately 0.45 bps. If anything, the results point in the opposite direction, green issuers face slightly higher capital costs, indicating a marginal penalty rather than a premium. Third-party certification is found to have no effect on the yield differential.

Roch, Brichetti, and Cavallo (2025) examines sovereign greeniums, focusing on Latin American countries, and estimates a panel regression with the z-spread as the dependent variable, controlling for liquidity and maturity. Across the full sample, they find a statistically significant greenium of -1.31 bps, rising to -6.04 bps when restricted to EUR- and USD-denominated bonds. Disaggregation reveals considerable heterogeneity. Advanced economies exhibit a significant greenium, while emerging market economies show a significant green penalty.

Lastly, MacAskill et al. (2021) provides a useful synthesis of the greenium literature through a meta-analysis of 15 published studies covering the period 2007 to 2019. The analysis uses Pearson correlation to identify the bond characteristics most associated with the presence of a greenium. They find that 56% of primary market studies and 70% of secondary market studies provide evidence of a greenium. Secondary market results are more consistent over time, with the greenium typically falling between -1 and -9 bps, while primary market estimates are more dispersed. In terms of bond characteristics, Climate Bonds Initiative (CBI) certification shows the highest correlation with a greenium, significant at the 1% level, followed by bonds that have undergone third-party assessment. Investment-grade credit rating and government or municipal issuers are also positively associated with a greenium, while bond type and time are weaker predictors. The overall findings suggest that credibility and verified governance increase investors' willingness to accept lower yields.

Take together prior research has yielded mixed results on whether a greenium exists. While some studies have confirmed its existence, findings tend to be heterogeneous across time, markets, bond types, and methodologies. A common thread, however, is that when a greenium is found, it is mostly small and centered on EUR-denominated government-sector-issued bonds. This study contributes to the green bond premium literature along several dimensions, combining replication, heterogeneity analysis, and policy identification within an empirical framework focused exclusively on the European secondary market.

4 Data

4.1 Raw Data

The bond universe for this study is constructed from the London Stock Exchange Group (LSEG) Refinitiv database (London Stock Exchange Group, 2026), which provides comprehensive coverage of fixed-income instruments across global markets.

The initial universe consists of euro-denominated (EUR) fixed-rate bonds issued in the European market. A series of filters is applied directly within LSEG to refine the sample and ensure comparability across instruments. First, the instrument type is restricted to bonds, excluding other debt instruments. Second, only plain-vanilla fixed-rate bonds are retained, with identical seniority and coupon frequency required across matched pairs to ensure that observed yield differentials reflect the green label rather than structural differences in the instruments. Third, the LSEG green bond indicator is included, which identifies instruments aligned with the CBI or certified under the ICMA GBP (LSEG Data & Analytics, 2024)

Additional bond characteristics are retrieved from the database to support the matching procedure implemented in R. These include issuer, credit rating, sector classification, issue amount, seniority status, and maturity. These characteristics serve as the matching criteria, pairing each green bond with its conventional counterparts. The sample construction and methodology follow the approach established by Zerbib (2019), ensuring comparability with prior research.

The data construction proceeds in three steps. First, a static matching procedure identifies pairs of green and conventional bonds that are comparable across key characteristics. Second, daily trading data are collected for each bond in the statically matched sample, and the pairs are expanded into a dynamic panel. Third, a synthetic conventional bond is constructed for each green bond by interpolating the yields and bid-ask spreads of the two matched conventional bonds in each triplet.

4.2 Static Matching

The sample is restricted to plain-vanilla, senior unsecured, fixed-coupon bullet bonds denominated in euros. Issuer types include Corporates, Agencies, Government/Treasury/Central Banks, and Other Government/Supranationals. All bonds are required to hold a Moody's rating, either directly or equalized from a Fitch rating. The sample is further restricted to investment-grade bonds only. Controlling for credit risk is essential in this context if green and conventional bonds differ systematically in credit quality, any observed yield differential may reflect a credit risk premium rather than a genuine green-label effect. Restricting the sample to investment-grade bonds ensures that matched pairs are drawn from a comparable credit-risk environment, thereby enhancing the interpretability of the results. While this restriction excludes a substantial portion of the initial bond universe, it is considered necessary to maintain the internal validity of the matching procedure and the greenium estimates derived from it.

The initial bond universe comprises 4,606 bonds. Of these, 1,535 are dropped due to missing yield-to-maturity or issue-date values, or because they fail to meet plain-vanilla bond criteria. A further 1,723 bonds are removed for lack of a credit rating. Imposing a four-year maturity window and retaining only the two closest conventional bonds per green bond yields 136 eligible conventional matches, resulting in an initial matched sample of 68 green–conventional bond pairs. One pair is subsequently excluded because one of the conventional bonds lacks historical yield data, leaving a final static matched sample of 67 pairs.

Green bonds are matched to conventional bonds with identical values across six characteristics: issuer, principal currency, coupon frequency, coupon type, seniority, and Moody's rating. The matching window allow the issue date to vary by up to six years, and the maturity date by up to four years. The issue date window ensures that matched bonds were issued in a reasonably comparable macroeconomic and interest-rate environment, preventing spurious yield differences driven by different issuance conditions.

The maturity window is wider than the two-year window used by Zerbib (2019), reflecting the European bond market's smaller size relative to the global universe in his study. A narrower window would shrink the pool of eligible conventional counterparts to the point that many green bonds could not be matched, making the deviation a necessary adaptation rather than a preference. The deviation applies to the maturity window rather than the issue date window because the maturity of the conventional bonds directly determines the quality of the synthetic counterpart. Widening the maturity window, therefore, trades a degree of matching precision for a meaningful gain in sample size, a trade-off considered appropriate given the constraints of the European market. The impact on matching quality is nonetheless partially mitigated by the interpolation procedure, which weights the two conventional bonds by their proximity to the green bond's maturity. While a wider window increases the distance between anchor points and may reduce precision relative to a stricter specification, it remains preferable to single-bond matching.

The final product of these matching procedures results in a sample consisting of bonds that satisfy all matching criteria; the six bond characteristics mentioned above, as well as the issue amount ratio imposed by Zerbib (2019), the issue date window, and the maturity window. The final sample is composed of 67 bond pairs. Full disclosure in the appendix, section 10.1.

4.3 Dynamic Panel Construction

The static matching identify matched pairs based on the fixed characteristics observed at one point in time. To be able to study the greenium on the European market, daily data is used to construct a dynamic panel.

Daily trading data are extracted from LSEG for each bond in the static sample, identified by ISIN. The variables extracted are the bid-price, ask-price, and ask-yield. The ask-yield is used as the primary yield variable throughout the analysis because it reflects the price at which a dealer sells a bond to an investor and therefore represents the investor's willingness to pay and the issuer's cost of capital. The bid-ask spread, computed from the bid and ask prices, serves as the liquidity proxy. The ask-yield is preferred over the mid-yield and bid-yield for identification. The mid-yield, being the average of the bid and ask, would introduce mechanical co-movement with the bid-ask spread when both appear in the same regression, creating an endogeneity problem. The bid-yield is similarly unsuitable, as it represents an exit price and would introduce a systematic upward bias across all observations, since the bid-yield systematically sits higher than the ask-yield.

In the final panel, the two conventional bonds in each triplet are ranked by maturity relative to their green-bond counterparts. The closer one is designated CB1 (conventional bond 1) and receives a higher interpolation weight, while the one further away is designated CB2. Each triplet is identified throughout by the green ID assigned during the static matching. Full disclosure in the appendix, section 10.2.

4.4 Creation of the Synthetic Bond

After the daily data is merged into the static panel, the final panel consists of multiple triplets, each comprising one green bond matched to two conventional bonds.

For each bond and each trading day, a bid-ask spread is computed as a percentage of that bond's mid price for that day. Expressing the spread as a percentage of the mid-price is a standard measure of liquidity that makes spreads comparable across bonds at different price levels. The liquidity variable BA will later be used in the fixed-effects regression of the main model.

$$\text{Mid}_{i,t} = \frac{\text{Ask}_{i,t} + \text{Bid}_{i,t}}{2}$$

$$\text{BA}_{i,t} = \frac{\text{Ask}_{i,t} - \text{Bid}_{i,t}}{\text{Mid}_{i,t}} \times 100$$

A synthetic conventional bond yield is then constructed for each green bond by linearly interpolating the yields of CB1 and CB2, weighted by the inverse of maturity distance. The bond closer in maturity to the green bond receives a higher weight, as its yield carries more information about the relevant point on the yield curve. The same interpolation is applied to the bid-ask spreads, ensuring that both the yield and liquidity measures are constructed on a consistent basis, following the approach used by Zerbib (2019).

$$Y_{CB,t} = \frac{d_2}{d_1 + d_2} \cdot Y_{CB1,t} + \frac{d_1}{d_1 + d_2} \cdot Y_{CB2,t}$$

$$BA_{CB,t} = \frac{d_2}{d_1 + d_2} \cdot BA_{CB1,t} + \frac{d_1}{d_1 + d_2} \cdot BA_{CB2,t}$$

This yields, for each matched pair on every trading day, a yield differential and a liquidity differential:

$$dY_{i,t} = Y_{GB,i,t} - Y_{CB,i,t}$$

$$dBA_{i,t} = BA_{GB,i,t} - BA_{CB,i,t}$$

The yield differential is the raw greenium, not adjusted for liquidity.

The bid-ask spread reflects a bond's liquidity and can be interpreted as the transaction cost of trading. A narrow spread indicates high liquidity, meaning the bond is actively traded with many buyers and sellers, making it less risky for dealers to hold. By contrast, an illiquid bond is traded infrequently, and dealers therefore demand a wider spread as compensation for the greater risk of holding it (Amihud and Mendelson, 1986). The bid-ask spread is maturity-adjusted in the same way as the yield, ensuring that both synthetic components are constructed on a consistent basis, following Zerbib (2019).

4.5 Descriptive Summary of the Raw Data

The full sample consists of 67 green bonds and an equal number of triplets, generating 35,365 bond-day observations in total. The raw yield differential has a mean of 3.06 basis points and a median of −1.57 basis points, with 58.1 percent of daily observations recording a negative yield differential. The divergence between the mean and median, combined with a standard deviation of 29.13 basis points, reflects considerable cross-sectional and time-series variation. The mean bid-ask spread differential is closely centered around zero, indicating small liquidity differences. Although it is marginally negative, this indicates that green bonds are, on average, marginally more liquid than their matched conventional comparators.

Table 1: Full Sample

Statistic	Value
Green bonds (triplets)	67.00
Bond-day observations	35365.00
Mean Δy (bps)	3.06
Median Δy (bps)	-1.57
SD Δy (bps)	29.13
% obs with $\Delta y < 0$	58.10
Mean ΔBA (%)	-0.01
Median ΔBA (%)	-0.00

Table 2: Trimmed Sample

Statistic	Value
Green bonds (triplets)	63.00
Bond-day observations	34090.00
Mean Δy (bps)	-1.44
Median Δy (bps)	-1.81
SD Δy (bps)	15.30
% obs with $\Delta y < 0$	60.30
Mean ΔBA (%)	-0.01
Median ΔBA (%)	-0.00

Source: Author's rendering of LSEG Refinitiv data (2026).

