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Does the green bond premium exist in the secondary market? Evidence from Nordic countries

JEL Classification: *G12; G15*

Keywords: *green bond premium; yield spread; liquidity spread; secondary market*

Abstract

Research background: The green bond market is growing every year. This market becomes an effective financing mechanism for climate change mitigation and adaptation. Even though approximately two-thirds of the research confirmed the existence of a green bond premium (GBP) in the secondary market, certain circumstances may deny it. Among them are comparable credit quality, market demand and supply dynamics, market liquidity, regulatory and policy support, investment preferences, etc. These circumstances are the main motivation for continuing the studies related to GBP, testing its existence for the issuers in Nordic countries. These countries have rather ambitious policies for environmental protection and low-carbon

These countries have rather ambitious policies for environmental protection and low-carbon development, the presence of a transformative Nordic model for greening the economy, and issuers overall are positive towards the EU Green Bond Standard.
Purpose of the article: This study aims to determine the GBP in the secondary market.
Methods: A matching method is used to determine the pairs of green and conventional bonds. A fixed-effects panel regression model is performed to control for the difference in liquidity between each green bond and its counterfactual to extract GBP. A Wilcoxon signed-rank test with continuity correction is applied to test the significance of GBP.
Findings & value added: The findings did not prove the existence of GBP, neither for the total sample nor for sub-samples by the issuer type. The study continued dividing the entire research period into three sub-periods (pre-COVID-19, COVID-19, and the Russian-Ukrainian war). However, the results did not change. The findings suggest that the GBP does not reflect market participants' willingness to pay more for environmentally friendly investments, and it is not incorporated into pricing models by adjusting for risk, preference, and regulatory impact.

Introduction

Climate change is one of the most common problems of today. As the likelihood of global warming increases due to carbon dioxide emissions, more and more countries are encouraging action to reduce environmental pollution. Implementation of green investment projects requires the mobilization of financial resources. One of the most popular financial instruments is green bonds.

The first green bonds were issued by the European Investment Bank in 2007. In 2008, the World Bank and the Bank of Sweden issued green bonds to help countries raise capital and finance projects that would solve the problems arising from climate change. It was an event that fundamentally united the initiatives of investors, politicians, and scientists (Frydrych, 2021). Over the past 15 years, the green bond market has expanded at a pace referred to in the scientific literature as the "green bond boom" and is receiving increasing attention from scholars. They focused on the characteristics of green bond markets, the pricing of green bonds, GBP, the connectedness of green bonds and other financial markets, the implications for issuers, etc. GBP is still the central focus of scholars. MacAskill *et al*. (2021) overviewed the previous findings and stated that GBPs exist within 56% of primary and 70% of secondary markets. Investors' willingness to pay a higher price for green bonds than conventional bonds encourages issuers to issue more green bonds to the market. They are increasingly motivated by the potential GBP, which allows them to issue green bonds with a lower

yield (Maltais & Nykvist, 2021). Meanwhile, despite the lower yield of green bonds, investors appreciate the opportunity to invest in environmentally friendly projects (Nanayakkara & Colombage, 2019).

Systematic rules and standardization based on sound governance of green bonds reduce information asymmetry. This makes it possible to reduce investors' doubts about the "greenness" of bonds, both when issuing and when reporting on performance. For example, CBI-certified green bonds issued by governments are one of the main drivers of the green premium (Frydrych, 2021). However, the evidence on non-existing or positive green premiums (Wu, 2022; Hyun *et al*., 2020; Larcker & Watts, 2020; Tang & Zhang, 2020; Bachelet *et al*., 2019; Karpf & Mendel, 2018) highlights the fact that investors do not always prefer green bonds. This can limit the issuers' ability to implement environmental projects at lower financing costs.

The contradictions in the existence of GBPs in the secondary market among the empirical studies could be based on several reasons. The GBP in the secondary market exists because of supply-demand imbalances (Maltais & Nykvist, 2021), investor preferences (Zerbib, 2019), and regulatory incentives (Azhgaliyeva & Kapsalyamova, 2023). The supply of green bonds is relatively limited compared to conventional bonds, leading to higher demand and lower yields. On the contrary, the demand is growing, especially due to the activity of institutional investors. If their strategies are ESG (Environmental, Social and Governance) focused, supply-demand imbalances increase sharply. Moreover, large institutional investors often hold green bonds in their portfolios for the long term, thus reducing liquidity and increasing scarcity. Environmentally friendly investors are willing to accept slightly lower yields for green bonds due to their alignment with sustainability goals. Investors also may view green bonds as less risky due to the perception that green projects are future-proof and less exposed to regulatory or transition risks. Governments and financial regulators promote green investments through tax benefits, lower capital requirements, or regulatory preferences, therefore, encouraging buying and holding lower-yielding fixed-income securities.

