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THE GREENIUM ILLUSION? RETHINKING GREENIUM ACROSS BORDERS, BONDS, AND SUKUK MARKETS

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ABSTRACT

Research originality – Greenium, the yield discount associated with green-labeled instruments, has drawn increasing attention as part of the global movement toward sustainable finance. Although greenium is an indicator of investors' willingness to accept lower yields in support of environmentally advantageous projects, empirical evidence of its existence remains limited, especially across issuer types and financial systems.

Research Objectives – This study aims to assess the presence and variability of greenium across sovereign and corporate bonds and sukuk, using a dataset spanning 2015 to 2024 over various jurisdictions.

Research Methods – To provide robust insights, we employed a multi-method approach combining a twin bond analysis with the Propensity Score Matching (PSM) to estimate the Average Treatment Effect on the Treated (ATT) in broader samples. These techniques allowed us to directly measure matched green and other non-green instruments.

Empirical Research – Our findings indicate that greenium exists in both sovereign and corporate markets, with diverse effects seen in issuer class and industry. The results also confirm the presence of greenium in green sukuk, which implies an increasing alignment between sustainability and Islamic finance. It indicates that green labeling has the potential to reduce the cost of capital.

Implication – The study contributes methodologically by integrating comparative and matching techniques, empirically by offering cross-country and cross-instrument insights, and practically by informing green finance policies in both conventional and Islamic financial markets. We propose that future research explores the statistical and economic significance of greenium, incorporates granular ESG investor data, and examines how greenium behaves under conditions of market uncertainty.

Keywords: Debt; Greenium; Green Bonds; Propensity Score Matching; Sovereign Debt; Sustainable Finance.

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INTRODUCTION

Green finance has experienced substantial growth over the past decade and has become an integral part of global efforts toward sustainable economic development. Since the introduction of “labelled” green bonds in 2007, the sustainable bond market has expanded significantly, from USD 246 billion outstanding in 2017 to approximately USD 4.3 trillion as of Q1 2024 (Cheng et al., 2024). According to the OECD (2017), green bonds serve a critical role in mobilizing capital for environmentally beneficial projects. They offer an alternative financing source, support longer-term investments, and can enhance an issuer's credibility. These instruments also help facilitate the transition of carbon-intensive sectors, broaden access to green financial products, and may even lower the cost of borrowing.

This cost advantage has become a key focus in discussions on the so-called "greenium" - a term referring to the yield premium that investors are willing to forgo when purchasing green bonds over comparable conventional bonds (Dorfleitner et al., 2022; Koziol et al., 2022; Zerbib, 2019). The willingness to accept lower returns is commonly attributed to an increasing demand for sustainable investment vehicles, aspiration to support environmental objectives, and perceived trustworthiness of green bond issuers (Partridge & Medda, 2020; Pirgaip & Arslan-Ayaydin, 2024). Recent studies suggest that investor motivations are not solely driven by traditional risk-return considerations but also shaped by ethical values and corporate social responsibility. Consequently, the ability of green bond issuers to tap into a broader and more committed investor base often results in higher order volumes and, in turn, more favorable financing terms (Hinsche, 2021; Partridge & Medda, 2020).

In managing sovereign debt, governments must secure funding at the lowest possible cost over a medium to long term without incurring excessive risk, as emphasized in the definition of debt management strategy by the IMF (IMF, 2014). This principle aligns with empirical findings, which show that rising public debt service costs exert significant pressure on economic performance, primarily through crowding-out effects and constraints on fiscal space. Dawood et al. (2024) provide robust evidence that high debt servicing in Asian developing economies leads to diminished public investment, narrow fiscal options, and constrained capital formation, which, in turn, inhibit long-term economic growth. Similarly, Saungweme & Odhiambo (2021) highlight that a high debt service burden forces governments to cut back on their contributions to productive sectors, such as infrastructure and social development, thereby blighting growth prospects. Against this background, the existence of a greenium, a potential reduction in borrowing costs through the issuance of green-labeled securities, becomes particularly relevant for sovereign debt management. Leveraging this cost advantage can help alleviate debt servicing pressures, strengthen fiscal sustainability, and simultaneously advance climate transition objectives.

However, accurate measurement of greenium remains a major challenge in sustainable finance literature due to methodological variations and data limitations. For example, Zerbib (2019) finds a small but statistically significant negative yield spread for green bonds, around 2 basis points on average, by using a matching estimator to control bond characteristics. Gianfrate & Peri (2019) also reveal a significant greenium in euro-denominated corporate bonds. In contrast, Larcker & Watts (2020) apply a quasi-natural experiment by analyzing near-identical green and conventional bonds issued by one firm under similar terms. They find that once issuer-level controls are incorporated, the greenium largely disappear. A more recent study by Ando et al. (2023) use a twin-bond framework for German and Danish sovereign bonds, revealing a small and sometimes negative greenium, which further illustrates the ambiguity in current findings.

These contrasting results largely stem from differences in methodological approaches. Early studies commonly rely on cross-sectional ordinary least squares (OLS) regressions, which may have inherent omitted variable bias or unobserved heterogeneity. Quasi-experimental designs and twin-bond analyses improve identification but are constrained by limited sample size and mostly restricted to advanced economies. Panel data approaches (Ando et al., 2023) broaden the sample but rely on strong functional form assumptions. These variations emphasize the need for a more flexible, nonparametric matching method that can account for observable differences in bond characteristics while enabling broader sample inclusion across issuer types and geographies.