A histogram of the full sample confirms a fat right tail, consistent with extreme observations. To guard against distortion and upward bias in the mean, a trimmed sample is constructed by excluding bond-level observations with premiums exceeding ± 50 bps, observations beyond this range represent clear outliers relative to the central mass of the data as illustrated by Figure 2 . This removes four bond pairs, leaving a trimmed sample of 63 green bonds and 34,090 bond-day observations. The trimmed sample, both the mean (−1.44) and the median (−1.81) are negative and much closer together, indicating a more symmetric distribution without heavy tails. The share of negative yield-differential observations rises slightly to 60.3 percent. The bid-ask spread differential behaves similarly to that in the full sample. The trimmed sample is used as the primary sample throughout the study, with the full sample serving as a diagnostic and sensitivity check.

5 Method

The first part of the analysis is an extended replication of Zerbib (2019)'s matched-sample methodology, with a sole focus on the European market from 2020 to 2026. In the study by Zerbib (2019), a -2 bps greenium is found in the full sample, and an additional premium of -1.7 bps for EUR-denominated bonds is observed during the period studied, from 2013 to 2017. By restricting the analysis to European bonds over a more recent and policy-rich time period, this study provides an updated, geographically focused estimate of the European greenium that is directly comparable to Zerbib's benchmark. Secondly, a heterogeneity analysis is performed, which also builds on the approach of Zerbib (2019). To examine which bond characteristics are systematically associated with the greenium, a cross-sectional analysis is conducted.

Thirdly, the greenium is evaluated in relation to the implementation of the CSRD and the subsequent introduction of the EU Omnibus Package. This is done to test how different information environments have impacted the greenium.

The empirical analysis is conducted in three phases. Phase 1 replicates Zerbib (2019)'s two-step methodology to establish a baseline and assess cross-sectional differences. Phase 2 extends the dynamic analysis, and Phase 3 employs an event study to analyze the premium's evolution around the implementation and subsequent amendment of the CSRD and the Omnibus Package.

5.1 Phase 1: Zerbib's Two Step Regression Procedure

5.1.1 Step 1. Panel Fixed Effects Regression

The first step employs a panel fixed-effects regression, where the yield differential is regressed on the liquidity differential using a bond fixed-effects panel model:

$$dY_{i,t} = \beta \cdot dBA_{i,t} + \alpha_i + \varepsilon_{i,t}$$

Where $dY_{i,t}$ is the yield differential between green bond i and its synthetic conventional comparator on day t; $dBA_{i,t}$ is the liquidity differential between green bond i and its synthetic conventional comparator on day t; α_i is the bond-fixed effect; and ϵ_{it} is the error term.

The regression calculates the average bond yield and liquidity differential across all observed days. The within transformation demeans all variables by subtracting bond-specific time averages. This eliminates the fixed effect α_i and centers each bond's data around zero. This allows us to estimate the liquidity coefficient β from the time-series variation within each bond pair, meaning how changes in liquidity affect changes in yield for the same bond over time.

Once β is estimated, the average yield differential for each bond is decomposed into two components, the portion attributable to the average liquidity differential between the green bond and its synthetic conventional counterpart, and the liquidity-adjusted component that remains after this liquidity effect is removed.

The α_i captures the time-invariant yield differential, a premium or a penalty, between the green bond and its conventional counterpart after controlling for liquidity. This variable is obtained by subtracting the portion of the yield difference explained by beta as a liquidity effect. We are then left with the estimated green premium for bond i as follows:

$$\hat{\alpha}_i = d\bar{Y}_i - \hat{\beta} \cdot \overline{dBA}_i$$

This represents the average yield differential for bond i that cannot be attributed to liquidity differences. Because the matching process ensures that the only systematic uncontrolled difference between the green bond and its synthetic counterpart is the green label, the residual persistent yield differential can thus be interpreted as the greenium. The bond fixed effects, representing the liquidity-adjusted yield differential attributed to the green label, are extracted and multiplied by 100 to express the greenium in basis points.

The β captures the simultaneous effect of liquidity on yield differences within the matched pair. Using the differenced variable, partly accounts for time variation and partly substitutes the usage of time fixed effects. Any persistent macroeconomic trend will impact both green and conventional bonds similarly, making time fixed effects redundant.

The validity of the fixed effects estimator rests on the following identifying assumptions. The most critical is strict exogeneity, which requires that the error term be uncorrelated with the liquidity differentials at all leads and lags. If violated, the within estimator might be biased. The relationship between the yield differential and the liquidity differential is further assumed to be linear, and the bond-specific fixed effect is assumed to be time-invariant, capturing a stable average greenium over the sample period. Simultaneity is ruled out by construction, as it is economically implausible that the yield differential between a green bond and its conventional counterpart would retroactively affect their relative liquidity within the same trading day. Finally, the within estimator is well-suited to the panel structure of the data, as the average number of observations per bond exceeds the number of bonds, supporting the estimator's reliability.

Robust standard errors are used. Newey-West standard errors account for serial correlation in the residuals. Beck-Katz standard errors additionally account for cross-sectional dependence across bonds, which may arise when multiple bonds from the same issuer or sector respond to similar common shocks. To test whether the distribution of extracted bond-level premia is significantly different from zero, the Wilcoxon signed-rank test is applied. Because the Shapiro-Wilk test rejects normality for both the full and trimmed sample, the Wilcoxon signed-rank test is used as the primary inference tool throughout, with the t-test reported alongside for completeness, as the trimmed sample is approaching normality.

5.1.2 Step 2. Cross-sectional Regression

In step 2, the bond-level premia $\hat{\alpha}_i$ estimated in step 1 become the dependent variable. For clarity of notation, I denote the estimated premium as $\hat{\alpha}_i = \hat{\rho}_i$. The second stage tests whether observed bond characteristics can explain cross-sectional variation in the premia.

Three main models are estimated:

Specification (a) is the full model, including rating group, sector group, remaining maturity, and log issue amount. Rating and sector are included as explanatory variables, consistent with the theoretical framework and prior literature, both of which have identified credit quality and issuer type as key determinants of cross-sectional variation. Maturity is included on the basis that investors with a preference for green assets may be more willing to accept a yield penalty over longer horizons, implying that longer-maturity bonds could carry larger premia. Log issue amount is included because larger issuance tends to be more liquid and more widely held, which could affect pricing independently of the liquidity differential already controlled for in Step 1. The log transformation is applied given differences in the distribution of issue sizes.

Specification (b) retains only rating and sector, removing bond characteristics. Specification (c) includes rating group alone.

AAA/AA serves as the reference rating category, and Government as the reference sector category in specifications (a) and (b). In specification (c), the reference category is AAA/AA-rated bonds regardless of sector.

Individual Moody's ratings are grouped into four broad categories: AAA/AA, A, BBB, and BB. AAA/AA comprises sovereign governments, supranational agencies, and the strongest corporate issuers, which are effectively considered risk-free. A is the second-highest group, comprising solid issuers with low but non-negligible default risk. BBB is the lowest investment-grade category and the largest subgroup in the sample. This grouping addresses the limitation of a smaller sample by equalizing group sizes for reliable estimation. Sector groups are assigned based on information provided by LSEG.

A minimum of four bond pairs per rating group and per sector is required for inclusion in the second stage to account for potential small-sample bias. Heteroskedasticity-robust standard errors are used throughout the Step 2 cross-sectional regression.

Regression specifications:

$$\hat{p}_i = \beta_0 + \beta_1 \text{RatingGroup}_i + \beta_2 \text{SectorGroup}_i + \beta_3 \text{Maturity}_i + \beta_4 \log(\text{IssueAmount}_i) + \varepsilon_i \quad \text{(a)}$$

$$\hat{p}_i = \beta_0 + \beta_1 \text{RatingGroup}_i + \beta_2 \text{SectorGroup}_i + \varepsilon_i \quad \text{(b)}$$

$$\hat{p}_i = \beta_0 + \beta_1 \text{RatingGroup}_i + \varepsilon_i \quad \text{(c)}$$

As an explanatory analysis, an additional specification, (d), is added, replacing the additive rating and sector terms with their full interaction. This allows the premium to vary across rating-sector combinations. It also tests whether certain rating-sector combinations exhibit distinct premia. However, given the small sample size relative to the number of parameters, results from this specification should be interpreted with caution.

$$\hat{p}_i = \beta_0 + \sum_{r,s} \gamma_{rs} (\text{RatingGroup}_i \times \text{SectorGroup}_i) + \varepsilon_i \quad \text{(d)}$$

In specification (d), the omitted baseline cell is AAA/AA-rated Financial bonds. All coefficients therefore represent the greenium for a given rating-sector combination relative to AAA/AA-rated Financial bonds. The constant term β_0 captures the premium for the baseline category, while each interaction coefficient $\gamma_{r,s}$ represents the additional premium for rating-sector combination (r, s) beyond this baseline.

5.2 Phase 2: Temporal Extension

The bond fixed effects in step 1 provide a time-invariant measure of the greenium for each bond over the full sample period. While this pooled estimate is informative as a baseline, it conceals potentially important variation in the greenium over time. Understanding how the greenium has evolved across years and quarters is valuable both in its own right and as a foundation for the event study that follows. If the greenium is not stable over time, this raises the question of what drives its evolution.

To examine the temporal structure of the greenium, the step 1 regression is estimated for each calendar year and each quarter, extracting fixed effects from each sub-period. A minimum threshold on the number of bonds is imposed to ensure estimation in each period.

For annual estimation, at least 3 bond pairs and 200 daily observations are required. For quarterly estimation, at least 3 bond pairs and 50 observations are required. These requirements prevent estimation in periods where the sample is too sparse for reliable fixed-effect identification. The Wilcoxon signed-rank test is applied to each sub-period's distribution.

5.3 Phase 3: Policy Study

To study dynamics, an event study is conducted on the implementation of the CSRD policy.

The bond-estimated premia in Step 1 are time-invariant by construction. The fixed effect captures a single effect per bond, representing its average yield advantage or disadvantage over the entire sample. While this property makes the greenium clean, it cannot be used in a dynamic study of the greenium's evolution. Thus, the event studies are carried out using the time-varying yield differential $dY_{i,t}$ rather than the time-invariant greenium $\hat{\alpha}_i$ estimated in Step 1. This allows us to examine how the green premium evolves quarter-by-quarter around the policy event. The event study regression controls for liquidity differences ($dBA_{i,t}$) and bond fixed effects (α_i), isolating the dynamic response of the green premium to the policy shock.

$$dY_{i,t} = \beta \cdot dBA_{i,t} + \sum_k \delta_k \mathbf{1}\{\text{event\_time} = k\} + \alpha_i + \varepsilon_{i,t}$$

Bond fixed effects α_i are included to absorb the persistent bond-level component of the yield differential within the event window, recovering the same identification logic as Step 1. The liquidity control dBA ensures that any detected shifts in dY around the event are not driven by changes in relative liquidity. The event time dummies δ_k capture how the yield differential in quarter k deviates from the baseline quarter after controlling for both liquidity and bond-level heterogeneity.

dY is defined as the green bond yield minus that of the synthetic conventional one. A positive δ_k implies that green bonds yield relatively more in quarter k, the baseline, meaning that the greenium has narrowed. Conversely, a negative value would imply that it has widened after the policy event.