Even though approximately two-thirds of empirical studies reviewed by MacAskill *et al*. (2021) proved the existence of GBPs in the secondary market, there are more explanations for why GBPs are often observed in the primary market and tend to disappear or significantly shrink in the secondary market. First, green bonds usually attract sustainability-focused

investors willing to pay a premium in the primary market. In the secondary market, trading activity is often lower for green bonds compared to conventional bonds, leading to wider bid-ask spreads and potentially reducing any pricing advantage. Green bonds often have lower liquidity than conventional bonds (Koziol *et al*., 2022) and this is partly due to the limited supply of green bonds (Bachelet *et al*., 2019; Febi *et al*., 2018). The impact of liquidity on bond pricing is still not fully explored (Yan *et al*., 2025) and imperfect control of the liquidity premium leads to mixed results (Zerbib, 2019). Second, the yield of green and conventional bonds from the same issuer often converge over time due to investor arbitrage: they sell green bonds and buy similar conventional bonds if a green bond trades at too high a price thus pushing yields to align. Market inefficiency creates uncertainty among investors about the true value of bonds and information asymmetry can result in a higher risk premium demanded by investors. This is a contradiction with rational pricing theory under which financial asset prices should reflect all available information and be consistent with the principles of arbitrage, i. e. in an efficient market no investor should be able to earn abnormal return. In addition, it should be pointed out that the green bond market is stronger connected with the fixed-income market, but weaker with other markets. When risk and payoffs are held constant and are known to investors ex-ante, investors view green and non-green securities by the same issuer as almost exact substitutes (Larcker & Watts, 2020). Third, green bonds carry the same credit risk as conventional bonds because they are issued by the same issuer. Later any initial greenium often vanished as investors adjust the required return by risk. The credit risk of a green bond can be considered identical to the credit risk of a conventional bond (Caramichael & Rapp, 2024). According to Karpf and Mandel (2018), the financial health and credit ratings of issuers significantly influence the yields of both green and conventional bonds. Even though green bonds have environmental labels, they share similar risk structures and pricing principles with conventional bonds (Yan *et al*., 2025). Fourth, recently greening the economy and ESG investing has become mainstream so investors may not require a separate green label to pay a premium. Under the institutional theory, institutions influence the behaviour of individuals and companies. Their decisions are based not only on efficiency or profit maximisation, but also on conforming to societal expectations, regulations, and cultural norms to gain legitimacy and stability. As was pointed out by Arat *et al*. (2023) and Stellner *et al*. (2015), GBP is moderated by the issuer coun-

try's environmental performance and is more pronounced for issuers from non-green countries. Finally, regulatory benefits or tax advantages to promote the implementation of green projects and their financing usually work at the moment of green bond issuance. Without regulatory benefits or tax advantages for holding green bonds, investors may not continue to pay a premium in the secondary market. Policymakers should allow tax-exempt green bond issues (Wu, 2022).

Considering the dominating findings on the existence of GBPs in the secondary market and scholars' insights about the relationship between companies' greenium, credit rating and ESG performance of countries in which companies are located, we choose the Nordic countries for testing GBP in the secondary market. The Nordic countries have rather ambitious policies for environmental protection and low-carbon development (Hildingsson *et al*., 2019). Khan *et al*. (2021) examined strategies for greening the economy in three Nordic countries. They indicated the presence of a transformative Nordic model for greening the economy, in which the state plays an active role in supporting innovation and technology development. Finally, the green bond issuers in Nordic countries overall are positive towards the EU Green Bond Standard (Björkholm & Lehner, 2021).

The findings of Karim *et al*. (2024) showed that green bonds offer financial markets sufficient diversification, safe haven, and hedging opportunities during stable and distressing periods. Arat *et al*. (2023) revealed that the geographic effect on GBP remains only during the time without financial distress. How does the financial turmoil influence the behaviour of investors and green premiums? It is also the research gap and a new niche for studies.

The study aims to determine the GBP in the secondary market for issuers in Nordic countries. The main value added of this research is that all the stakeholders should rethink the valuation of green options because green and conventional bonds are valued using similar techniques but with adjustments for factors specific to green investments. They should also rethink the dynamics of market demand and supply, expansion of the green bond market with increasing liquidity and diversity, regulatory and policy support, non-financial motives, and long-term perspective of investors.

