Greenium and Its Determinants at Various Phases of Life Cycle of European Green Bond Market

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Abstract. The paper explores the evolution of greenium in European corporate primary green bond markets from 2013 to 2023. It introduces a new perspective by studying the phases of the life cycle of this market. The sample included 22,259 bond issues from 23 European countries, with 1,040 being green bonds. During this period the green bond yield discount was around 15 bps for banks and 40 bps for non-financial companies. Our findings revealed significant dependence on the size of the greenium on the phases of the lifecycle of the market. The most significant shift was observed after 2022 when the yield discount for green bonds changed by the premium to conventional bond yields of 36 bps. For non-financial corporates the previous 70 bps discount has been replaced by a premium of up to 27 bps compared to conventional bonds. Issuers in "clean" industries saw their yields increase by 43 basis points compared to conventional bonds. The result reflected energy crisis in Europe which is accompanies by tighter monetary policy, and reduction of corporate profits. The findings are crucial for researchers, central banks, and authorities responsible for financial stability and sustainable development.

Key words: Greenium; European bond market; Green bonds; Sustainable development; Risk controlling.

1 Introduction

In recent years, global investors have shown increased interest in financial instruments linked to sustainable development, particularly green bonds. According to some academics and practitioners, green bonds can act as a hedge against tail risks in financial markets [1]. The Climate Bond Initiative's analysis shows that the global annual volume of green bonds issued in 2023 totalled $587 billion, exceeding half a trillion for the third consecutive year [2]. One of the important and widely debated features of the green bond market is the existence of

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green premium (or the "greenium"). This is the magnitude by which the yield of a green bond is lower than an otherwise identical regular bond of the same credit quality [3]. The greenium is considered by many academics and practitioners as a central impact measure for ESG investors [4]. Many researchers found the greenium in both the primary and secondary debt markets, albeit no consensus has been reached. The magnitude of greenium varied from 0.1 basis points (bps) to 70 bps on average and results depends on the sample geography and timing [5].

However, recent regulatory and practical studies revealed the significant diminishing or even evaporation of greenium in the last couple of years. They argued that at times of increased risks in the bond markets and in conditions of market saturation investors are not willing to forgo returns on fixed income instruments to support the ESG transition. For example, the recent research done by European Securities and Market Authority argued that even though that ESG bond investors benefited from greenium before 2021, there is the systematic absence of greenium after 2021 [6].

The goal of our study is to address the above-mentioned controversies and to assess the magnitude and the drivers of greenium at various stage of life cycle of European green bond market. The object of the study were green and conventional bonds issued between 2013-2023. The scientific novelty of the study lies in exploration of the influence of the dynamics of the size of the green bond market, the industry affiliation of issuers, as well as changes in monetary policy on the value of greenium. We provided the evidence that the magnitude of greenium is heterogeneous in time and reduced because of green bond market saturation, rising interest rates, rising geopolitical risks and a general decline in interest in the sustainable development agenda amid fears of greenwashing. We also investigated how the COVID-19 pandemic impacted the magnitude of greenium across "clean" and "dirty" industries. Our findings can be relevant to financial executives and risk controllers of financial and non-financial organizations as a consideration in forming a strategy to raise funds for projects in sustainable development.

2 Materials and Methods

The paper focused on examining the green bond market and its determinants at different stages in the primary bond market in Europe. The study looked at both green and conventional bonds issued from 2013 to 2023. To achieve the study's objectives, several steps were taken. Firstly, an analysis of the developments in the green bond primary market in European countries was conducted to identify its different stages. Secondly, we will examine the potential of the green bonds market in Central Asia and Uzbekistan and discuss how the emergence of greenium can contribute to its growth. Thirdly, a literature review was performed to categorize theories and empirical findings on the topic and to identify any research gaps. Fourthly, hypotheses were formulated, and a research methodology was chosen to collect the necessary data. Finally, the results were obtained, discussed, and potential directions for future research were identified.

2.1 Green bond markets in Central Asia: trends and challenges

The green bond market in Central Asia holds significant potential for expansion. International agencies report a 200-400% growth in the markets of the Caucasus, Central Asia, and the Middle East over recent years. Kazakhstan leads in green investments in the region, with green bonds and loans totalling approximately KZT 150.2 billion issued over the past 3.5 years. The main drivers of this growth are international and local financial institutions, as well as energy companies. Although the green bond market in Uzbekistan is still in its early stages, its growth is integral to the country's overall financial strategy. The government aims

to achieve a 35% reduction in greenhouse gas emissions per unit of GDP compared to 2010 levels by 2030. This objective will be met through the accelerated integration of renewable energy sources and the electrification of transportation networks.