To ensure the model's validity, a diagnostic test is run to check for pre-trends. A joint F-test is conducted on the null hypothesis that all pre-event coefficients are jointly equal to zero. Failing to reject this null implies that the yield differential was statistically stable before the policy event. This can be interpreted as the parallel trends analogue in a matched-pair design. If the spread was already moving prior to the event, any post-event shift could reflect a pre-existing trend rather than a policy response.

Given the structure of the dependent variable, a unit-specific linear trend is not required for the model. The difference variable $dY_{i,t}$ already removes common trends affecting both green and conventional bonds, while bond fixed effects absorb cross-sectional heterogeneity. Miller (2023) cautions that unit-specific linear trend controls risk conflating pre-event trends with post-event dynamics when treatment effects are themselves trending, as in the case of daily trading data. The joint F-test on pre-event coefficients is the methodologically appropriate tool to validate the parallel trends analogue. Therefore, the differenced structure of $dY_{i,t}$, combined with bond fixed effects, already accounts for the sources of variation that linear trends would otherwise control for, making such trends redundant.

The design does not employ a traditional control group. Instead, the control is embedded in the yield differential $dY_{i,t}$, with conventional bonds serving as the counterfactual for what green bonds would yield in the absence of their green designation. While this does not prevent identifying whether an impact occurred, it limits interpretation of the effect's source. Dynamic reactions around CSRD implementation could be driven by policy affecting green bond yields, conventional bond yields, or both simultaneously. The observed shift in $dY_{i,t}$ captures the net differential impact on green versus conventional bonds, rather than isolating effects on green bonds alone.

The primary event study examines CSRD's entry into force in Q1 2023, using Q4 2022 as the baseline quarter. This tests whether mandatory sustainability reporting requirements affected the relative pricing of green and conventional bonds.

As a sensitivity check, I also examine the 2025 announcement of the Omnibus package, which proposed delays and easing of CSRD requirements. This tests whether a regulatory rollback reversed the initial effect of the CSRD.

5.4 Specification Tests and Robustness Checks

To validate the model structure, a series of specification tests are conducted, including the Hausman test, F-test, and Honda LM test for individual effects, and Breusch-Godfrey and Breusch-Pagan tests for serial correlation and heteroskedasticity. Additionally, strict exogeneity, volatility, and stringent matching robustness checks are performed. Full results are reported in the appendix, section 10.7.

6 Results

Throughout the analysis, both the median and mean greenium are reported and interpreted together. The median reflects the cost-of-capital benefit available to the typical issuer, while the mean captures the aggregate effect across the full distribution.

6.1 Step 1. Panel Fixed Effect Regression

Table 3: Step 1 Panel Regression — Trimmed Sample

	$dY_{i,t}$	
	(1) NW	(2) BK
$\Delta BA_{i,t}$	-0.239^{***}	-0.239^{***}
	(0.028)	(0.027)
Bond FE	Yes	Yes
SE type	Newey-West	Beck-Katz
Obs	34,090	34,090
R^2	0.027	0.027
Adj R^2	0.025	0.025

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$. Standard errors in parentheses.

NW = Newey-West, BK = Beck-Katz.

Author's calculations based on LSEG Refinitiv data (2026)

Running the step 1 panel fixed-effects regression yields a liquidity coefficient of approximately -0.239, indicating that if the bid-ask spread increases by 1 percentage point relative to the control bond, the yield differential falls by about 23.9 bps. The coefficient is statistically significant at the 1% level under both Newey-West and Beck-Katz standard errors, indicating robustness to different assumptions about serial correlation and cross-sectional dependence.

The negative sign indicates that when a green bond becomes relatively less liquid than its synthetic conventional counterpart, the yield differential falls, implying that green bonds yield relatively less. In other words, when the bid-ask spread increases, the yield differential falls, which implies that green bonds yield relatively less. [1]

The bond-level premia extracted from the Step 1 fixed-effects regression are summarized in Table 4 the full sample is included for descriptive purpouses.

The trimmed sample has mean of -1.88 bps and an median of -1.63 bps neither the Wilcoxon signed-rank test ($p = 0.323$) nor the t-test ($p = 0.329$) reject the null of a zero greenium. The 95% confidence intervals under both tests straddle zero. The mean and

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[1] Liquidity results are consistent with those found by Zerbib (2019), the full sample regression yields a negative and significant liquidity coefficient, directionally consistent with the trimmed sample results.

median of the full sample are considerably wider a part due to the extreme premia bonds, neither are significant.

Nonetheless, the trimmed sample median of -1.63 bps and the fact that 57.1 percent of bonds exhibit a negative premium indicate a tendency toward a premium among green bonds, even if this cannot be established with statistical precision. The results fail to reject the null hypothesis and no statistically significant greenium is detected on aggregate data in either samples, nor the mean or median estimates.

Table 4: Distribution of Green Bond Premia $\hat{p}_i$

	Full Sample	Trimmed
N bond pairs	67	63
Min	-48.66	-48.62
Q1	-5.92	-7.39
Mean	5.58	-1.88
Median	-1.30	-1.63
Q3	7.12	4.04
Max	177.95	35.27
SD	34.31	15.20
% Negative	53.7	57.1
Wilcoxon W	1138	863
Wilcoxon p	0.998	0.323
Wilcoxon 95% CI	$[-3.55,\ 3.64]$	$[-4.86,\ 1.37]$
t-statistic	1.332	-0.984
t-test p	0.188	0.329
t-test 95% CI	$[-2.79,\ 13.95]$	$[-5.71,\ 1.94]$

All premia reported in basis points (bps).

Wilcoxon: H_0 median = 0. t-test: H_0 mean = 0.

Author's calculations based on LSEG Refinitiv data (2026)

6.2 Step 2. Cross-sectional Regression

While Step 1 estimates the average greenium at the bond level, the second-stage cross-sectional regression in Step 2 tests whether the size of the greenium is systematically related to observable bond characteristics. If bonds defined by credit quality, sector, maturity, or issue size consistently carry larger or smaller premia, this would provide insight into which issuers benefit from the green label. After excluding groups with fewer than four observations, the Step 2 sample consists of 59 bond pairs.

Table 5: Step 2 Cross-Sectional Regressions — Trimmed Sample

	$\hat{p}_i$		
Variable	(a)	(b)	(c)
Constant	-11.959^{**}	-8.223^{*}	-7.656^{*}
	(5.850)	(4.111)	(4.156)
Rating (ref: AAA/AA) A	1.750	2.508	6.272
	(8.349)	(7.953)	(6.629)
Rating (ref: AAA/AA) BBB	3.338	4.070	7.297
	(6.257)	(5.959)	(4.719)
Sector (ref: Government) Financial	4.980	5.007	—
	(8.909)	(8.416)	
Sector (ref: Government) Utilities	6.023	6.893	—
	(5.144)	(5.136)	
Sector (ref: Government) Other	2.704	3.119	—
	(6.864)	(6.417)	
Maturity (years)	0.870	—	—
	(0.585)		
log(Issue amount)	−0.754	—	—
	(4.554)		
Rating controls	Yes	Yes	Yes
Sector controls	Yes	Yes	No
Bond characteristics	Yes	No	No
SE type	HC1	HC1	HC1
Observations	59	59	59
R^2	0.103	0.068	0.036
Adjusted R^2	−0.021	−0.020	0.002

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$. HC1 heteroskedasticity-robust standard errors in parentheses.

Dependent variable: bond-level greenium $\hat{p}_i$ estimated in Step 1 (bps).

Reference categories: (a)-(b) AAA/AA (rating) and Government (sector), (c) AAA/AA (rating)

Author's calculations based on LSEG Refinitiv data (2026)

The intercept in specification (a) is estimated at −11.959 bps and is statistically significant at the 5% level. As the reference cell corresponds to AAA/AA Government bonds, this indicates that high-quality sovereign green bonds carry a meaningful negative greenium even after controlling for all available characteristics. None of the remaining slope coefficients reach statistical significance, meaning that no other rating or sector group can be shown to carry a greenium that is statistically different from the AAA/AA Government baseline. This does not imply that the greenium is absent among other groups, but rather that the data do not provide sufficient power to detect meaningful differences from the reference category.

Specification (b) removes maturity and log issue amount, retaining only rating group and sector. The intercept remains significant at the 10% level (-8.223), consistent with specification (a), and no slope coefficient reaches significance.

In the simplest specification (c), only rating group is retained, and sector is excluded. The intercept is estimated at -7.656 bps and is statistically significant at the 10% level. As no sector controls are included, the reference category is AAA/AA-rated bonds regardless of sector, implying that high-quality green bonds does exhibit a greenium and yield less than their conventional counterparts after controlling for liquidity. The A-rated coefficient is estimated at $+6.272$ bps and the BBB coefficient is at $+7.297$ bps, neither of which reach statistical significance ($p > 0.10$). This means that the premia for both rating groups cannot be statistically distinguished from that of the AAA/AA reference category. The positive sign of both coefficients is nonetheless directionally consistent with premia diminishing at lower rating grades, though this pattern cannot be confirmed with statistical precision in this sample.

Taken together, the results across all three specifications provide evidence of a statistically significant greenium concentrated among high-quality AAA/AA-rated sovereign bonds. While the insignificant slope coefficients prevent firm conclusions about whether other rating or sector groups carry meaningfully different premia from the reference category, no other group produces a statistically detectable greenium in its own right. These findings point to that high credit quality and public sector character are the key determinants of where investors are willing to accept lower yields for green exposure. [2]

Specification (d) replaces the additive main effects of specifications (a)–(c) with a fully interacted model, estimating the greenium for each rating × sector combination jointly. Rather than assuming that the rating effect is constant across sectors and vice versa, each rating-sector cell carries its own predicted greenium, directly revealing which combinations of credit quality and issuer type drive the cross-sectional pattern.

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[2] The full sample including outliers yields qualitatively different results, driven primarily by the presence of extreme observations. Most notably, the BB-rated category carries a large and highly significant positive coefficient across all specifications, consistent with the high-yield penalty documented in the broader greenium literature. The constant remains negative and significant in specification (c) (-7.486, $p < 0.10$), broadly consistent with the trimmed sample, though larger in magnitude in specification (a) (-24.349, $p < 0.05$). The BBB coefficient reaches marginal significance in specification (c) ($+12.300$, $p < 0.10$), suggesting that extreme observations amplify the perceived difference between rating groups.

Table 6: Step 2 Cross-Sectional Regression — Specification (d): Trimmed Sample

	$\hat{p}_i$	
Variable	Estimate	Std. Error
Constant	1.55	(1.80)
Rating AAA/AA × Sector Government	-9.78^{**}	(4.61)
Rating BBB × Sector Government	-5.67	(5.33)
Rating A × Sector Financial	-21.60	(22.05)
Rating BBB × Sector Financial	5.75	(5.26)
Rating A × Sector Utilities	10.71	(9.30)
Rating BBB × Sector Utilities	-1.98	(2.97)
Rating AAA/AA × Sector Other	-6.62	(14.88)
Rating A × Sector Other	-5.02^{**}	(2.07)
SE type	HC1	
Observations	58	
R^2	0.199	
Adjusted R^2	0.068	

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$. HC1 robust standard errors in parentheses.

Dependent variable: bond-level greenium $\hat{p}_i$ estimated in Step 1 (bps).