The purpose of this study is to investigate the presence, magnitude, and variability of greenium in sovereign, corporate, and sukuk markets. To achieve this, the research adopts a dual-method approach. It combines a twin bond analysis in advanced economies with a global quantitative assessment using Propensity Score Matching (PSM). This design enables high-precision evidence obtained through controlled research. It also offers a more general understanding of various markets where perfect bond pairs do not exist.

The contributions of this study are threefold. First, it provides extensive empirical evidence of greenium across different issuer types and sectors. The magnitude ranges from strong effects in banking and special-purpose entities to more modest or mixed outcomes in industrial and utility-electric sectors. Second, the study reveals how greenium varies across markets, maturities, and institutional settings. This highlights its dependence on such factors as environmental, social, and governance (ESG) demands,

APPLICATIONS FOR PRACTICE

- Encourage green bond and green sukuk programs as part of a national debt strategy to reduce borrowing costs and diversify the funding sources.
- Develop policies that promote long-term green finance markets, including awareness campaigns and incentives.
- Leverage green sukuk issuance to widen the investor base and strengthen sovereign greenium in Islamic finance market.

verification standards, and market structures. Finally, it makes a policy-relevant contribution by positioning greenium as a potential tool for reducing sovereign borrowing costs while advancing climate finance objectives. At the same time, we caution against assuming uniform pricing benefits, thus stressing the need to consider market-specific dynamics.

LITERATURE REVIEW

Green bonds were first issued by the World Bank in 2008. These instruments are designed to finance projects that deliver environmental benefits, including renewable energy development, energy efficiency, waste management, and climate change adaptation. The issuance of green bonds generally adheres to the Green Bond Principles (GBP) developed by the International Capital Market Association (ICMA, 2021). Green sukuk, on the other hand, are Sharia-compliant financial instruments that comply with Islamic finance principles. Like green bonds, green sukuk can also be used to finance eco-friendly projects, however, they must also conform to Islamic legal prohibitions, including the avoidance of *riba* (interest), *gharar* (excessive uncertainty), and *maisir* (speculation).

The term “greenium”, a coined word combining “green” and “premium,” is frequently used in the context of green-labeled instruments, including green sukuk. Scholars and market analysts have proposed various definitions of the term. It generally refers to the lower investor returns expected than green bonds when compared to conventional bonds (Li et al., 2023; Zerbib, 2019). In other words, greenium denotes the price premium that investors are willing to pay for green instruments, resulting in lower yields due to the inverse relationship between bond price and yield.

This phenomenon reflects investors’ growing preference for environmentally responsible investments, which may provide non-financial utility such as alignment with sustainability goals or ESG mandates. Such behavior is typical in green bond markets, where proceeds finance environmentally beneficial projects such as renewable energy, energy efficiency, and waste management (Lau et al., 2022). In this context, Flammer (2021) finds that greenium can reduce issuers’ cost of capital. Similarly, in the case of green sukuk, greenium serves as an added incentive for Muslim-majority countries to leverage these instruments as part of broader sustainable finance strategies. The implication is that greenium is seen as an important predictor of a green market’s success in attracting environmentally conscious investments.

The existence of greenium can largely be attributed to investor motivations that differ from traditional financial logic. These motivations generally fall into three interrelated categories: environmental preferences, ESG mandates, and reputational incentives.

Many investors derive non-financial utility from allocating capital to environmentally responsible projects. These pro-social preferences reflect a willingness to accept lower financial returns in exchange for contributing to long-term environmental objectives, such as climate mitigation, renewable energy development, or biodiversity protection (Zerbib, 2019). This behavioral dimension of investing is in accordance with the impact-aligned utility concept, in which the satisfaction of supporting sustainability goals offsets the opportunity cost of reduced yields (Kölbel et al., 2020).

Institutional investors are increasingly influenced by formal ESG mandates stemming from internal sustainability frameworks or regulatory requirements, such as the EU Sustainable Finance Disclosure Regulation (SFDR). These mandates frequently require a minimum allocation to green or ESG-compliant assets (Flammer, 2021). Consequently, institutional demand for green bonds persists due to portfolio compliance requirements rather than merely maximizing returns, even if they offer lower yields (Gianfrate & Peri, 2019).

Participation in the green bond market may also serve as a signaling tool, allowing investors to bolster public trust. Financial institutions may use green investments to demonstrate ESG commitment, differentiate themselves in competitive markets, or reduce reputational risk associated with fossil-fuel exposure (Bachelet et al., 2019). In this context, the cost of lower yields is justified by the reputational capital accrued through alignment with environmental norms and investor expectations.

The empirical evidence on the existence of greenium, which is a yield discount that investors are willing to accept for green bonds, is mixed across the literature. Several studies report no consistent evidence of greenium. Ostlund & Le Coq (2021), for instance, find no statistically significant yield difference between green and conventional bonds after controlling for the key bond characteristics. Similarly, Larcker & Watts (2020) argue that any observed pricing difference disappears once methodological biases are addressed. Using a rigorous matched-pairs design that compares 640 green and non-green municipal bonds issued by the same issuers on the same day with similar terms, the authors find that the average yield difference is economically and statistically insignificant (0.45 bps). In fact, 85% of matched pairs show no pricing difference at all. Petrova & Fullbrunn (2021) also reveal that green bond premiums are negligible or inconsistent over time and across issuer types.