It has been observed that Uzbekistan has achieved a 14% reduction in greenhouse gas emissions per unit of production. In order to sustain this progress, the country should seek investment from banks and private investors to support sustainable development projects. By issuing green bonds, Uzbekistan can secure funding for initiatives that promote environmental sustainability and contribute to the country's long-term economic growth. In 2023, Uzbekistan successfully issued international sovereign bonds amounting to 4.25 trillion soums (approximately $335 million) at a rate of 16.25%, which was lower than the rate for conventional bonds, around 17.5%, due to high demand. Additionally, SanoatQurilishBank issued corporate green bonds worth $100 million in the same year.

The primary challenge of the local green bond market is the limited participation of domestic investors. To address this, it is crucial to create incentives for domestic investors to invest in green bonds, such as easing banks' requirements for calculating capital reserves and providing tax benefits for both the issuers and buyers of green bonds. These measures will help to create a favourable environment for the growth of the green bond market. Investors pay close attention to traditional credit risks when evaluating bonds, as demonstrated in this paper. Therefore, significant effort is required to create a sustainable market for green bonds as well to create the conditions of emerging of stable greenium. Developing infrastructure for sukuk (Islamic bonds) green instruments can act as a significant incentive for market growth. The main goal is to encourage both private and state-owned companies in Uzbekistan to issue green bonds. To achieve this, it is necessary to create a large number of cost-effective projects in the field of sustainable development. The lessons learned in Europe can provide a solid foundation for Uzbekistan's green financial markets. We believe that the development of the green finance market in Uzbekistan would accelerate if we could attract investors from Eurasian Economic Union (EAEU) countries. Additionally, actively harmonizing infrastructure and green taxonomies between EAEU countries is crucial. It is also necessary to establish mutual recognition of ESG ratings and second-party opinions between EAEU countries, which would help to boost market growth and strengthen the local base of investors and issuers.

2.2 European green bond market and its lifecycle

According to the Climate Bonds Initiative report [2], the total volume of issuance of sustainable development instruments worldwide in 2023 was approximately $870 billion, representing an increase of about 3% from the previous year. However, despite this growth, the market continues to show signs of maturity, as the maximum output of $1.1 trillion in 2021 has yet to be exceeded. In fact, in 2022, the global output of green bonds decreased by 24%, to $858.5 billion, due to the aggravation of geopolitical tensions and rising interest rates, which have significantly ‘dented’ the interest of issuers in new borrowing, including for sustainable development purposes. The European market for these instruments remains of the greatest interest to investors, as it accounts for approximately 50% of the global total. Green bonds continue to account for the vast majority of new sustainable development instruments issued. Their share is slightly less than 70%. The growth of the green bond market can be attributed to the release of the Green Bond Principles in 2014 by the International Capital Market Association (ICMA) [7]. Additionally, another investor-focused non-profit organization, the Climate Bond Initiative (CBI), issued its standards, which establish the requirements for green bond certification [2, 8]. These standards allow investors, governments, and other stakeholders to identify and prioritize low-carbon and climate-resilient investments, helping to avoid "greenwashing."

European markets are leading in terms of green financial instruments, with the volume of green bond issuance reaching approximately $310 billion; an increase of 23% compared to the previous year (Fig. 1). This volume has set a record and exceeded that of 2021, which was $307 billion. European markets will likely remain the largest in this field, supported by projects under the European Green Deal, continued transition to renewable energy, and efforts to achieve carbon neutrality by 2050. Additionally, the development of the green bond market will be facilitated by strong corporate planning for the transition, the inclusion of carbon transition requirements in government regulations, and the full implementation of carbon border adjustments (CBAM). Moreover, the EU and other green markets differ in terms of instruments, liquidity, taxonomies, and disclosure framework. European investors tend to be more stringent compared to their other counterparts when it comes to green investing. Research also show that the dynamics of demand and supply can be different and lowly correlated, affecting green bond prices and greenium [2]. Therefore, studying greenium in individual European country markets is valuable.