Baseline cell: AAA/AA-rated Financial bonds

Author's calculations based on LSEG Refinitiv data (2026)

Two interaction terms reach statistical significance. The AAA/AA × Government combination carries a coefficient of -9.78 bps, significant at the 5% level, indicating a greenium that is 9.78 bps more negative than the baseline, consistent with specifications (a)–(b). The A × Other combination is also significant, with a predicted greenium 5.02 bps more negative than the AAA/AA-rated Financial baseline. Examining this category more closely reveals that it comprises sub-sovereign and quasi-governmental entities that do not qualify as national governments but retain a strong public sector character, including regional governments, public development institutions, and public transport authorities. Pointing to the importance of the public sector character.

Notably, BBB-rated government bonds do not carry a significant greenium, indicating that sovereign status alone is insufficient without high credit quality. The remaining interaction terms are statistically insignificant, however, the small sample size relative to the number of parameters estimated should be acknowledged, large standard errors limit the precision of cell-specific estimates and the risk of overfitting cannot be dismissed.

Specification (d) should therefore be interpreted as exploratory, with the simpler additive specifications providing the more reliable basis for inference about the main effects of rating and sector on the greenium. Nonetheless, the two significant interaction terms offer suggestive evidence that it is the specific combination of high credit quality and public sector character that drives the cross-sectional pattern.

For descriptive purposes and to further strengthen the evidence from the cross-sectional regression, Table 9 in the Appendix reports the unconditional distribution of premia across sector groups. The Government sector is the only group to reach statistical significance.

6.3 Temporal Stability of the Greenium

The first thing to notice in the annual breakdown is that the two samples are identical throughout 2023, because trimming affects only bond pairs from 2024 onward. The outliers in the full sample materially influence the outcomes in later years due to the extreme positive bond premia excluded from the trimmed sample.

Table 7: Annual Green Bond Premia — Full and Trimmed Sample

Sample	Year	N	Mean (bps)	Median (bps)	% Neg.	Wilcoxon p	t-test p	$\hat{\beta}_{liq}$	SE
Full	2020	3	−2.87	−3.91	66.70	0.423	0.354	−0.02	0.03
Full	2021	5	−0.10	−2.04	60.00	0.787	0.971	−0.07	0.01
Full	2022	10	−10.18	−4.65*	80.00	0.083	0.123	−0.19	0.08
Full	2023	29	−3.07*	−1.60**	69.00	0.080	0.020	−0.44	0.07
Full	2024	43	8.28	−1.08	58.10	0.899	0.119	0.28	0.06
Full	2025	64	6.49	0.14	48.40	0.849	0.158	−0.42	0.05
Full	2026	67	4.56	−0.67	53.70	0.933	0.279	−0.18	0.04
Trimmed	2020	3	−2.87	−3.91	66.70	0.423	0.354	−0.02	0.03
Trimmed	2021	5	−0.10	−2.04	60.00	0.787	0.971	−0.07	0.01
Trimmed	2022	10	−10.18	−4.65*	80.00	0.083	0.123	−0.19	0.08
Trimmed	2023	29	−3.07*	−1.60**	69.00	0.080	0.020	−0.44	0.07
Trimmed	2024	41	1.60	−2.09	61.00	0.542	0.530	0.06	0.05
Trimmed	2025	60	−1.66	−0.73	51.70	0.482	0.424	−0.43	0.06
Trimmed	2026	63	−2.57	−1.34	54.00	0.333	0.217	−0.08	0.02

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.
Wilcoxon: H_0 median = 0. t-test: H_0 mean = 0.
Stars on median reflect Wilcoxon significance; stars on mean reflect t-test significance.
Source: Author's rendering of LSEG Refinitiv data (2026)

A significant median is detected for both 2022 and 2023 in both samples. The Wilcoxon test is significant at the 10% level ($p = 0.083$) in 2022. In 2023, both the Wilcoxon signed-rank test ($p = 0.02$, significant at the 5% level) and the t-test ($p = 0.08$, significant at the 10% level) reject the null and confirming a statistically significant greenium in the aggregate sample in 2022 and 2023.

Outside 2022 and 2023, no year produces statistically significant results in either sample. Notably, the full sample shows a positive mean in 2024, 2025 and 2026 (8.28 bps, 6.49

bps, and 4.56 bps respectively), which is considerably attenuated under trimming, where the average decreases sharply (1.60 bps, -1.66 bps and -2.57), consistent with outliers driving the divergence between samples in later years. The median of the trimmed sample is consistently negative.

Annual sample sizes grow considerably over the period, reflecting the growth of the European green bond market. The early years, 2020 and 2021, should be treated as indicative rather than inferential given the limited number of bond pairs and correspondingly low statistical power. The 2022 and 2023 results rest on larger samples and carry more weight, while the post-2023 divergence between the full and trimmed samples underscores the importance of the trimming procedure.

Table 14 in the appendix presents the quarterly breakdown of the greenium for both the full and trimmed samples. The quarterly results corroborate the annual findings and offer finer granularity on the timing of the greenium.

6.4 CSRD Event Study

The pre-event coefficients show no systematic directional movement, and none are statistically significant. The null hypothesis of jointly zero pre-event coefficients cannot be rejected, supporting the identifying assumption and providing confidence that the yield differential was stable prior to the CSRD adoption.

Table 8 show the market's reaction to the entry into force of the CSRD. Following the baseline quarter (Q4 2022), a persistent positive shift in the yield differential emerges. The first three post-event quarters are positive but insignificant (+3.056, +4.563, and +3.104 bps respectively). From quarter four onward, the coefficients reach statistical significance. Quarter four (+4.808 bps, $p = 0.09$), quarter five (+5.381 bps, $p = 0.053$), and quarter six (+4.843 bps, $p = 0.096$) are significant at the 10% level. Quarter seven reaches significance at the 5% level (+6.454 bps, $p = 0.029$), representing the peak of the effect. Quarter eight (+5.836 bps, $p = 0.05$) remains significant at the 10% level.

Each event-time coefficient captures how the yield differential in that quarter deviates from the baseline quarter, after controlling for liquidity and bond fixed effects. A positive coefficient therefore implies that yield differential is less negative compared to the baseline, which is consistent with a narrowing of the greenium. The magnitude of the post-event shift is growing as reporting requirements come into force, suggests that the effect deepens the further the market moves into the implementation stage of the regulation.[3]

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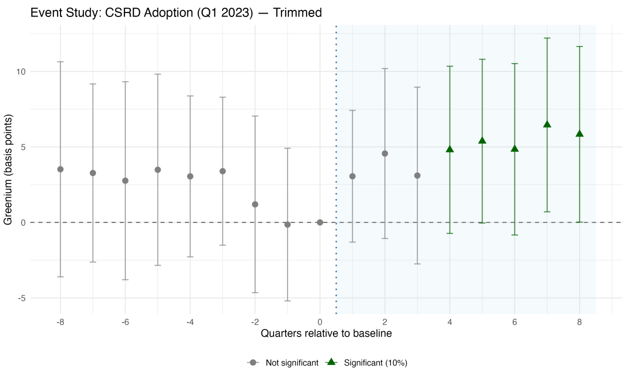
[3] The full sample results are consistent with the trimmed sample, with the post-event pattern showing a similar persistent positive shift. The effect becomes statistically significant from the fourth post-event quarter onward, with quarter four (+5.191), quarter five (+5.846), quarter six (+5.228) quarter seven (+6.471) and quarter eight (+6.273 bps). The pre-event coefficients are jointly insignificant, supporting

Table 8: CSRD Adoption

Event time	Estimate (bps)	Std. Error	t value	p-value	Sig.
-8	3.520	3.634	0.969	0.334	
-7	3.273	3.009	1.087	0.278	
-6	2.762	3.345	0.826	0.41	
-5	3.487	3.230	1.080	0.281	
-4	3.049	2.719	1.122	0.263	
-3	3.391	2.501	1.356	0.176	
-2	1.196	2.983	0.401	0.689	
-1	-0.144	2.579	-0.056	0.955	
0	0.000			—	(baseline)
1	3.056	2.225	1.374	0.171	
2	4.563	2.871	1.589	0.113	
3	3.104	2.986	1.040	0.3	
4	4.808	2.824	1.703	0.09	*
5	5.381	2.767	1.945	0.053	*
6	4.843	2.896	1.672	0.096	*
7	6.454	2.935	2.199	0.029	**
8	5.836	2.967	1.967	0.05	*

Figure 1: CSRD Adoption



Baseline = Q4 2022. NW SEs. Significance: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$. Event time measured in quarters relative to the baseline quarter, Q4 2022 the quarter preceding the CSRD adoption.

Source: Author's rendering of LSEG Refinitiv data (2026)

To complement this and assess whether markets respond to regulatory announcements rather than binding commitments alone, the same framework is applied to the announcement of the EU Omnibus Package. The announcement occurred in Q1 2025, making Q4 2024 the baseline quarter. The joint F-test on pre-event coefficients cannot reject the null of no systematic pre-trend, supporting the validity of the event study specification. The event study provides no evidence that the announcement of the EU Omnibus Package had a statistically detectable effect on the green-conventional yield differential. The estimates range from $+0.073$ bps in quarter one to -1.537 bps across the four available post-event quarters, small and stable in magnitude. The negative sign is directionally consistent with a partial restoration of the greenium following the announcement, pointing in the opposite direction to the CSRD result, but none of the estimates are statistically significant, and no firm conclusion can be drawn.[4] Results are presented in Table 15 and Figure 3 in the appendix.

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the identifying assumption. The slight differences in magnitude relative to the trimmed sample reflect the influence of extreme observations in the full sample, but the directional conclusion remains unchanged.

[4] Full sample results are consistent with the trimmed sample, with post-event coefficients ranging from -0.136 to -1.550 bps across the four post-event quarters, none of which reach statistical significance. The null result is unchanged across both samples.

7 Specification Tests and Robustness Checks

7.1 Model Specification Tests

The Hausman test rejects the null hypothesis of consistent random effects ($p = 0.064$), providing statistical support for the fixed-effects specification. However, the two-step procedure requires fixed effects regardless of this outcome, because bond-level intercepts $\hat{\alpha}_i$ extracted in Step 1 serve as the greenium estimates in Step 2, and a random-effects specification does not permit extracting bond-specific intercepts in this way.

The F-test and Honda LM test both reject the null hypothesis of no individual effects, confirming that bond fixed effects are present and that pooled OLS is inappropriate. The Breusch-Godfrey and Durbin-Watson tests reject the null hypothesis of no serial correlation, justifying the use of Newey-West and Beck-Katz standard errors. The Breusch-Pagan test rejects the null hypothesis of homoskedasticity, further supporting the use of robust standard errors. All specification tests support the choices made for the model. Full test statistics are reported in section 10.6 in the appendix.

7.2 Test of Strict Exogeneity

To validate the results of the fixed-effects model, and by extension the estimated greenium, the consistency of the fixed-effects estimator is examined. The estimator is consistent only under strict exogeneity, which requires that the error term be uncorrelated with past, present, and future values of the explanatory variable. The lagged liquidity term is insignificant, supporting the exogeneity assumption with respect to past liquidity. The lead term is significant at the 10% level, constituting a mild violation of strict exogeneity. The mild violation of strict exogeneity in the trimmed sample implies that the fixed-effects estimator may be subject to some bias. Nevertheless, this need not be interpreted as a fundamental identification failure, as it is most plausibly explained by micro-level market dynamics rather than a structural endogeneity issue, and that it constitutes a feedback channel running from yields to liquidity rather than the reverse.