On the other hand, a growing body of literature supports the presence of greenium. Zerbib (2019) demonstrates a small but statistically significant negative yield premium for green bonds using a matched-

pairs method. On average, the premium is -2 basis points (bps) for the entire sample and for Euro and USD bonds separately. Gianfrate & Peri (2019) find that verified green bonds issued by supranational and corporate entities tend to receive lower yields, indicating investor preference for sustainability. Focusing on the European market from 2013 - 2017 and using a propensity score matching (PSM) approach in a sample of 121 green bonds, the study finds that green bonds are associated with significantly lower spreads at issuance, averaging about 18 basis points. In the secondary market, the green advantage remains, but its impact is smaller. Depending on the matching method and the observation period, green bonds exhibit spreads that are 5–13 bps lower than conventional bonds. Preclaw & Bakshi (2015) report pricing advantages in the U.S. green bond market, particularly for highly rated issuers. Hyun et al. (2020) mention that the greenium effect is stronger with a more established sustainable finance environment.

Bachelet et al. (2019) reveal that a greenium is present only when green bonds are certified and issued by credible institutions. Meanwhile, Kapraun et al. (2021) find that greenium varies significantly according to market liquidity, bond maturity, and regional regulations. More recently, Arat et al. (2023) observed that greenium not only exist under normal market conditions but also widened significantly amidst the economic shock of the COVID-19 pandemic.

The main reason for these inconsistent findings lies in the methodological challenge. Many inconsistencies in prior findings come from difficulties in selecting an appropriate benchmark for yield comparison since conventional bonds often differ in issuance date, tenor, coupon structure, or liquidity profile. As highlighted by De Vincentiis & Abis (2025), the significant challenge for scholars is in identifying, for each green bond, a truly comparable conventional counterpart. Differences in issuer creditworthiness, coupon rate, maturity, currency, and market liquidity can all influence yield spreads, making it nearly impossible to achieve a perfect match across all dimensions.

To overcome these limitations, the "twin bond" approach has emerged as a rigorous solution. This framework compares green and non-green bonds issued by the same entity under nearly identical conditions. The twin bond framework is therefore considered an ideal setting for analyzing greenium, as it allows researchers to isolate the genuine environmental "taste premium" built into investor preferences from other financial or cash-flow-related effects (D'Amico et al., 2025). However, the twin bond framework is limited in scope, as only Germany and Denmark have issued such pairs. Since true twin bonds are unavailable in most other markets, estimating greenium requires alternative approaches. Several rigorous financial methodologies have therefore been developed, including the regression-based models (Zerbib, 2019; Lau et al., 2022) and matching techniques, such as the Propensity Score Matching (PSM), as employed by Larcker & Watts (2020) and Gianfrate & Peri (2019), which aims to isolate the effect of "green label."

Several important factors have been revealed as the key to the existence or magnitude of greenium. External verification or third-party certification plays a significant role in enhancing investor confidence and may reduce information asymmetry (Bachelet et al., 2019; Gianfrate & Peri, 2019). Issuer type also matters as governments, supranational, and highly rated corporates tend to exhibit stronger greenium effects (Hyun et al., 2020; Preclaw & Bakshi, 2015). In addition, credit rating influences investor perception of risk and therefore affects yield spreads (Kapraun et al., 2021). Currency denomination and tenor have also been found to affect pricing outcomes, with euro-denominated and shorter-maturity green bonds often reflecting clearer pricing differences (Zerbib, 2019).

Despite the growing volume of literature, some research gaps remain. First, most studies focus on either developed or emerging markets in isolation, thus restricting cross-country comparisons. Meanwhile, integrating both market types is essential in assessing how institutional quality, regulatory maturity, and investor preferences shape green bond pricing (Kapraun et al., 2021). Second, more multi-method research is needed to integrate comprehensive case-level analysis with broader generalizations from empirical findings. This will enhance the understanding of context-specific factors while allowing for robust statistical inference.

METHODS

This study utilizes a twin bond comparative analysis, identified as optimal for greenium measurement in the literature (D'Amico et al., 2025). The key feature of this method is the selection of bond pairs that are uniform in maturity, credit rating, and structure, as this uniformity enables a precise isolation of the green label's effect on yields, a point emphasized by Pastor et al. (2022). The greenium is more easily observed in the context of twin bonds because the similarity in maturity and credit risk reduces potential confounding factors, thereby allowing for a more accurate assessment of the effect of the "green" designation on bond yields. However, the application of twin bond structures among sovereign issuers remains very limited. To date, only Germany and Denmark have consistently implemented the twin bond approach. Therefore, this study employs the twin bond issuances of Germany and Denmark for its comparative analysis. The concept of twin bonds was introduced by Germany in 2020. This concept is applied through the following approach: any new Green German Federal security will always be issued alongside an existing, conventional German

Federal security, with the same characteristics, i.e., the same maturity and coupons. Meanwhile, Denmark began to adopt the twin bond concept in 2022. All green government bonds issued by the Kingdom of Denmark is twin bonds. This implies that the green bonds will be issued with the same financial characteristics as one of the central government's existing conventional on-the-run bonds.