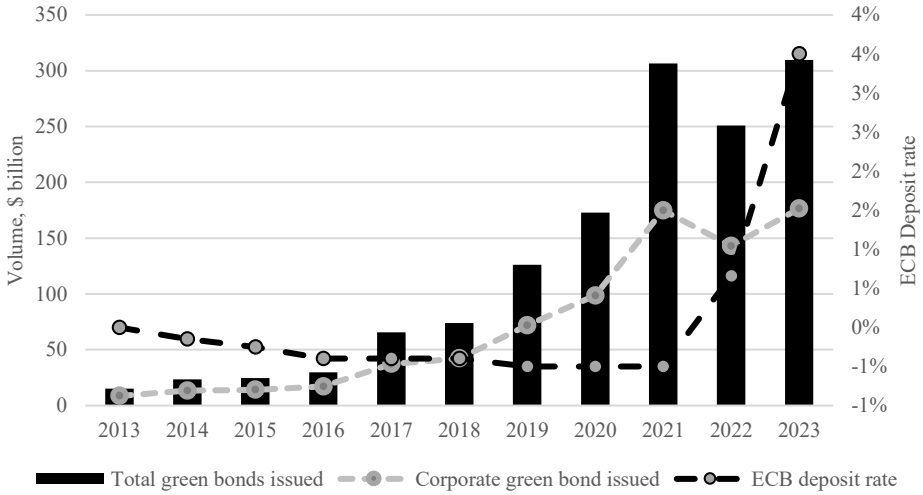

Fig. 1. European green bond market.
Source: Bloomberg, Climate Bond Initiative.

The analysis of Fig. 1 helps us to distinguish the several phases of lifecycle in European green bond markets (Table 1).

Table 1. Phases of lifecycle of green bond markets.

Timeframe	Phases	Explanation
2013–2015	Youth	This period represents the initial phase of green bond market development in our study, characterized by relatively low supply and growing demand. During this time, green bonds were just beginning to establish themselves as a capital-raising tool for environmental projects but had not yet gained widespread adoption.
2016–2019	Initial growth	During this period, there was an increase in the supply and development of green market infrastructure and regulation. The investor base grew as taxonomies and green instruments were developed and issued by sovereign and supranational institutes. Green bonds were also used as a marketing tool to show an intention to integrate a sustainability agenda. However, demand was limited due to the risks of greenwashing and the lack of standardization and regulation.

Timeframe	Phases	Explanation
2020-2021	Fast growth amid COVID-19 pandemic	The COVID-19 crisis impacted the real economy and financial markets, leading to increased demand for liquidity and concerns about the global economic outlook. Despite initial setbacks, the green bond market saw a strong recovery in 2020 and 2021, driven by government support, low interest rates, and growing interest in green projects. Demand for green bonds increased due to the growing standardization of financial instruments and the improvement of infrastructure, making them an effective means of financing projects in renewable energy, energy efficiency, and other environmental initiatives.
2022–2023	Post-COVID shake-out	The current period is characterized by increased geopolitical risks, disruptions in traditional logistics chains, and rising inflation. This has led to higher interest rates and a realization that short-term profits from green projects are not feasible, requiring larger, long-term investments. As a result, investor interest in green instruments has decreased, creating a balance between supply and demand in this market. Simultaneously, regulations for green bond issuances have matured, with stricter requirements and priorities for green financing shifting toward clean transport, energy efficiency, and adaptation in the traditional energy sector. If interest rates decrease and European standards for green financial instruments are introduced in 2025, the green market may experience rapid growth between 2025 and 2027.

Source: developed by authors.

The green bond market is influenced by specific factors during each phase of its life cycle. These factors affect the availability, sustainability, and size of greenium in the market. Academic and practical research on green bonds provides valuable conclusions on this topic.

2.3 Theories around greenium: A literature review

The concept of the green premium, also known as ‘greenium’, refers to the situation in which green bonds are traded at a premium for the issuer (and a discount for the investor) compared to traditional bonds [5]. The literature on the impact of a bond's green status on its prices is still developing but has been rapidly growing. Some academics and practitioners believe that the greenium could play a significant role in reallocating capital from green firms to "brown" firms. The greenium leads to a reduction in the cost of capital for environmentally friendly companies and an increase for polluting firms, as investors in green bonds are willing to accept lower yields in support of green companies [3-5]. The effectiveness of this reallocation mechanism largely depends on the size of the greenium. A larger greenium encourages more issuance of green bonds, which supports the sustainability agenda. However, critics argue that structurally, green bonds are similar to conventional debt instruments and should be priced equally if they have the same credit quality. They see the greenium as primarily a marketing tool and a price anomaly rather than a distinctive feature of sustainable financial instruments [9].

The literature review uncovered significant variations in the extent and characteristics of the greenium. MacAskill's findings indicated that the greenium was observed in 56% of primary market studies and 70% of secondary market studies, particularly for government or supranational institute-issued green bonds, those of investment grade, or those that adhere to defined green bond governance and reporting procedures [9]. Similarly, Cortellini and Panetta reported that the greenium was observed in 40% of primary market studies and 64%

of secondary market studies, with evidence of its existence being more contentious in primary than in secondary markets [5]. The size of the green premium largely depends on sample timing, sample size, market geography, and market type, as well as the chosen research method [5, 9].