Taken together, the results suggest that, although the exogeneity assumption is mildly violated in the trimmed sample, the main liquidity coefficient remains stable in both magnitude and significance, and the use of Newey-West standard errors accounts for the serial correlation present in the residuals. These factors provide reassurance that the extracted fixed effects $\hat{\alpha}_i$ remain reliable estimates of the greenium. Full results are presented in section 10.7 in the appendix.

7.3 Volatility Test

To assess the sensitivity of the main results to alternative model specifications and matching criteria, the baseline Step 1 regression controls for liquidity differences between matched green and conventional bonds through the bid-ask spread differential. However, it does not explicitly account for residual risk differences between matched pairs. Since bonds are matched within the same rating category, systematic credit risk differences are largely controlled for by design, but short-term yield volatility differences may remain. A volatility robustness check therefore augments the Step 1 regression with a control for the volatility differential between matched bonds across three rolling windows of 10, 20, and 30 days, assessing whether residual risk differences contribute to the yield differential beyond what is already captured by the matching procedure.

The liquidity coefficient remains strongly significant and stable in magnitude across all three windows, supporting the reliability of the baseline estimates. The volatility coefficient is insignificant at the 10-day and 20-day windows, suggesting that over short horizons the liquidity effect identified in Step 1 reflects genuine liquidity differences rather than residual risk differences between matched pairs. At the 30-day window, the volatility coefficient becomes significant at the 5% level, constituting a minor caveat alongside the mild exogeneity violation noted above. It can also be explained by persistent market dynamics over longer horizons, where liquidity, volatility, and risk are tightly interconnected. Full results are reported in section 10.8 in the appendix.

7.4 Stringent Matching

To validate the approach used for matching bonds, an additional robustness test is conducted for the first-stage regression to assess whether the findings are sensitive to matching quality.

The sample is derived by imposing a more stringent matching criterion, requiring the closest conventional bond in maturity to fall within one year of the green bond, this reduces the sample from 63 to 42 bond pairs. The yield differential, both median and mean, remains statistically indistinguishable from zero under both the Wilcoxon signed-rank test and the t-test, and the direction and magnitude of the median and mean are consistent with the main results of the trimmed sample. This provides comfort that the main findings are not an artifact of poor matching quality, and further motivates the trimming of the full sample. Full results are reported in section 10.9 in the appendix.

8 Discussion

In line with prior research, the results of this study on the greenium are ambiguous. Pooled across all bond pairs, this study finds no statistically significant greenium, in contrast to Zerbib (2019), who identifies a significant greenium in both the aggregate sample and the EUR subsample. The heterogeneity analysis, however, reveals that the greenium is not absent but rather concentrated, with rating and sector emerging as key moderating factors, consistent with large part of prior research.

The cross-sectional analysis, across specifications (a), (b), and (c) points to high credit quality and public sector character as the key determinants of where the greenium is present. In addition to this, the full interaction model, specification (d), further identifies the AAA/AA × government and the A × Other segment combinations as those carrying a statistically significant greeniums. The A × Other segment, comprising sub-sovereign and quasi-governmental entities that retain a strong public sector character, again points to the role of high credit rating in combination with public sector status in determining where a greenium exists, as no greenium could be statistically proven in the BBB government segment. This in turn provides evidence of within which segments investors can accept lower yields.

Additional heterogeneity emerges as the sample is studied annually and quarterly. This disaggregation reveal a statistically significant greenium during 2022 and 2023, a pattern further confirmed in the quarterly breakdown. This would suggest that the greenium is sensitive and fluctuates over time. The smaller sample sizes in the earlier years of the study naturally limit statistical power and should be taken into account. Nonetheless, the observed temporal variation is consistent with prior research and the broader conclusion that the greenium is time-varying rather than a persistent structural feature of the market, which motivates continued studying of it's evolution over time.

Löffler, Petreski, and Stephan (2021) could only detect a significant greenium in the secondary market in the latter part of their sample, during 2018 and 2019. Similarly, Caramichael and Rapp (2024), studying European corporate bonds, could only identify a greenium over one year, in 2019. A large portion of the papers reviewed in the literature section find that the greenium is most consistently detected through heterogeneity analysis and less frequently when a market is studied in aggregate. Taken together, the results of this study support both conclusions, namely that the greenium is conditioned by heterogeneity and that it is time-dependent. The latter most likely reflects prevailing attitudes toward sustainability and the broader ESG landscape at any given point in time.

Beyond this, the matching approach and methodology employed to study the greenium play a significant role in the dispersed results across the literature. For instance, Pietsch and Salakhova (2025) identifies a persistent greenium in the Euro-area from 2016 to 2023 using k-prototypes matching, without directly controlling for credit rating. By contrast, Zerbib (2019) treats rating as one of the more fundamental characteristics on which bonds are matched, and his framework remains one of the most cited and replicated frameworks for isolating the green component of bond pricing. Replicating this framework therefore offers an advantage. It ensures comparability with a well-established benchmark which the majority of the studies mentioned in the literature review uses. The absence of a shared methodological standard nonetheless contributes meaningfully to the ambiguity observed across the literature.

What are the implications of the outcomes? Whereas it cannot be concluded that the typical green issuer does benefit from better capital conditions, the main finding of the cross-sectional analysis is that the greenium was detected only among government and quasi-governmental issuers of high credit quality, raising important questions about whether the desired outcome of the EGD as a whole is being reached. As briefly mentioned in the background section, the Commission has been trying to direct and push the Union toward the green transition by advancing policy in that direction. The European Green Deal and its subsequent policy framework were designed from the beginning to channel private capital into the green transition by lowering the cost of capital for corporate actors allocating funds toward green activities.

The findings of this study, suggest that the greenium is most prevalent in the government sector. This implies that the entities benefiting from lower capital costs are those already in a position to access cheaper funding, namely governments and quasi-governmental institutions, rather than private corporations. As such, the aim of the European Green Deal framework is not reached. The incentive mechanism intended to redirect private capital toward the green transition by making it cheaper for green actors to contribute to the change, does not appear to be functioning as intended. Whether the greenium reflects investor preferences or serves as a hedge against climate-related risks, the evidence suggests that investors assign greater credibility to high-rated public-sector issuers when evaluating green credentials.

Two caveats regarding the Phase 1 estimates are worth noting before turning to the event study. The fixed-effects estimator may be subject to mild bias arising from the violation detected in the strict exogeneity test. The violation is believed to stem from market microstructure dynamics, in which the significant lead term reflects a feedback channel running from yields to liquidity rather than the reverse. When the yield differential between a green bond and its conventional counterpart shifts, traders and liquidity providers adjust their quoting behavior, resulting in a measurable change in bid-ask spreads in subsequent periods. A similar reasoning applies to the volatility test, which provides evidence that, over longer horizons, volatility, liquidity, and risk become increasingly difficult to disentangle and may therefore influence the fixed-effects estimator. These dynamics are not believed to materially distort the results but rather reflect realistic market behavior. Nonetheless, they are important to acknowledge, as the results are inferred.

The CSRD event study shows that by the time of policy implementation, a narrowing of the greenium is observable following CSRD adoption. This suggests that as the reporting environment becomes more harmonized and standardized, the greenium declines relative to the quarter preceding the directive's entry into force.

The embedded control approach, while well-suited to the matched-pair structure of the data, does not permit the same degree of precision in isolating the treatment effect as a classical difference-in-differences design with a separate control group. However, this limitation is inherent to the nature of the research setting. There is no natural counterfactual when studying the greenium, as it is necessary to account for liquidity and bond-level attributes. Comparing raw green yields to conventional yields without controlling for other bond characteristics would fail to isolate the green component, making the use of embedded controls the most viable approach.

What the study is able to detect is the direction and magnitude of the change in the greenium relative to the baseline, the cost advantage of being green narrowed following the CSRD adoption. Identifying the precise transmission mechanism through which this occurred is not possible from yield differentials alone, though this is a general feature of observational policy evaluation rather than a limitation specific to this design. The potential channels are instead examined theoretically below, drawing on the framework outlined earlier.

Multiple mechanisms could explain how the greenium would be affected. Green bonds are relatively rare compared with the broader bond universe, and prior to the policy taking effect, investors relied on the green label, which carries signaling value and makes investors willing to accept lower yields.

Before a standardized reporting framework existed, investors faced a more cumbersome process for accessing public information about their investments, making reliance on the green label itself more critical. This is where information asymmetry arises. Investors could verify the existence of a green label and the certification body behind it, but the underlying activities and documentation tied to that certification were not readily accessible. This gave certified issuers a distinguishing signal, making them stand out and appeal to those seeking green investments. The CSRD, in contrast, was designed to increase ESG transparency across all firms, not only those seeking to signal greenness through voluntary certification.

The CSRD represents a fundamental shift in the information environment surrounding sustainable finance. Its direct effect is to reduce the informational advantage previously conferred by voluntary green certification and to reduce the persistent information asymmetry between issuers and investors. Reduced information asymmetry and increased transparency can affect the greenium through two distinct channels: by weakening the green label or by strengthening it, unless through both simultaneously.

The first channel operates through a weakening of the green label. Under the CSRD, standardized reporting obligations apply to all eligible corporates, regardless of whether they hold green certification. Obtaining green label certification is costly and therefore not pursued by all firms, even those actively allocating capital toward green activities. Not all companies seek to signal greenness or are willing to bear the cost of certification. Those that do undergo the process most likely anticipate a tangible benefit from the label, an expectation not universally shared. Crucially, however, regardless of whether a firm holds green certification, it is now obligated under the CSRD to report its ESG activities and disclose where capital is being deployed.

This means that a conventional bond issuer with genuine green undertakings, but no prior incentive to signal them, is now required to make that information publicly available. The standardized reporting framework effectively illuminates the green credentials of non-certified issuers, revealing that firms may nonetheless be allocating capital toward sustainable activities. As a result, it becomes possible to issue conventional bonds that are still sustainability-oriented in practice, which broadens the pool of potential investors as well as the supply on the market. Investors with a preference for issuers allocating capital toward sustainable projects can now satisfy that preference without requiring a formal green label, reducing their reliance on certification as a signal and, by extension, increasing the supply, which spills over into investors' willingness to pay a premium for it.

Given the results of the CSRD event study, it can be concluded that the second channel, whereby green instruments benefit from standardized disclosure through enhanced credibility, is either ruled out or represents the weaker of the two effects. It cannot be ruled out that both channels operate simultaneously, nor that conventional issuers are the only ones affected. However, the evidence does support that, at the time of implementation, the dominant effect lies with conventional issuers. As information asymmetry diminishes, the signaling value of the green label weakens. A higher degree of transparency creates an investment environment in which investors no longer need to rely on a label as a proxy for what is green or sustainable, but can instead evaluate disclosed information directly against their own values and investment objectives, rendering the label itself less indispensable and, with it, the premium attached to it.