In this case study of twin bonds issued by Germany and Denmark, we compare the yields between green bonds and their conventional counterparts, disaggregated by tenor (i.e., 5-year, 6–10-year, and over 10-year). This analysis aims to investigate the presence of greenium in these twin bond issuances and to examine whether the bond maturity length is associated with the magnitude of greenium. Although the findings from this study on twin bonds reflect the characteristics of advanced European markets, they cannot be generalized to developing or Islamic countries due to differences market structures, regulatory environments, and investor preferences. There is limited implementation of the twin bond concept in green bond issuance at a broad level, and therefore, case studies, especially those using a twin bond technique, cannot be used to explain the broader phenomenon of greenium in green bond markets.

To capture the broader presence of greenium in green bond markets, many studies have examined greenium performance in green bond issuance. However, empirical evidence on greenium remains mixed and inconclusive, particularly across issuer types and financial systems. The contribution of this research is to fill the knowledge gap on greenium by using a new, diverse dataset, including Indonesian green sukuk. We adopt the Propensity Score Matching (PSM) method for broader cross-country analysis. The PSM is a statistical approach that matches two groups of data (treatment and control groups) based on their propensity scores to minimize selection bias and ensure a more accurate comparison of outcomes (Austin, 2011). It is used to compare the yields of green bonds and non-green bonds by ensuring that the matched control group shares similar characteristics with the treatment group. The key components of PSM include:

Data matching in PSM can be performed using several techniques, including nearest-neighbor matching and optimal matching. Nearest-neighbor matching ensures that each unit in the treatment group is matched to one or more units in the control group with similar characteristics, without optimizing match quality across the entire sample. In contrast, optimal matching aims to collectively optimize match quality across all treated units.

Although PSM generally reduces imbalances between treatment and control groups, the quality of matching must still be evaluated. If imbalance persists after matching, it reflects unsuccessful matching. Matching quality can be measured by three parameters: standardized mean difference (Std. Mean Diff), variance ratio (Var. Ratio), and empirical cumulative distribution functions mean (eCDFs Mean) (Stuart et al., 2011). Std. Mean Diff measures the mean difference of each covariate between groups, standardized by a common factor (typically the standard deviation) to ensure comparability. A threshold of 0.1 is commonly used to assess acceptable balance (Stuart et al., 2011). Meanwhile, the Var. Ratio compares the variances of covariates between groups, where a ratio close to 1 indicates good balance due to similar sample variances (Austin, 2009; Stuart et al., 2011). In addition, eCDFs Mean represents the average estimated cumulative distribution functions of the samples; values approaching 0 further confirm a balanced match (Dekking et al., 2006; Stuart et al., 2011; Stuart & Austin, 2015).

Once the PSM successfully establishes a balanced treatment and control group, the yield differential between green and non-green bonds can be estimated using the Average Treatment on the Treated (ATT). The ATT measures the average effect of a treatment on those factually receiving the treatment (Liu et al., 2024). The ATT, as applied in several studies, including Liu et al. (2024), is calculated as:

$$\tau_{ATT} = E\{Y(1) - Y(0) | Z = 1\} = E\{Y | Z = 1\} - E\{Y(0) | Z = 1\}$$

where:

- $E\{Y | Z = 1\}$ is the average outcome (in this case, yield at issuance) for green bonds/sukuk (treatment group),
- $E\{Y(0) | Z = 1\}$ is the counterfactual average yield at issuance of non-green bonds/sukuk with the closest characteristics to the treatment group as determined by the PSM.

This analysis draws on sovereign bond issuance data in USD from 2015 to Q3 2024 and corporate bond issuance data from 2023, both obtained from Bloomberg. The matching process is based on key characteristics, such as bond tenor, issuance date, and credit rating of the issuer.

RESULTS AND DISCUSSION

Twin bond studies, where one bond is labelled “green” and the other is conventional, allow for isolating the effect of the “green” label on yields. Karpf & Mandel (2017) highlight the same features of twins as maturity, rating, and structure, where, therefore, twin bonds provide the most valid measurement of greenium. Their approach helps to minimize confounding variables, making it easier to determine whether any yield difference is truly due to the green label rather than other factors such as credit risk or liquidity. Löffler et al. (2021) report that in the European market, particularly in Germany and Denmark, an average

greenium of **15–20 bps** emerges due to strong investor demands, indicating a willingness to pay more for bonds supporting sustainable projects.

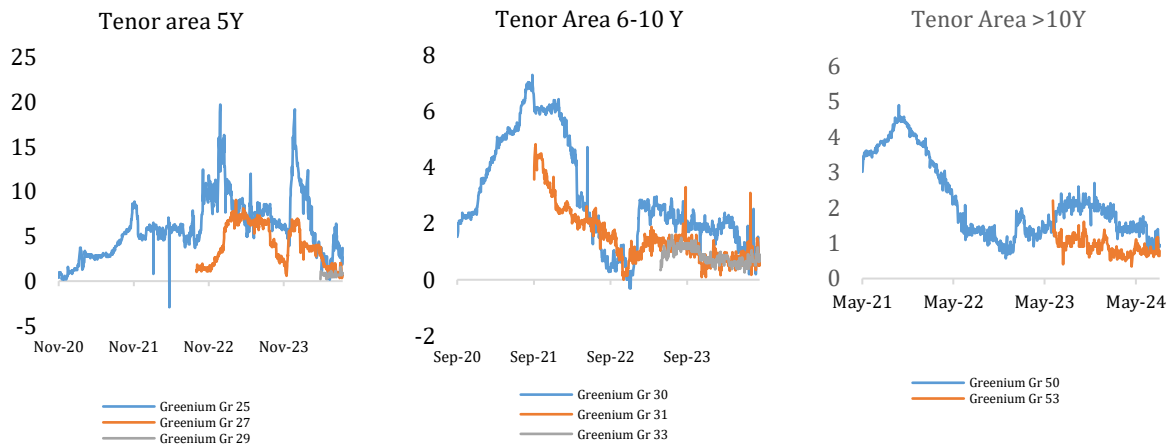
Table 1 Comparison Between Germany Conventional Bonds and Green Bonds