Many research studies utilize either ordinary least squares (OLS) regression or generalized least squares (GLS) regression when analysing time series data. This approach offers the benefit of identifying the presence of the green premium and determining the factors influencing yields in a specific market. However, a drawback of this model is the challenge of accurately matching conventional and green bonds based on criteria such as amount, maturity, rating, coupon, or currency. In cross-country environment the difference between the yields of green bonds and Treasury bonds have been shown as comparable in terms of maturity and the country in which the issue was used as a green premium [10, 11]. Some papers, to overcome the difficulty of matching maturity and cash flow of various bonds defined "greenium" as an option-adjusted spread [12, 13]. The matching approach, utilized in other papers, involves the selection of bond issues that are identical in terms [14-16]. It offers the advantage of isolating the greenium by controlling other characteristics of the bonds.

The outcome in the literature depends on the research methodology used, the timing of the sample and the market (both in terms of geography and type of bonds). For example, Karpf and Mandel studied the US municipal bond market and discovered a positive difference in the yield of green bonds compared to traditional bonds [17]. However, Baker et al. [18] found a completely different result, with the yield on green bonds being approximately 6 basis points lower than that of regular bonds. They attributed this difference to the significant role taxes play in the US municipal bond market. Zerbib [14] utilized a matching method for green and traditional bonds on the secondary financial sector market and discovered a small but significant greenium of 2 bps on average.

Fatica et al. [10] found that the presence of a greenium was a characteristic of bonds issued by non-financial organizations and supranational institutions. They noted that despite financial institutions being the most active participants in the green bond market, investors were not willing to sacrifice returns for issuers. This was attributed to the challenge for financial institutions to connect financing to a specific project compared to non-financial organizations.

Several studies have highlighted the growing presence of greenium in the latter part of the 2010s. Löffler et al. [15] found that the emergence of greenium in the secondary market was evident from 2018 and 2019, with a noticeable increase during the COVID-19 pandemic. It was noted that the market type is a significant factor. Ivashkovskaya and Mikhailova [12] revealed that investors were willing to accept lower returns on green bonds only in developed countries. Conversely, green bonds encounter higher financing costs in emerging markets, especially when issued in national currencies. Specifically for the European corporate green market, Intonti et al. [19] discovered that the size of greenium was about 6 bps, which was lower than that of government bonds, based on the sample obtained between 2017 and 2023.

Recent regulatory and academic studies have shown that the size of the greenium is not consistent over time and likely depends on the stages of the lifecycles of the sustainable debt market (as mentioned in paragraph 1.2) [6, 19]. For example, ESMA's research paper examined the presence of greenium in the broader ESG financial instruments markets in Europe. The sample consisted of 8696 ESG bonds from the EU and the United Kingdom outstanding in 2023 (including those issued by sovereigns and supranationals). The findings did not confirm the systematic presence of greenium in 2023; however, the authors argued that ESG bond issuers had previously benefited from the yield discount [6].

To conclude, the literature review indicates a lack of consensus on the existence and size of greenium in the European green bond market. Additionally, greenium was less frequently

detected in later stages of the bond life cycle. We propose examining greenium size dynamics by life cycle stage for insight. Although limited, this topic presents significant research opportunity.

2.4 The hypotheses

To achieve the goals of the paper we tested the following hypotheses:

Hypothesis 1 (H1). In the EU, from 2013 to 2023, issuers of green bonds benefited from a yield discount known as "greenium". The hypothesis should align with the findings outlined in references [3, 9, 10, 18] concerning the existence of greenium in the European green bond market. Furthermore, the magnitude of greenium in these studies ranged from 4 to 70 basis points.

Hypothesis 2 (H2). In the specified period, the value of greenium in the EU sustainable debt market for financial institutions was lower than for non-financial companies. The argument is supported by Fatica et al.'s findings, suggesting that investors may struggle to connect a financial institution's green bond with specific green projects, unlike with non-financial companies. In the latter case, investors can clearly track the use of green bond funds for sustainable development projects [10].

Hypothesis 3 (H3). The issuers in "dirty" industries enjoyed a higher greenium than those in "clean" industries. Research suggests that companies in "dirty" industries tend to have a higher green premium compared to those in "clean" industries. Despite initial assumptions that they would struggle to obtain capital through green bonds, embracing sustainable technologies and mitigating environmental impact can enhance their investment appeal and financial performance [5].