Although the greenium begins narrowing from the first quarter onward, the effect only becomes statistically significant in the fourth quarter relative to the baseline. This delayed onset can most likely be explained by the reporting timeline. Formal reporting obligations commenced in 2024 for Phase 1 companies, four quarters after the directive's entry into force, with official disclosures scheduled for the first quarter of 2025. Throughout 2024, however, Phase 1 companies were actively preparing and, in many cases, signaling their sustainability positions through existing voluntary frameworks and semiannual reporting obligations. Bond markets, being forward-looking, could therefore begin pricing the anticipated improvement in disclosure quality from the moment the regulatory timeline was credibly established at entry into force in January 2023, rather than waiting for formal disclosures to be published in 2025.

Another potential explanation could be attributed to annual portfolio adjustment cycles among institutional investors, such as pension funds and insurance companies, which often operate on annual mandates. Reallocation of money could therefore be prone to delays, which would push pricing effects, and the incorporation of regulatory signals into assessment also takes time.

A distinction worth noting, and one some would argue, is that if markets are truly forward-looking, the pricing response should have occurred at the point of announcement rather than at entry into force. The CSRD was first proposed in April 2021, nearly two years before the directive entered into force. The Omnibus announcement offers a further lens through which to examine this. The Omnibus study does not provide evidence of a statistically detectable effect on the green-conventional yield differential following the announcement of the policy package.

While the post-event coefficients of the Omnibus event study are directionally consistent with a partial restoration of the greenium, they point in the opposite direction of the narrowing observed following CSRD adoption. However, the magnitude is small, and the estimates are statistically indistinguishable from zero. The absence of a statistically detectable market response to the announcement suggests that markets might not re-price green instruments in response to announcements alone, but rather to actual entry into force or binding commitments. On the other hand, the Omnibus announcement does not constitute a clear and binding regulatory event and comprises a broader set of amendments that affect more policies than the CSRD. This might be another explanatory factor in the Omnibus outcome, in combination with the short post window. Any or all of which could independently suppress a detectable market response.

The main takeaway from the event study is that the introduction of the CSRD produced a measurable narrowing of the greenium, consistent with the theoretical prediction that mandatory disclosure reduces the information asymmetry that underpins part of the green label's pricing advantage. This aligns with the mechanism identified by Leuz and Wysocki

(2016), who conclude that information asymmetry is persistent and that disclosure can mitigate this gap, and with Steuer and Tröger (2021), who argue that investors overvalue the label in the absence of means to verify the activities behind it.

9 Conclusion

This study examines the existence and determinants of a greenium in the European bond market and assesses whether the introduction of the CSRD had a measurable effect on the green-conventional yield differential, the greenium. The findings contribute to a growing, relevant, but ambiguous body of literature and offer several insights relevant to both academic research and policy evaluation.

The aggregate sample analysis does not provide evidence of a statistically significant greenium, consistent with a substantial portion of prior research. However, the heterogeneity analysis reveals that the greenium is not absent but rather concentrated. Top-rated bonds in the government segment consistently command a greenium across multiple model specifications. This points to both a high credit rating and a public-sector character as key determinants of where investors are willing to accept lower yields in exchange for investing green, aligning with their preferences.

The temporal analysis reinforces the conclusion that the greenium is time-dependent, which is consistent with prior studies' findings of greenium effects in specific sub-periods and suggests that the greenium is sensitive to the broader ESG landscape and prevailing investor attributes at any given point in time, rather than being a persistent structural feature of the market.

Taken together, these findings carry important implications for the evaluation of European green policy. The European Commission has sought to channel private capital toward the green transition by creating incentives for corporate actors through green frameworks and disclosure requirements. The evidence from this study suggests that those benefiting from lower capital costs are governments and quasi-governmental institutions, rather than the private corporations. This runs counter to the broader objective of "greening" the European corporate sector and underscores both the importance and the difficulty of rigorously evaluating green policy amid significant research ambiguity.

The CSRD event study provides evidence that the greenium narrows after the directive's entry into force, suggesting that increased transparency and harmonized disclosure reduce the informational advantage previously conferred by the green label. The findings are most consistent with the first of the two channels examined. The value of the green label weakens as mandatory disclosure makes green-relevant information available across the broader bond market, reducing investor reliance on certification as a proxy for sustainability because information is now more easily accessible. The second channel, whereby standardized disclosure strengthens green bond credibility by addressing greenwashing concerns, is either ruled out or represents the weaker of the two effects. The Omnibus null result further supports the interpretation that markets respond to binding regulatory commitments rather than announcements alone.

However, there are limitations that need to be acknowledged. The fixed-effects estimator in the Phase 1 regressions may be subject to mild bias arising from market microstructure dynamics. Although these dynamics are not believed to materially distort the results, it is important to keep that in mind when interpreting the results and drawing inferences from the regression output. The sample size is an inherent constraint when applying a strict matching methodology to distinguish what can be attributed to the greenium from what cannot. While the robustness checks provide comfort that poor matching is not driving the greenium, the cross-sectional analysis would benefit from a larger sample, a limitation common to many greenium studies. The embedded control approach is the most viable identification strategy given the absence of a natural counterfactual, and provides directional evidence of how binding regulatory commitments translate into market pricing. The Omnibus, as a secondary exploratory event study, is inherently less well-defined as a policy event, and its null result should be interpreted with caution given both the announcement nature of the event and the limited post-event window available for estimation.

Future research would benefit from a longer post-CSRD window as more disclosure data become available, enabling a more precise assessment of whether the narrowing observed in this study persists or reverses as the regulatory framework matures. Further work examining the corporate segment in Europe more specifically, and whether the greenium eventually extends beyond the government sector as disclosure quality improves, would speak directly to the policy question of whether the EGD's intended incentive mechanism is beginning to function as designed. Comparing how the greenium evolved across EU and non-EU markets around the time of CSRD implementation would allow researchers to assess whether the narrowing observed in this study is specific to the European regulatory environment or reflects broader market-wide trends, and to isolate the regulatory effect more cleanly by using non-EU markets as a natural control group.

Most importantly, the development of a shared methodological standard for greenium research would meaningfully reduce the ambiguity that currently characterizes the literature and complicates cross-study comparison.

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10 Appendix

10.1 Static Matching

This section describes the step-by-step matching procedure implemented in R.

The procedure begins with cleaning three key variables. Yield to maturity is converted to a numeric variable, and observations with missing values are dropped. Bonds with missing values in maturity or issue date are similarly dropped, ensuring complete data for all bonds in the sample.

Following the initial cleaning, the data is filtered so that all bonds are plain-vanilla, senior unsecured, fixed-coupon bullet bonds denominated in euros. This implies that all bonds meet the following: the instrument type must be classified as a bond, and the issuer type must be either Corporate, Agency, Government/Treasury/Central Bank, or Other Government/Supranational. This ensures against misclassification in LSEG and that yield differences in the subsequent analysis are not driven by structural differences between bonds.

A rating filter is then applied. The sample includes bonds with either a Moody's rating, a Fitch rating, or both. When only a Fitch rating is available, it is converted to the corresponding Moody's rating, which is used throughout the analysis. Bonds without a rating are excluded, regardless of whether they are investment-grade or sub-investment-grade. This step removes a substantial portion of the sample but is necessary to control for credit risk in the matching of bonds. Once cleaning and filtering are complete, green and conventional bonds are separated. Each green bond is assigned a unique green ID, which serves as the identifier for each matched triplet.

Each green bond is matched to conventional bonds that share identical values across six characteristics: issuer, principal currency, coupon frequency, coupon type, seniority, and Moody's rating. All conventional bonds meeting these criteria are retained and assigned the corresponding green ID. A maturity gap and an issue date gap are computed between the matched green and conventional bonds to identify the two closest neighbors, which will be used for interpolation later.

The issue amount ratio is computed as the conventional bond amount divided by the green bond amount. Conventional bonds may be at most four times as large as their green counterparts. Those exceeding this threshold are dropped. The issue date window allows a deviation of up to 6 years from the green bond's issue date. This ensures that matched bonds were issued in a reasonably comparable macroeconomic and interest-rate environment, preventing spurious yield differences driven by differing issuance conditions. The maturity window allows a deviation of up to four years in either direction, compared with the two-year window used by Zerbib (2019). This wider window reflects the European bond market's smaller size.

The deviation is applied to the maturity window rather than the issue date window because of how the yield comparison is subsequently constructed. Since two bonds rarely share an identical maturity, the model does not select only the single nearest conventional bond. Instead, the two conventional bonds closest in maturity to the green bond, one with a slightly shorter maturity and one with a slightly longer maturity.

The synthetic conventional bond yield is constructed by linearly interpolating between the two matched conventional bonds, weighted by their respective maturity distances from the green bond. The bond closer in maturity receives the higher weight, reflecting its greater relevance to the relevant point on the yield curve. Because the interpolation explicitly accounts for residual maturity differences within the matching window, widening the maturity window is preferable to widening the issue date window, although a wider maturity window places the two anchor points further apart and may reduce precision, but remains a more reliable approach than single-bond nearest-neighbor matching.

10.2 Dynamic Panel Construction

The static matching identifies matched pairs based on fixed bond characteristics observed at a single point in time.

For the dynamic panel, daily trading data are extracted from LSEG on a bond-by-bond basis using each bond's ISIN number. The ISIN is a twelve-character alphanumeric code that uniquely identifies financial securities. The ISIN serves as the key for both extracting time-series data from LSEG and merging it with the static matching file.

For each ISIN, the extracted price history includes the bid-price, ask-price, and ask-yield. The bid and ask prices are used to compute the daily bid-ask spread, which serves as the liquidity proxy in the model. The ask-yield is later used to compute the greenium. Once all ISIN-level data have been extracted, they are merged into a single dataset and joined with the static matching file by the ISIN number.

Following the merge, the two conventional bonds in each triplet are ranked by maturity distance relative to their green bond counterpart. The bond with the closer maturity is designated CB1 and receives a higher weight in the interpolation, the bond with the more distant maturity is designated CB2. All triplets remain identified by the green ID assigned during the static matching stage. This classification is later used in the interpolation of the synthetic time-series variables.

10.3 Creation of The Synthetic Bond

After merging, each triplet consists of one green bond paired with two conventional bonds, all sharing the same green ID. For each bond on each trading day, the mid-price is first computed as the midpoint between the bid and ask prices:

$$\text{Mid}_{i,t} = \frac{\text{Ask}_{i,t} + \text{Bid}_{i,t}}{2}$$

The mid-price serves as the denominator in the spread calculation, expressing the spread as a percentage of the bond's price rather than in absolute units. This ensures that liquidity differences are comparable across the full sample, regardless of price level. The liquidity variable BA will later be used in the fixed-effects regression of the main model.

$$\text{BA}_{i,t} = \frac{\text{Ask}_{i,t} - \text{Bid}_{i,t}}{\text{Mid}_{i,t}} \times 100$$

A synthetic conventional bond is then constructed for each green bond by linearly interpolating the yields of CB1 and CB2, with weights inversely proportional to maturity distance. The bond closer in maturity to the green bond receives a higher weight, as its yield provides more information about the relevant point on the yield curve. The same interpolation is applied to the bid-ask spreads, ensuring that both the yield and liquidity measures are constructed consistently, following the approach used by Zerbib (2019).

$$Y_{CB,t} = \frac{d_2}{d_1 + d_2} \cdot Y_{CB1,t} + \frac{d_1}{d_1 + d_2} \cdot Y_{CB2,t}$$

The same weighting is applied to the bid-ask spreads of the two conventional bonds, so that the synthetic liquidity measure is maturity-adjusted in the same way as the yield:

$$BA_{CB,t} = \frac{d_2}{d_1 + d_2} \cdot BA_{CB1,t} + \frac{d_1}{d_1 + d_2} \cdot BA_{CB2,t}$$

Any observation with either variable missing is dropped. The yield and liquidity differentials are then computed as:

$$dY_{i,t} = Y_{GB,i,t} - Y_{CB,i,t}$$

$$dBA_{i,t} = BA_{GB,i,t} - BA_{CB,i,t}$$

The yield and liquidity differentials together form the basis for the regression analysis.