Item	Conventional	Green
A. General		
1. Issuer		German Federal Government
2. Investor actions (required)	Bond purchase	Bond purchase + declaration of allocation and impact reporting
3. Agreement with the Government	Agreement on interest and principal repayment	Agreement on interest and principal repayment + commitment to report on allocation and impact of green expenditures
4. Reporting	—	Reporting on allocation and impact of green expenditures
B. Similarities		
1. Tenor		10 years
2. Coupon		2.3%
3. Interest dates		15 February 2033
4. Future Contracts		Deliverable
C. Differences		
1. Issuance date	11 January 2023	25 April 2023
2. Outstanding size (as of 14 April 2024)	€38.25 billion	€7.25 billion
3. Price/Yield	99.77 / 2.329%	99.81 / 2.324%

Source: Processed by the authors

Table 1 compares the German government’s twin bonds. Both bonds share nearly identical characteristics, including maturity, coupon, payment dates, and interchangeability. These similarities make them ideal for analysing greenium. However, there are a few key differences: the green twin was issued on a different date and in a smaller volume, but it includes additional commitments such as allocation and environmental impact reporting. In contrast, the conventional twin lacks these sustainability elements. This structure enables an evaluation of the market’s added value for green bonds.

Figure 1 Comparison of Greenium in German Twin Bonds

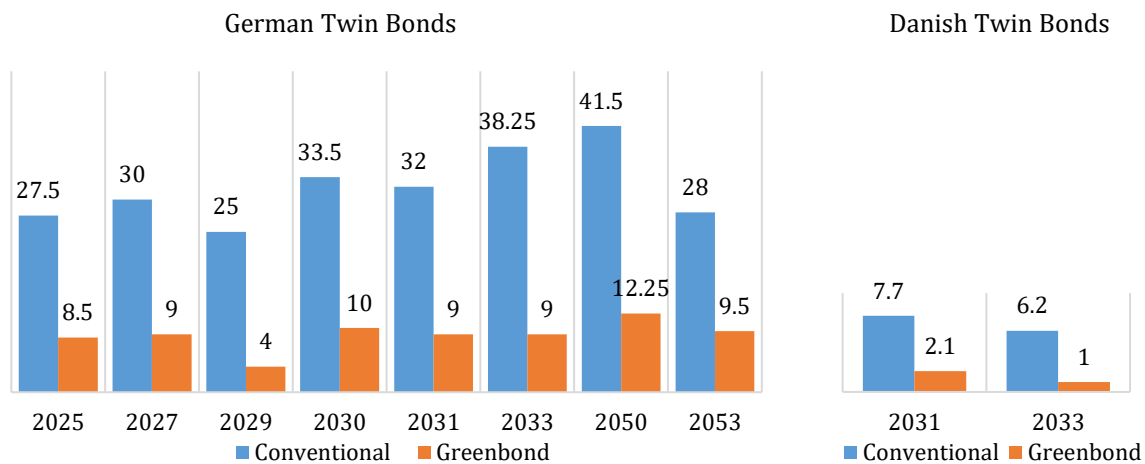


Source: Processed by the authors

Based on Figure 1, the size of greenium depends on the tenor of the bonds. In the short-term tenor (5Y area), the greenium tends to be higher, even reaching 20 basis points in December 2022. In the medium-term tenor (6–10 Y area), the greenium shows a more stable, moderate trend, with lower values than in the 5Y area. In this medium-term tenor, after increasing until early 2022, the greenium gradually and consistently declined, indicating that the market had started to balance its valuation between green and non-green bonds over the medium term. Conversely, in the long-term tenor (>10 years), the greenium appears much smaller, falling below 5 basis points. These findings reinforce the results of Pastor et al. (2022), who found that greenium tends to diminish for longer maturities due to uncertainty surrounding long-term sustainability projections.

Germany and Denmark are examples of countries that have issued twin bonds. Both nations have been pioneers in green bond issuance, with Germany among the largest markets for green bonds in Europe, while Denmark has also demonstrated a strong commitment to sustainability through significant green bond issuance.