Hypothesis 4 (H4). In high-risk environments, there is a lack of systematic presence of greenium. This hypothesis aligns with the literature's conclusion that greenium significantly decreases during times of high risk, such as ongoing energy crises, high inflation, and increased geopolitical tensions in the EU.

2.5 The model and the data

We are adopting the approach put forward by Baker et al. [4], which was also employed by Fatica et al. [10]. Baker et al. [18] formulated a pricing model for financial assets driven by non-pecuniary client motivations, building upon the groundwork laid by Fama and French. The model's functional form is as follows.

$$Yield_{b,i,t,c} = \beta_1 Green_b + \beta_2 X_b + \beta_3 Z_c + \alpha_i + \gamma_t + \varepsilon_{b.i,t,c} \qquad (1)$$

The dependent variable, *Yield*, represents the offering yield of bond b, issued by issuer i, at the time of issue t, in country c. A crucial Boolean variable in our research is "*Green*", where 1 indicates that the bond is green and 0 otherwise. We will use the value of coefficient β_1 to measure the magnitude of the greenium, specifically indicating how many basic points the yield of a green bond is higher or lower compared to a conventional bond. The vector X represents the terms of the bond that may influence its yield:

Callable is the variable which indicates whether the bond is callable, with 1 for yes and 0 for otherwise;

Bond size is the categorial fixed effect variable which controls for the bond size and reflects the relative decile of the instrument's size in the sample;

Currency is the fixed effect variable, which reflects one the of the 34 currencies of issued bonds;

Maturity is the variable which is coded as "1" for short-term bonds (with maturities of than five years); as "2" for the medium-term bonds (with maturities between 5 and 10 years); and "3" for the long-maturity bonds (with maturities of more than 10 years);

Rating – the variable, corresponds to the minimum credit rating of the bond assigned by the international rating agencies (Fitch, S&P and Moody's). The rating is coded from 1 to 20 where "1" corresponds to AAA(Aaa); "2" corresponds to AA+(Aa1) or "21" corresponds to Ca (CC);

Maturity x Rating x Time is the complex variable which captures a significant part of the yields [10, 18];

γ_t captures time fixed effects which represent the month in which the bond was issued;

α_i is the variable which captures the fixed effects of issuer;

Z_c is reflects the value of policy interest rate of country of bond issuance;

ε_{bitc} is the error term which is clustered at the issuer level. This ensures robust standard errors, guarding against biased inference due to correlated residuals within groups of bonds issued by the same entity.

The primary data sources were Bloomberg, Refinitiv Eikon and Cbonds databases. The study focused on the primary bond market in European countries, specifically looking at investor demand for green bonds. We were only including traditional direct issuance bonds and excluding securitized bonds to narrow the focus. The study focused on bonds issued between 2013 and 2023 in the primary bond market. This market directly reflects investor demand and their willingness to pay a premium for green bonds.

The research focused on European countries and included 22,259 bond issues after removing outliers. Of these, 1,040 were identified as green. The sample covered 24 European countries, with Germany representing 53%, followed by France with 12%, and the United Kingdom with 8%. The remaining countries collectively accounted for 27% of the sample, including Austria, Belgium, Hungary, Denmark, Ireland, Iceland, Spain, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Finland, Czech Republic, Switzerland, and Sweden. The study only included corporate bonds, excluding government, municipal, and supranational issuers. This decision was made to focus on examining bond yields for sectors considered more polluting versus those that are not. The distribution of green bonds in the sample was as follows: Germany issued 44% of the green bonds, followed by France with 15%, and the Netherlands with 9%. The remaining countries collectively accounted for 32% of the green bond issuance. Banking sector represented around 65% of green bonds in the sample and 85% of conventional bonds in the sample. The descriptive statistics of the sample is presented in Tables 2 and 3.

Table 2. Average yields of bonds in the sample.

Type of bonds	Green			Conventional		
Issuers	Banks	Corporate	Average	Banks	Corporate	Average
Average yield (%)	1.585	2.453	1.868	1.880	2.871	2.029

Source: Cbonds.

Table 3. Descriptive statistics of variables in the model (1).

Variable	Average	St. Deviation	Minimum	Maximum
Yield	2.021	1.831	0.010	20.000
Green	0.047	0.211	0	1
Z (Policy Rate)	0.676	1.443	-0.750	13.000
Callable	0.159	0.366	0	1
Maturity	2.032	0.748	1	3
Time	6.379	3.433	1	12
Rating	4.882	3.203	1	21

Variable	Average	St. Deviation	Minimum	Maximum
Currency	13.682	9.636	1	39
Bond size	5.840	2.801	1	10

Source: Cbonds, Bloomberg, Eikon Refinitiv.