10.4 Premia Distribution Full and Trimmed Sample

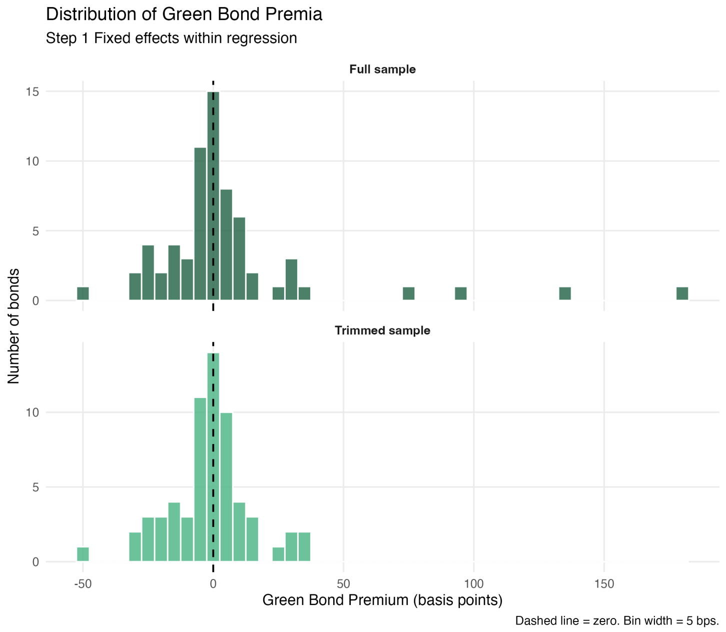


Figure 2: Distribution of Green Bond Premia

Source: Author's rendering of LSEG Refinitiv data (2026).

10.5 Descriptive Representation of the Premia by Sector

Table 9: Green Bond Premia by Sector — Trimmed Sample

Sector	N	Mean (bps)	Median (bps)	SD (bps)	% Neg.	Wilcoxon p	t-test p
Government	23	-5.81^{*}	-3.63^{*}	14.94	60.90	0.097	0.075
Financial	8	0.46	5.07	22.35	37.50	0.441	0.955
Utilities	18	2.39	1.75	12.25	44.40	0.486	0.419
Corporate	4	-1.00	-10.52	24.46	75.00	0.855	0.940
Other	10	-2.78	-2.56	9.61	80.00	0.262	0.383

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

Wilcoxon: H_0 median = 0. t-test: H_0 mean = 0.

Source: Author's rendering of LSEG Refinitiv data (2026)

10.6 Specification Test

Table 10: Specification Tests — Trimmed Sample

Test	Statistic	df	p-value	Conclusion
Hausman (FE vs RE)	3.42	1	0.064	Fixed effects preferred
F-test (individual effects)	1969.40	62, 34026	0.00e+00	Individual effects present
Honda (individual effects)	2410.07		0.00e+00	Individual effects present
Breusch-Godfrey (serial corr.)	32963.57	5	0.00e+00	Serial correlation present
Durbin-Watson (serial corr.)	0.03		0.00e+00	Serial correlation present
Breusch-Pagan (heteroscedasticity)	165.04	1	8.96e-38	Heteroscedasticity present

FE = Fixed Effects, RE = Random Effects.

Serial corr. = serial correlation. Heteroscedasticity tested via Breusch-Pagan Lagrange multiplier test.

Results justify the use of Newey-West and Beck-Katz robust standard errors throughout.

Author's calculations based on LSEG Refinitiv data (2026)

To justify the model, the following specification tests validate the structure choices.

The Hausman test evaluates whether the fixed-effects or random-effects estimator is appropriate for the model. The FE estimator allows for correlation between regressors and unobserved individual effects, $\text{Cov}(x_{it}, \alpha_i) \neq 0$, and remains consistent even when time-invariant bond characteristics, such as issuer type or maturity, are correlated with the dependent variable. The random-effects estimator assumes $\text{Cov}(x_{it}, \alpha_i) = 0$. Rejection of the null hypothesis confirms that fixed effects is the appropriate specification.

The Hausman test rejects the null hypothesis that the random effects estimator is consistent at the 10% significance level ($p = 0.064$), providing statistical support for the fixed effects specification. However, the choice of fixed effects is not driven by the Hausman result alone. The fixed effects estimator is required by the design of the two-step procedure. The bond-level intercepts $\hat{\alpha}_i$ extracted from Step 1 are the premium estimates that serve as the dependent variable in Step 2. A random effects specification does not permit the extraction of bond-specific intercepts in this way, making fixed effects the only viable choice regardless of the Hausman outcome. Furthermore, the underlying data structure supports this choice. Bond-specific unobserved characteristics, such as issuer identity, credit quality, and maturity profile, are plausibly correlated with the liquidity differential, which is precisely the condition under which the fixed effects estimator remains consistent, and the random effects estimator would be biased.

The F-test and Honda LM test assess individual effects. The F-test evaluates whether bond-specific intercepts are jointly different from zero, with the null hypothesis that pooled OLS is sufficient. Rejection confirms that each bond has persistent yield characteristics that must be accounted for, validating the panel structure. The Honda LM test corroborates this finding through an independent test.

The null hypothesis of no individual fixed effects is rejected, indicating that bond fixed effects are present and necessary. This is expected given that each bond carries its own persistent yield characteristics. Pooled OLS is therefore inappropriate, and panel methods are required. Additionally, the Honda LM test concludes that the null hypothesis of no individual effects is rejected, confirming the presence of significant bond-specific effects and corroborating the conclusion of the F-test that panel methods are required.

The Breusch-Godfrey and Durbin-Watson tests assess serial correlation. The Breusch-Godfrey test checks for serial correlation in the residuals; rejection indicates that residuals are correlated over time, consistent with the persistence of market shocks and confirming that standard OLS errors would be incorrect. The null of no serial correlation is rejected, confirming that residuals are serially correlated over time. This is common in daily financial data, particularly yield data, where the error term in period t depends on outcomes in the previous period. Newey-West and Beck-Katz standard errors are used to account for this. The Durbin-Watson statistic provides a complementary check; a value below 2 is consistent with positive serial correlation. Testing confirms the presence of positive serial correlation. The DW value returned is 0.03.

The Breusch-Pagan test for heteroskedasticity evaluates whether the error variance is constant across observations. Rejection of the null hypothesis of homoskedasticity further supports the use of robust standard errors. The null is rejected, indicating that the error variance differs across observations, which is common in financial data. Together, these results justify the use of Newey-West and Beck-Katz robust standard errors throughout.

10.7 Test of Strict Exogeniety

Table 11: Strict Exogeneity Test — Trimmed Sample

Variable	Estimate	Std. Error	t value	p-value
$\Delta BA_{i,t}$	-0.15^{***}	0.03	-5.52	3.41×10^{-8}
$\Delta BA_{i,t+2}$ (lead)	-0.07^{*}	0.04	-1.75	0.080
$\Delta BA_{i,t-2}$ (lag)	-0.04	0.04	-0.97	0.334

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$. Newey-West standard errors.

Lead and lag window of 2 periods. Dependent variable: $dY_{i,t}$.

Author's calculations based on LSEG Refinitiv data (2026)

The strict exogeneity test assesses whether the error term is uncorrelated with past, present, and future values of the liquidity regressor. This guards against reverse causality and ensures that the estimated liquidity coefficient β is unbiased, and consequently that the recovered greenium, the α, is reliable. The test of strict exogeneity is conducted by augmenting the fixed-effects regression with lead and lagged values of the liquidity differential.

A key identifying assumption of the fixed-effects model is strict exogeneity, which requires that the error term be uncorrelated with past, present, and future values of the explanatory variable. Following Su, Zhang, and Wei (2016), the assumption is tested by augmenting the fixed-effects regression with lead and lagged values of the liquidity differential.

The lead liquidity term is significant at the 10% level, indicating that future liquidity differentials are correlated with current yield differentials. This constitutes a mild violation of strict exogeneity in the trimmed sample and implies that the fixed-effects estimator may be subject to some bias.

The small, mild violation of the lead liquidity could, on the other hand, be explained by microdynamic structure and thus does not need to be interpreted as a strict violation. The most plausible explanation for the significant lead is a feedback channel running from yields to liquidity rather than the reverse. When the yield differential between a green and its conventional counterpart shifts, traders and liquidity providers react by adjusting their quoting behavior, resulting in a measurable change in the bid-ask spread in subsequent periods.

This type of forward-looking adjustment is consistent with standard market microstructure dynamics, as concluded by Amihud and Mendelson (1986), where yields and the bid-ask spread are tied through trading costs. If yields change, it signals a mismatch with the compensation required for these costs, so markets adjust spreads to restore equilibrium. Importantly, it is the lead rather than the lag term that is significant, had the lagged liquidity term been significant instead, it would have constituted a more serious concern, indicating that past liquidity drives current yield differentials and raising genuine questions about the direction of causality. The significant lead should therefore not be interpreted as a violation of the underlying economic identification, but as liquidity responding to pricing signals.

10.8 Volatility Test

Table 12: Volatility Robustness test — Trimmed Sample

	Liquidity (dBA)		Volatility ($dVol$)		
Window	$\hat{\beta}$	SE	$\hat{\gamma}$	SE	N obs
10-day	-0.2428^{***}	(0.0299)	0.0037	(0.0111)	33,527
20-day	-0.2427^{***}	(0.0298)	-0.0138	(0.0098)	32,912
30-day	-0.2304^{***}	(0.0298)	-0.0184^{**}	(0.0087)	32,312

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$. Newey-West standard errors in parentheses.

Dependent variable: $dY_{i,t}$. Bond fixed effects included. Volatility measured as rolling standard deviation of $dY_{i,t}$ over the specified window.

Author's calculations based on LSEG Refinitiv data (2026)

Across the 10-day and 20-day windows, the liquidity coefficient remains strongly significant ($\hat{\beta} = -0.2428$, $p < 0.001$ and $\hat{\beta} = -0.2427$, $p < 0.001$ respectively), while the volatility coefficient is statistically insignificant ($\hat{\gamma} = 0.0037$ and $\hat{\gamma} = -0.0138$, both $p > 0.10$). This indicates that short-term yield volatility differences between green and conventional bonds do not drive the yield differential, the results are explained by liquidity rather than residual risk differences.

At the 30-day window, the volatility coefficient becomes marginally significant ($\hat{\gamma} = -0.0184$, $p < 0.05$), suggesting that longer-term risk differences between matched bonds may have a small but detectable effect on the yield differential.

This robustness check is further motivated by the mild exogeneity violation detected in the trimmed sample, which raises the possibility that the liquidity coefficient is partly influenced by dynamic interactions between yields and liquidity. Chordia, Roll, and Subrahmanyam (2001) demonstrates this dynamic in their empirical findings. Over longer horizons, liquidity, volatility, and risk are tightly interconnected because they are jointly driven by other factors, such as market conditions and trading behavior. As a result, it is inherently difficult to empirically separate their individual effects, since observed changes in spreads or trading reflect a combination of these forces.