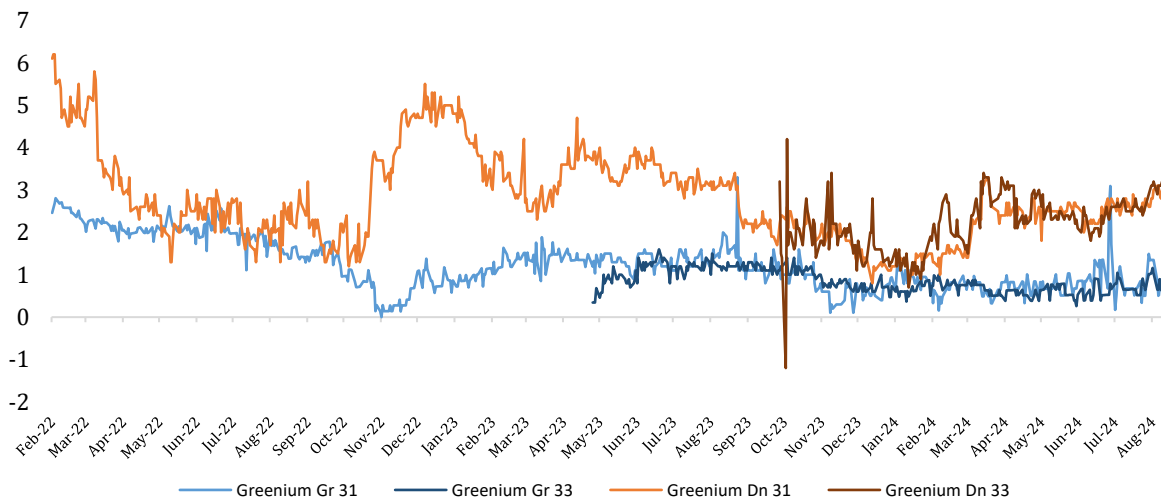
Figure 2 German vs Danish Twin Bonds Maturity Profile (in million EUR)



Source: Processed by the authors

Germany records a total issuance of €69.75 billion, spread across 8 series and carried out in 27 issuances. The issuance volume is evenly distributed across tenors from 2025 to 2053, with the portion of green bonds consistently smaller than that of conventional bonds. Meanwhile, Denmark records a total issuance of kr 23.98 billion (approximately €3.1 billion), comprising only 2 series and 11 issuances, all of which are concentrated in the 2031 and 2033 tenors.

Figure 3 Comparison of Greenium in German vs Danish Twin Bonds



Source: Processed by the authors

As shown in Figure 3, the comparison between the greenium of Germany and Denmark indicates that the greenium in Denmark’s green bonds is higher than that in Germany’s for bonds with equivalent maturities (2031 and 2033), with yield differences reaching 3–5 basis points, whereas Germany’s greenium remains around 1–3 basis points. This finding suggests that investors in Denmark are willing to accept lower returns for green bonds, thus reflecting a higher demand for green-labeled instruments in the country.

In this study, to assess the performance of greenium in global sovereign green bonds, data on USD-denominated sovereign bond issuances from 2015 to Q3 2024 were used, sourced from Bloomberg. Green bonds were matched with non-green bonds based on tenor, issuance date, and issuer rating.

In terms of covariate balance, the standardized mean differences (SMDs) range from 0.00 to 0.04, which remains well below the conventional threshold of 0.05. Similarly, the variance ratios are consistently close to 1, and the mean empirical cumulative distribution function (eCDF) differences are recorded at 0.00. These metrics collectively indicate a high degree of balance between the treatment and control groups. Accordingly, it can be inferred that the matching quality is robust across all applied methods, including nearest matching (with ratios of 1, 3, 5, and 8) and optimal matching. Overall, these results provide additional support for the suitability of using the Propensity Score Matching (PSM) technique in the subsequent estimation process.

Table 2 Matching Quality Results for Sovereign Issuers

Metric	Distance Value		Interpretation
	Method='nearest' (ratio 1,3,5,8)	Method="optimal"	
Std. Mean Diff.	0.00 - 0.04	0.00	<0.05 threshold → well balanced
Variance Ratio	1.08 - 1.10	1.01	≈1 → variance similarity
eCDF Mean	0.00	0.00	minimal distributional difference

Source: Processed by the authors

Table 3 ATT (Average Treatment on the Treated) Results for Sovereign Issuer

Matching Method	ATT (bps)	Finding
Method="nearest" (ratio 1,3,5,8)	-9 to -35	Greenium detected (strong)
method="optimal"	-19	

Source: Processed by the authors

To determine whether a greenium exists, as described in the methodology, this study uses the Average Treatment effect on the Treated (ATT) from the Propensity Score Matching (PSM) approach. ATT is obtained by comparing each treated unit with non-treated units with similar propensity scores, thereby ensuring a more balanced comparison between groups. If the ATT value is negative, it indicates that the green bond or Sukuk (treated) has an impact on lowering the yields, meaning that a greenium is detected, and vice versa. As shown in Table 2, the estimated ATT values are negative, indicating the presence of greenium for Sovereign issuers. The magnitude of greenium varies depending on the matching method employed, ranging from approximately 9 to 35 basis points. This finding is in accordance with that of Liu et al. (2024), who also report negative ATT values, indicating evidence of greenium, although the results vary significantly across different matching methods.

To measure greenium performance in global corporate green bond issuances, this study uses data on USD-denominated corporate bonds issued in 2023 from Bloomberg, with the following industry distribution in Table 4.

Table 4 Industry Distribution

Issuer Industry	Non-Green Bond	Green Bond	Total
Bank	390	26	416
Financial	335	9	344
Industrial	657	26	683
Special_Purpose	166	10	176
Supra_National	49	2	51
Utility_Elec	161	16	177
Total	1758	89	1847

Source: Processed by the authors

From the issuer industries listed above, a matching method was applied. The results show that for the Supra-National sector, the matching quality was insufficient, as indicated by a Standardized Mean Difference (SMD) exceeding the threshold; therefore, this sector was excluded from the nearest-neighbour analysis.