Lastly, to distinguish between “dirty and “clean” industries (more polluting and less polluting industries) we used ESG Risk Atlas developed by S&P. Their classification system divides all industries into 6 groups based on their level of ESG exposure. According to the atlas, banking, telecommunications, and homebuilding development are classified as clean, while oil and gas, chemicals, and metals and mining are classified as "dirty". Before finalizing the choice of variables, we assessed the correlation between the independent variables and found no significant paired correlations. Given the heteroscedasticity in the data, we also used a robust option to estimate standard errors in the regression.

3 Results and Discussion

3.1 Testing the hypotheses H1 and H2

The results of testing of hypotheses H1 and H2 are presented in Table 4.

Table 4. The results of testing of H1 and H2.

Independent variables	Entire sample	Financial institutions	Non-financial companies
Green	-0.2043*** (0.0558)	-0.1574* (0.0762)	-0.3959*** (0.0825)
Policy rate	0.7321*** (0.0187)	0.7352*** (0.0200)	0.7092*** (0.0220)
Callable	-0.0270 (0.0350)	0.0178 (0.0433)	-0.1892** (0.0581)
Fixed effects:			
Issuer	Yes	Yes	Yes
Maturity x Rating x Time	Yes	Yes	Yes
Currency	Yes	Yes	Yes
Bond size	Yes	Yes	Yes
N of Obs	22259	18728	3531
R2	0.7940	0.7725	0.8732
F-	156.85***	141.48***	182.48***

Note: *, **, *** is significance of metrics at 10%, 5% and 1%, robust standard errors are shown in parentheses.
Source: calculated by the authors.

In Table 4, the coefficient for the ‘green’ variable is shown to be negative and statistically significant at the 1% level. This indicates that green bonds have a negative premium of around 20 basis points. Therefore, hypothesis H1 is supported. These results and the magnitude of the greenium align with the findings of Loffler et al. or Ivashkovskaya et al. [12]. Also, the obtained greenium value is very close to the result of Fatica et al. [10]. The estimated difference in yield between green and conventional bonds is approximately 10%.

Table 4 shows that the greenium was higher for bonds issued by non-financial companies compared to those issued by financial institutions, supporting hypothesis H2. The yield gap between green and conventional bonds issued by non-financial companies was approximately 14%, while for bonds issued by banks, this gap was only about 9%.

This difference may be due to the easier tracking of funds from non-financial companies for specific sustainable development projects. Fatica et al. [10] argued that funding obtained from green bonds in financial institutions could only be traced back to a portfolio of green

projects, increasing the likelihood of greenwashing. Conversely, our results show a statistically significant premium at the 10% level in green bonds issued by banks, indicating that investors see these bonds as a signal of reduced financing for environmentally harmful projects. This contrasts with the findings of Fatica et al., who found no significant premium at the any level of significance for green bonds issued by banks.

The model is specified correctly as it shows a positive and significant coefficient for the policy rate, supporting the idea that tightening monetary policy increases yields across all debt instruments [6]. The significance of fixed effects variables aligns with the findings of Baker et al. [18] and Fatica et al. [10], indicating that conventional and green bond pricing depends on similar fundamental risk factors, such as issuer creditworthiness, issuance currency strength, bond size, and time to maturity, rather than the bond's green status [6]. The statistical significance of the coefficient for the variable "Callable" differs for non-financial companies and banks. This difference can be explained by the fact that banks have higher ratings in the investment category compared to non-financial companies. Therefore, the refinancing risks for banks are significantly lower than those of non-financial companies.

3.2 Testing the hypothesis H3

The results of testing of hypothesis H3 are presented in Table 5.

Table 5. The results of testing of hypothesis H3.

Independent variables	'Clean' industries	'Dirty' industries	'Clean' industries excluding financial institutions
Green	-0.1528* (0.0736)	-0.5574*** (0.1136)	-0.2449 (0.1779)
Policy rate	0.7364*** (0.0196)	0.7014*** (0.0262)	0.7557*** (0.0454)
Callable	-0.0062 (0.0389)	-0.0942 (0.0814)	-0.2154* (0.0896)
Fixed effects:			
Issuer	Yes	Yes	Yes
Maturity x Rating x Time	Yes	Yes	Yes
Currency	Yes	Yes	Yes
Bond size	Yes	Yes	Yes
N of Obs	20,185	2,026	1,457
R2	0.79058	0.86326	0.92916
F-	101.85***	131.48***	232.48***

Note: *, **, *** is significance of metrics at 10%, 5% and 1%, robust standard errors are shown in parentheses.
Source: calculated by authors.