Therefore, the 30-day window likely reflects the rolling window construction rather than a structural problem with the model. The liquidity coefficient remains largely unchanged in magnitude across all three windows, and the collective evidence supports the conclusion that the fixed effect extracted in step 1 remains a reliable estimate of the greenium, though this should be acknowledged when interpreting results.

10.9 Stringent Matching

Table 13: Stringent Matching Robustness test

Statistic	Trimmed	Stringent
N bonds	63	42
Mean (bps)	-1.88	-0.92
Median (bps)	-1.63	-0.60
SD (bps)	15.20	13.23
% Negative	57.1	54.8
Wilcoxon p	0.323	0.484
Wilcoxon 95% CI	$[-4.86,\ 1.37]$	$[-3.65,\ 1.94]$
t-test p	0.329	0.654
t-test 95% CI	$[-5.71,\ 1.94]$	$[-5.04,\ 3.20]$

All premia reported in basis points (bps).

Wilcoxon: H_0 median $= 0$. t-test: H_0 mean $= 0$.

Stringent matching restricts CB_1 maturity gap to less than one year, following Zerbib (2019).

Author's calculations based on LSEG Refinitiv data (2026)

Imposing more stringent matching in constructing bond pairs is intended to rule out the possibility that poor matching quality is driving the results.

The stringent matching restricts the sample to triplets where the closest conventional bond CB1 has a maturity gap of less than one year, replicating the stricter matching tolerance applied by Zerbib (2019). This is done to guard against potential bias from a poor maturity match, as time to maturity and yields are related.

Imposing this criterion reduces the sample from 63 to 42 bond pairs. The mean yield differential narrows from -1.88 bps to -0.92 bps under stringent matching, and the median shifts from -1.63 bps to -0.60 bps, remaining small in magnitude. Neither the Wilcoxon signed-rank test ($p = 0.484$) nor the t-test ($p = 0.654$) rejects the null of no yield differential, consistent with the main results. The 95% confidence intervals under stringent matching ($[-3.65, 1.94]$ bps and $[-5.04, 3.20]$ bps, respectively) both include zero, reinforcing this conclusion. Overall, the stringent matching results provide comfort that the main findings are not an artifact of poor matching quality. Even under considerably tighter matching criteria, the green bond yield differential remains negative but statistically indistinguishable from zero at the aggregate level.

10.10 Quarterly Extension

Table 14: Quarterly Green Bond Premia — Full and Trimmed Sample

Sample	Quarter	N	Mean	Median	% Neg.	CI lo	CI hi	Wilcoxon p	t-test p	$\hat{\beta}_{liq}$	SE
Full	2020 Q2	3	−3.75	−0.90	66.70	−12.15	1.78	0.789	0.472	−0.10	0.02
Full	2020 Q3	3	−3.18	−3.77	66.70	−7.50	1.75	0.423	0.359	−0.09	0.04
Full	2020 Q4	3	4.97	4.65	0.00	1.94	8.31	0.181	0.115	−0.84	0.11
Full	2021 Q1	3	−2.20	−2.22	100.00	−4.02	−0.37	0.181	0.172	−0.05	0.01
Full	2021 Q2	3	−0.09	−3.18	66.70	−27.81	30.71	1.000	0.996	5.00	1.98
Full	2021 Q3	3	−1.31	−0.72	66.70	−4.14	0.93	0.789	0.472	−0.16	0.04
Full	2021 Q4	5	−0.12	−2.10	60.00	−3.67	3.42	0.787	0.963	−0.04	0.01
Full	2022 Q1	7	−2.96	−3.44	71.40	−10.22	4.44	0.272	0.304	−0.05	0.01
Full	2022 Q2	8	−6.51	−4.80	75.00	−17.78	2.54	0.183	0.154	−0.08	0.04
Full	2022 Q3	8	−7.97*	−5.54*	87.50	−17.58	1.93	0.080	0.083	0.03	0.06
Full	2022 Q4	10	−9.60	−4.12	70.00	−26.85	2.59	0.103	0.141	−0.24	0.10
Full	2023 Q1	13	−5.68	−1.89	69.20	−13.33	0.74	0.108	0.158	−0.43	0.08
Full	2023 Q2	15	−4.51	−2.90	60.00	−9.88	2.07	0.293	0.221	−0.28	0.12
Full	2023 Q3	24	−5.01***	−4.82***	83.30	−7.56	−2.33	0.001	0.004	−0.31	0.12
Full	2023 Q4	29	−3.78**	−2.89**	72.40	−7.32	−0.90	0.018	0.035	−0.78	0.34
Full	2024 Q1	34	−0.82	−3.19	61.80	−5.51	1.69	0.225	0.717	−0.06	0.05
Full	2024 Q2	39	4.46	−2.81	69.20	−5.72	1.34	0.165	0.428	−0.21	0.03
Full	2024 Q3	42	9.82	−1.46	57.10	−3.24	10.93	0.736	0.075	0.37	0.08
Full	2024 Q4	43	6.65	−0.24	51.20	−4.08	5.53	0.976	0.195	−0.24	0.08
Full	2025 Q1	52	5.91	0.02	50.00	−2.75	5.29	0.620	0.177	−0.09	0.03
Full	2025 Q2	61	5.54	1.17	45.90	−3.75	5.07	0.757	0.217	−0.09	0.05
Full	2025 Q3	64	6.07	−0.07	50.00	−3.39	4.54	0.731	0.179	−0.15	0.08
Full	2025 Q4	64	6.10	−0.14	51.60	−3.39	4.49	0.917	0.178	−0.07	0.03
Full	2026 Q1	67	4.56	−0.67	53.70	−3.61	3.44	0.933	0.279	−0.18	0.04
Trimmed	2020 Q2	3	−3.75	−0.90	66.70	−12.15	1.78	0.789	0.472	−0.10	0.02
Trimmed	2020 Q3	3	−3.18	−3.77	66.70	−7.50	1.75	0.423	0.359	−0.09	0.04
Trimmed	2020 Q4	3	4.97	4.65	0.00	1.94	8.31	0.181	0.115	−0.84	0.11
Trimmed	2021 Q1	3	−2.20	−2.22	100.00	−4.02	−0.37	0.181	0.172	−0.05	0.01
Trimmed	2021 Q2	3	−0.09	−3.18	66.70	−27.81	30.71	1.000	0.996	5.00	1.98
Trimmed	2021 Q3	3	−1.31	−0.72	66.70	−4.14	0.93	0.789	0.472	−0.16	0.04
Trimmed	2021 Q4	5	−0.12	−2.10	60.00	−3.67	3.42	0.787	0.963	−0.04	0.01
Trimmed	2022 Q1	7	−2.96	−3.44	71.40	−10.22	4.44	0.272	0.304	−0.05	0.01
Trimmed	2022 Q2	8	−6.51	−4.80	75.00	−17.78	2.54	0.183	0.154	−0.08	0.04
Trimmed	2022 Q3	8	−7.97*	−5.54*	87.50	−17.58	1.93	0.080	0.083	0.03	0.06
Trimmed	2022 Q4	10	−9.60	−4.12	70.00	−26.85	2.59	0.103	0.141	−0.24	0.10
Trimmed	2023 Q1	13	−5.68	−1.89	69.20	−13.33	0.74	0.108	0.158	−0.43	0.08
Trimmed	2023 Q2	15	−4.51	−2.90	60.00	−9.88	2.07	0.293	0.221	−0.28	0.12
Trimmed	2023 Q3	24	−5.01***	−4.82***	83.30	−7.56	−2.33	0.001	0.004	−0.31	0.12
Trimmed	2023 Q4	29	−3.78**	−2.89**	72.40	−7.32	−0.90	0.018	0.035	−0.78	0.34
Trimmed	2024 Q1	34	−0.82	−3.19	61.80	−5.51	1.69	0.225	0.717	−0.06	0.05
Trimmed	2024 Q2	37	−1.95	−3.98**	73.00	−6.43	−0.37	0.032	0.337	−0.22	0.03
Trimmed	2024 Q3	40	3.84	−2.00	62.50	−4.18	6.26	0.877	0.208	0.31	0.12
Trimmed	2024 Q4	41	0.60	−0.48	53.70	−5.17	3.27	0.613	0.810	−0.23	0.07
Trimmed	2025 Q1	50	1.09	−0.55	52.00	−3.42	4.16	0.977	0.642	−0.08	0.03
Trimmed	2025 Q2	58	−0.95	0.25	48.30	−5.04	3.26	0.745	0.691	−0.04	0.05
Trimmed	2025 Q3	60	−1.89	−1.28	53.30	−4.97	2.46	0.614	0.357	−0.07	0.07
Trimmed	2025 Q4	60	−1.86	−1.51	55.00	−4.93	1.83	0.451	0.370	−0.02	0.02
Trimmed	2026 Q1	63	−2.57	−1.34	54.00	−5.18	1.39	0.333	0.217	−0.08	0.02

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

Wilcoxon: H_0 median = 0. t-test: H_0 mean = 0.

Stars on median reflect Wilcoxon significance; stars on mean reflect t-test significance.

Source: Author's rendering of LSEG Refinitiv data (2026)

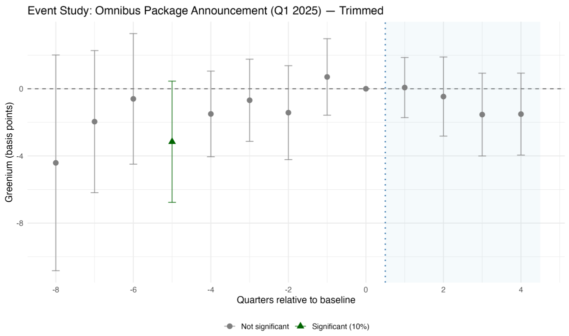
The quarterly breakdown offers finer granularity than the annual analysis and serves as a check on the temporal stability of the results. Comparing the full and trimmed samples, both are identical through 2023 Q4, with trimming affecting only observations from 2024 Q2 onward. The quarterly findings corroborate the findings on annual basis.

10.11 Omnibus Announcement

Table 15: Omnibus Announcement

Event time	Estimate (bps)	Std. Error	t value	p-value	Sig.
-8	-4.412	3.277	-1.346	0.179	
-7	-1.957	2.159	-0.907	0.365	
-6	-0.601	1.983	-0.303	0.762	
-5	-3.155	1.841	-1.713	0.087	*
-4	-1.499	1.301	-1.152	0.25	
-3	-0.685	1.248	-0.549	0.584	
-2	-1.422	1.427	-0.997	0.32	
-1	0.705	1.162	0.606	0.545	
0	0.000			—	(baseline)
1	0.073	0.913	0.080	0.936	
2	-0.464	1.201	-0.386	0.699	
3	-1.537	1.258	-1.222	0.222	
4	-1.509	1.245	-1.212	0.226	

Figure 3: Omnibus Announcement



Baseline = Q4 2024. NW SEs. Significance: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$. Event time measured in quarters relative to baseline quater, Q4 2024 the quarter preceding the Omnibus package announcement.
Source: Author's rendering of LSEG Refinitiv data (2026)