Table 5 ATT (Average Treatment on the Treated) Results for Corporate Issuer Industry

Industry	ATT (bps)		Finding
	Method="nearest" (ratio 1,3,5,8)	Method="optimal"	
Bank	-28 to -43	-42	Greenium detected (strong)
Financial	-17 to +10	-13	Greenium detected (mixed)
Industrial	-21 to +13	11	Greenium detected (mixed)
Special Purpose	-110 to -125	-110	Greenium detected (strong)
Utility (Electric)	-16 to +15		Greenium detected (mixed)
Supra-national	N/A	-15	Insufficient match quality

Source: Processed by the authors

The magnitude of greenium varies considerably across sectors. As shown in Table 5, the strongest greenium is observed in the Special Purpose sector, with the ATT values ranging from -125 to -110 basis points, indicating a substantial premium for green bonds. The Banking sector follows, showing consistently negative ATT estimates between -43 and -28 basis points under nearest-neighbor matching and -42 basis points under the optimal method, suggesting a strong and stable greenium effect. On the other hand, the Financial and Utility (Electric) sectors display mixed results as the ATT values range from -17 to +10 and -16 to +15 basis points, respectively. While most of the estimates are negative, the occasional positive values

indicate sensitivity to the matching ratio applied. The Industrial sector also exhibits a mixed pattern, with the ATT values fluctuating between -21 and +13 basis points, and a positive estimate (+11 bps) under the optimal matching method, implying that the greenium may exist under certain specifications. Finally, the Supra-national sector yields an ATT of -15 basis points; however, due to insufficient match quality, these results are not considered reliable for interpretation.

Empirical findings from the German and Danish bond markets confirm the presence of greenium across various maturities. As highlighted in the results section, in the German twin bond case, green bonds consistently had marginally lower yields than their non-green counterparts across all observed tenor segments, short (1–5 years), medium (6–10 years), and long (>10 years). This trend suggests the presence of greenium, since the twin bond design controls issuer and structural characteristics, thus isolating the effect of the green label.

Notably, the magnitude of greenium varies by bond tenor. In Germany's case, shorter-tenor bonds showed stronger yield differentials, while longer-tenor bonds showed smaller greenium effects. This tenor-dependent variation may reflect differences in investor preferences, risk appetites, or duration sensitivities, indicating that greenium is not uniformly distributed along the yield curve.

A cross-country comparison reveals that Denmark exhibited a larger greenium than Germany for bonds with similar tenors. This disparity may result from factors, including differing investor demand, policy environments, or market liquidity (Bachelet et al., 2019; Karpf & Mandel, 2017). Furthermore, Danish green bonds may benefit from a stronger domestic ESG investment culture or greater scarcity, both of which could contribute to a more pronounced greenium.

Despite their analytical clarity, twin bond studies have intrinsic limitations in terms of generalizability. The European sovereign bond markets, particularly Germany and Denmark, represent mature, high-transparency environments with active ESG (Environmental, Social, and Governance) investor bases and well-established verification processes among them. These conditions are not always replicable in emerging markets or in Islamic finance contexts, such as green sukuk issuances. Consequently, while the twin bond data provides strong evidence for the presence of greenium, they risk over-simplifying its prevalence or magnitude in markets with different structural characteristics.

Overall, the twin bond methodology confirms the presence of greenium in advanced economies while revealing important tenor- and country-level variations. However, caution should be exercised when extrapolating from all to other settings, thus reinforcing the importance of employing additional methods, including matching techniques, when assessing greenium across more diverse global settings.

In implementing PSM, we conducted separate analyses for sovereign and corporate issuers of both conventional bonds and sukuk to control for heterogeneity in issuer profiles and investor preferences. To ensure the reliability of the estimation, we assessed the quality of matches by using three widely accepted balance diagnostics: the standardized mean difference (Std. Mean Diff), the variance ratio (Var. Ratio), and the empirical cumulative distribution function (eCDF) mean difference. As shown in Table 1 (matching quality results), the matching procedure, applied across both nearest-neighbor algorithms (with matching ratios of 1, 3, 5, and 8) and optimal matching algorithms, produced high-quality matches.

Once confidence in the quality of matching was built, we proceeded to analyze the ATT results. In Table 2 (ATT results for sovereign bonds), the estimates for sovereign bonds and sukuk, across various nearest-neighbor ratios and the optimal matching algorithm, consistently produced negative ATT values. The consistency of negative ATT values across all methods supports the hypothesis that the green label contributes to a pricing advantage for sovereign issuers within the green finance market. These findings demonstrate that the presence and value of greenium are not consistent across sectors. The potential cost advantage of issuing green bonds seems to depend on the sector and the matching method used, which means that investors perceive sustainability differently across bond market segments.

A similar pattern was observed for corporate bonds and sukuk. As with sovereign instruments, the Propensity Score Matching (PSM) analysis for corporate issuances consistently yielded negative ATT values across most sectors and matching methods, indicating that green-labeled corporate bonds and sukuk were, on average, issued at lower yields than their conventional counterparts.

The strongest greenium effect was observed in the banking industry, with ATT values ranging from -28 to -43 basis points across all matching specifications. This consistent negative yield spread indicates an entrenched investor preference for green instruments in this area, due to institutional ESG policies and green credit standards for financial providers. Similarly, special-purpose entities and supranational issuers showed substantial negative ATT values, thus reinforcing the presence of greenium in sectors closely linked to public financing or development mandates.