In Table 5, the coefficients for the Greenium variable are found to be statistically significant at the 1% and 10% levels for both 'dirty' and 'clean' industries (including banks). However, this ratio is statistically insignificant for the sample of companies from 'clean' industries excluding financial institutions. These results provide support for the H3 hypothesis. The absence of a statistically significant greenium for non-financial companies in 'clean' industries may indicate a low evaluation by green debt investors of the effectiveness of green investments in these industries, as well as significant concerns about greenwashing. Conversely, a statistically significant and substantial greenium in 'dirty' industries may suggest an increased importance of green projects in these industries for investors, reflecting their confidence in companies' ability to significantly reduce environmental pollution through such projects [6].

3.3 Testing the hypothesis H4

The results of testing of hypothesis H4 are presented in Tables 6 and 7.

Table 6. The results of testing of hypothesis H4**.**

Independent variables	The entire sample
Greenium by phases of the life cycle	
Green x 2013-2015	-0.3383* (0.1699)
Green x 2016-2019	-0.4190*** (0.0821)
Green x 2020-2021	-0.3920*** (0.0641)
Green x 2022-2023	0.3554*** (0.0970)
Control variables	
Policy rate	0.7250*** (0.0193)
Callable	-0.0357 (0.0350)
Fixed effects	
Issuer	Yes
Maturity x Rating x Time	Yes
Currency	Yes
Bond size	Yes
N of Obs	22259
R2	0.79479
F-	109.75***

Note: *, **, *** is significance of metrics at 10%, 5% and 1%, robust standard errors are shown in parentheses.
Source: calculated by authors.

In Table 6, the data demonstrates the discernible dynamics of the green bond market across its various life cycle phases. During the initial phase from 2013 to 2015, a greenium of 34 basis points was observed, with the coefficient being statistically significant at the 10% level. Subsequently, during the initial growth phase spanning 2016 to 2019, the greenium value increased to 42 basis points. This increase is attributed to the excess demand for these instruments outstripping the available supply.

During the fast growth phase of 2020-2021 despite the COVID-19 pandemic, the value of the greenium decreased only slightly compared to the previous phase of the life cycle. This was due to two opposing forces. Investors focused more on short-term risks, primarily credit and interest rate risks, while viewing green bonds as less volatile and a form of natural hedge [20]. There was also increased interest in green projects to mitigate long-term environmental risks. All these factors prevented the greenium from growing or shrinking. However, our findings differ from those of Intonti et al. [19] and Arat et al. [21], who argued that the negative impact of COVID-19 increases the greenium.

It is worth noting that during the post-COVID adjustment phase of the green bond market lifecycle in 2022-2023, no greenium was observed. In contrast, the yield of green bonds increased by 36 basis points compared to conventional bonds. Therefore, our hypothesis H4, which suggests that in high-risk environments, there is a lack of consistent presence of greenium, has been confirmed.

The main reasons for this include the impact of energy and real estate crises on sectors such as utilities, real estate, mining, and energy, which reduced profits and increased credit risks for investors. Additionally, concerns about greenwashing and anticipated regulation of green bond issuance have contributed to the decline in green premiums. Finally, the novelty effect of green bonds has diminished, prompting investors to prioritize traditional factors such as credit quality, interest rate risk, and liquidity when evaluating green bond pricing.

Table 7 shows that the recent shift from green discount to green premia occurred in both financial and non-financial companies, as well as in ‘clean’ and ‘dirty’ industries.

Table 7. Testing the hypothesis H4 by types of companies and industries.

Independent variables	Financial companies	Non-financial companies	'Clean' industries	'Dirty' industries
Greenium by phases of the life cycle				
Green x 2013-2015	-0.4258* (0.2078)	-0.2005 (0.2290)	-0.4034* (0.2050)	-0.3551 (0.2166)
Green x 2016-2019	-0.3874*** (0.1102)	-0.5797*** (0.1205)	-0.3469*** (0.1041)	-0.7642*** (0.1739)
Green x 2020-2021	-0.3456*** (0.0468)	-0.6971*** (0.1847)	-0.3450*** (0.0494)	-0.9378*** (0.2254)
Green x 2022-2023	0.4227** (0.1275)	0.2715* (0.1331)	0.4268*** (0.1204)	0.2287 (0.1573)
Control variables				
Policy rate	0.7307*** (0.0202)	0.6686*** (0.0240)	0.7314*** (0.0198)	0.6384*** (0.0289)
Callable	0.0132 (0.0422)	-0.2226*** (0.0587)	-0.0117 (0.0383)	-0.1514. (0.0816)
Fixed effects				
Issuer	Yes	Yes	Yes	Yes
Maturity x Rating x Time	Yes	Yes	Yes	Yes
Currency	Yes	Yes	Yes	Yes
Bond size	Yes	Yes	Yes	Yes
N of Obs	18,728	3,531	20,185	2,026
R2	0.77340	0.87323	0.79144	0.86482
F-	118.45***	121.95***	199.44***	196.45***

Note: *, **, *** is significance of metrics at 10%, 5% and 1%, robust standard errors are shown in parentheses.
Source: calculated by authors.

The analysis shows no significant difference in the environmental impact of 'dirty' industries during 2022-23. However, the financial institutions sector experienced a shift from negative to positive greenium, attributed to increased risks associated with banks' green loan portfolio, mainly consisting of utilities, real estate, energy, and mining companies. The high-interest rate environment amplified risks for the entire banking industry. ESG integration into bank activities seems to concern investors less than overall financial stability. Green bond issuers from 'clean' industries also have undergone a notable transition from a negative to a positive greenium. This shift can be primarily attributed to concerns about greenwashing, as well as investors' anticipation that during periods of high interest rates, environmental projects within clean industries may have adverse effects on the companies' stakeholders and might not fulfil their objectives. Also, non-financial companies have exhibited a shift in the greenium trend from negative to positive, albeit to a lesser extent than observed for banks. Furthermore, there has been a reduction in the statistical significance of the greenium to just 10% of its prior level. These findings indicate that, under specific conditions, it is reasonable to conclude that there is currently no greenium present for non-financial companies at this stage of the green bond debt market's life cycle.

Finally, our findings confirm the conclusions of [6] that, at this stage of the green bond market, debt issuers' public commitments to ESG no longer impact green bond prices. This suggests that investors prioritize traditional bond pricing drivers, such as credit risks, interest rate risks and liquidity, undervaluing issuers' sustainability commitments. The results we have achieved provide a significant opportunity for future research. Our most promising line of inquiry is the evolution of the greenium over time, for various types of sustainable development instruments in emerging capital markets. Additionally, future research will

focus on examining the impact of discounts on the profitability of "green" securities issued in accordance with the principles of Islamic finance. Furthermore, it is important to extend the scope of our research to encompass the full range of debt financing available for sustainable development purposes. We also intend to increase the number of factors we investigate that affect the greenium, including both financial and non-financial metrics of issuers.

Conclusion

The purpose of this study was to explore the size and drivers of greenium in European corporate bond markets from 2013 to 2023. Additionally, it seeks to analyse how greenium evolves based on the stages of the life cycle of green bond markets in the region. The significance of this research is tied to the important role of green bonds in financing the sustainable development agenda in the area. There are also concerns among researchers and practitioners regarding the potential disappearance of greenium, as well as the possibility of green bond yields in Europe exceeding conventional bond yields. This could increase the risks associated with implementing the Environmental, Social, and Governance (ESG) agenda in the region. Our research introduces a new perspective by identifying the stages of the life cycle of green bond markets in Europe and evaluating the changes in the premium for green bonds at each stage. We considered different types of issuers, such as banks and non-financial companies, and industries with varying environmental impact. To assess the premium for green bonds, we conducted regression analysis using an asset pricing model. Our sample included 22,259 primary bond issues from 23 European countries, with 1,040 being primary green bond issues.

We discovered that during this period, issuers of green bonds experienced a significant yield discount. For financial institutions, the premium was approximately 15 bps, while for non-financial companies it was around 40 bps. This difference can be attributed to the challenge for investors in monitoring the use of funds from green bond issuances in banks' loan portfolios. The premium for green bonds varies significantly based on the phases of the green bond markets' lifecycle. From 2016 to 2021, the maximum amount of yield difference between the green and conventional bonds amounted to about 40 bps.

Between 2022 and 2023, there was a significant shift in the primary market regarding the pricing of green bonds. Instead of offering a discount, there was a premium of up to 36 basis points compared to regular bonds. Non-financial corporate issuers saw the most notable changes, with the previous 70 basis points discount on green bonds being replaced by a premium of up to 27 basis points compared to conventional bonds. There was no statistically significant yield discount for issuers of green bonds in polluting sectors. However, issuers in "clean" industries saw their yields increase by 43 basis points compared to conventional bonds, a significant change from the 34-basis points discount seen in 2020-2021. These changes are attributed to energy and geopolitical crises in Europe, leading to higher inflation and a tighter monetary policy. As a result, the risks associated with implementing ESG projects increased, making them less attractive. These findings are important not only for researchers studying green bond markets but also for central banks and other authorities responsible for ensuring financial stability and implementing the sustainable development agenda.

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