Although the overall trend supports the existence of greenium in corporate space, the results also reveal notable variations across industries. For instance, in the industrial and utility-electric sectors, some ATT estimates were slightly positive (e.g., +13 bps and +15 bps), particularly under certain matching ratios.

This could be due to industry risk premiums, supply-demand imbalances, or lower investment confidence in green instruments in those markets. However, these exceptions are relatively limited and do not detract from the overarching conclusion.

This presence of greenium is consistent with previous studies by Baker et al. (2018) and Zerbib (2019), which report modest greenium values of approximately 6 and 2 basis points, respectively. Similarly, Ehlers & Packer (2017) and Preclaw & Bakshi (2015) find a greenium of 17 and 18 basis points, respectively, based on direct comparisons of credit spreads. However, several other studies by Larcker et al. (2020), Ostlund & Le Coq (2021), and Petrova & Fullbrunn (2021) reveal no significant evidence of greenium.

Meanwhile, some studies indicate that the presence of greenium is situational and driven by various factors. First, external green certification plays a critical role; studies by Bachelet et al. (2019); Fatica et al. (2021); and Hyun et al. (2020) find that greenium tends to increase when third-party verification is present. Second, issuer type does matter; Kapraun et al. (2021) show that national government issuers generally achieve better greenium than corporates, unless the corporates are certified green. Third, market conditions also influence greenium; studies by Arat et al. (2023) and Intonti et al. (2023) report increased greenium during periods of uncertainty, such as the COVID-19 pandemic, indicating that green bonds may be more resilient in volatile markets.

Taken together, the findings from both sovereign and corporate segments suggest that the green label is related to yield benefits at issuance, corroborating the greenium phenomenon among relatively heterogeneous issuers. However, the heterogeneity of effects across sectors also underscores the need for a nuanced understanding of how market structure, investor composition, and issuer characteristics shape the greenium phenomenon in different contexts.

The empirical results described in the preceding sections provide strong evidence of the presence of greenium in sovereign and corporate bond markets, including Islamic finance instruments such as sukuk. However, the observed heterogeneity in greenium magnitudes across issuer types, sectors, and methodologies warrants a cautious interpretation. Although the green label is typically linked with lower yields on issuance, the presence and size of greenium are not uniform and cannot be guaranteed for all issuers.

This variability highlights the need for policymakers, regulators, and issuers to avoid assuming greenium as an automatic or consistent cost advantage when designing green finance strategies. In some sectors, the green label may result in modest or negligible price benefits, especially where market awareness, ESG demands, or verification infrastructure are less developed. In other markets, such as in the banking and sovereign sectors, greenium can be observed more consistently as investors show faith in green label products, or they are subject to stronger sustainability requirements.

Ultimately, while the presence of greenium can serve as a market signal of investor commitment to sustainability, policy frameworks must be adapted to local market conditions to fully realize the benefits of green-labeled instruments. A “one-size-fits-all” approach may not suffice, and subtle solutions will be necessary to develop a green finance market that is open, credible, and efficient.

CONCLUSION

This study investigates the presence of greenium, a term referring to the yield discount associated with green-labeled financial instruments, to the extent to which investors are willing to accept lower returns in exchange for supporting environmentally sustainable projects. In doing so, it analyzes whether the emergence of greenium is uniform for issuers of different types, jurisdictions, and financial tools. Against a background of conflicting and contradictory empirical evidence in the literature, this study responds to growing academic and policy interest in whether green labeling translates into measurable financing advantages amid the rapid expansion of sustainable finance instruments. To enrich the discussion, this study analyzes a more current and diverse dataset, including green sukuk. In addition, it employs twin bond analysis and Propensity Score Matching (PSM) to provide a broader perspective on global trends with greater generalizability. The findings indicate that greenium can be observed across various issuer types, markets, and instruments, including green sukuk. The results of twin bond analysis show that green-labeled bonds tend to have lower yields than similar non-green bonds at different maturities. This reflects a potential pricing advantage attributable to the green label under controlled conditions. Similarly, the application of Propensity Score Matching (PSM) to a broader cross-country dataset supports the presence of greenium in many cases, showing that green-labeled sovereign bonds, sukuk, and corporate bonds often achieve lower yields at issuance. However, the analysis also reveals that the magnitude and presence of greenium are not uniform across all market conditions, issuer types, or sectors.

These results suggest that while greenium has the potential to reduce financing costs for issuers, it should not be assumed as a guaranteed outcome in all circumstances. Issuers and policymakers should carefully anticipate the emergence of greenium and plan for green issuance accordingly so that the full advantages of sustainable finance instruments can be realized. These conclusions are nonetheless subject

to several limitations that also define an agenda for future research. First, although the Twin Bond Comparison and PSM techniques are well tested, the resulting models rely on observed bond characteristics and cannot fully account for unobserved investor behavior, particularly ESG preferences. Future studies could incorporate more granular data on investor mandates, fund flows, or portfolio ESG ratings to capture how particular type of investors contribute to the greenium effect. Second, this study provides a static, issuance-period view of greenium, which may not be constant over time and can be influenced by macroeconomic conditions such as interest rate cycles, climate-related policy changes, or financial uncertainty, hence dynamic analysis through time-series or panel data techniques is warranted. Finally, while this paper documents the presence of greenium, it does not formally test its statistical significance or economic importance in terms of issuer cost saving. Addressing these gaps will provide clearer insight into whether greenium reflects a tangible financing advantage or is shaped by specific market condition.

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