The study is carried out by applying a matching method, a fixed-effects panel regression model and a Wilcoxon signed-rank test with continuity correction.

The paper is organized as follows. In Section 2, we review previous studies on the GBPs in the secondary market. In Section 3, we describe the research data and methods. In Section 4, we make the empirical study to assess GBP and differences during stable and unstable periods of the economy. In Section 5, we develop the scientific discussion. Finally, in Section 6, we present the main findings of our study.

Literature review

The existence of the GBP is ambiguous due to the different research results presented. Some scholars studied GBPs in primary markets (Caramichael & Rapp, 2024; Flammer, 2021; Tang & Zhang, 2020; Ehlers & Packer, 2017), others — in secondary markets (Arat *et al*., 2023; Grishunin *et al*., 2023; Intonti *et al*. 2023; Immel *et al*., 2021; Hyun *et al*., 2020; Wu, 2020; Agliardi & Agliardi, 2019; Zerbib, 2019), and some — in both markets (Hu *et al*., 2022; Kapraun *et al*., 2021; Hu *et al*., 2022). MacAskill *et al*. (2021) overviewed the previous findings and stated that GBP exists within 56% of primary and 70% of secondary market studies, particularly for those green bonds that are government-issued, investment grade, and that follow defined green bond governance and reporting procedures. A comparative analysis revealed that MacAskill *et al*. (2021) overviewed research articles investigating GBP from 2015 to 2019. Meanwhile, Zerbib (2019) — from 2015 to 2018. Zerbib (2019) noticed that liquidity control was done only in five empirical studies among eight in total. Even more, the liquidity was measured either by the date of issuance or issue amount. Therefore, liquidity is a crucial factor that should be controlled and measured correctly to determine GBP.

Few studies confirm the existence of GBPs in the secondary market. Nanayakkara and Colombage (2019) identified the pricing difference between green and conventional bonds in capital markets worldwide. Hu *et al*. (2022) found large GBPs in the Chinese bond market. They observed that the magnitude of the Chinese green premium is substantially greater than other international green bond markets. One of the problems that arise in this area of research is data sample. For example, Intonti *et al*. (2023) investigated green bonds approved by the Climate Bond Initiative. Despite the confirmation of GBPs, this study has an important limitation — an extremely small sample. Meanwhile, Zerbib (2019) examined the entire sample of green bonds complying with the Green Bond Principles and found

small GBPs. In addition, Zerbib (2019) revealed that negative premiums are higher for financial and low-rated bonds. Their results highlighted the low impact of green investors' preferences on bond prices, which currently shows little support for the development of the green bond market. Immel *et al*. (2021) examined the existence of GBP globally and found a negative premium. Further, they were interested in the influence of ESG ratings on green bonds to determine if investors differentiate between the shades of green and found a negative relationship between the ESG score and green premium. Gianfrate and Peri (2019), who investigated the European green bond market, pointed out that green bonds are more financially convenient than conventional bonds. Zerbib (2019) summarised previous empirical findings and disclosed that negative premiums tend to decrease over time. The newest empirical studies disclosed evidence of the existence of small GBPs (Fiorillo *et al*., 2024), time-varying and mean-reverting GBPs converging to a negative value in the long term (Kanamura, 2025), decreasing over time GBPs and reflecting growing investor scepticism about the credibility of sustainability-linked bond targets (Poggensee, 2025).

On the contrary, some studies deny the GBPs. For example, Bachelet *et al*. (2019) investigated green bonds listed on the Climate Bonds Initiative website and found that private green bonds have a positive premium and a much narrower liquidity advantage concerning their brown bond twins. Hyun *et al*. (2020) also investigated green bonds globally and found that there is no robust and significant liquidity-adjusted GBP. Larcker and Watts (2020) analysed municipal green bonds and found a positive GBP. Comparing green securities to nearly identical securities issued for non-green purposes by the same issuers on the same day, they observed economically identical pricing for green and conventional issues. A study by Karpf and Mendel (2018) showed that, although returns on conventional municipal bonds are on average higher than for green bonds, the differences can largely be explained by the fundamental characteristics of the bonds. Historically, green bonds have been traded at lower prices and higher yields than expected by their credit profiles. Flammer (2021) did not find evidence that corporate green bonds are priced at a premium compared to conventional bonds. Similar results were obtained by Wu (2022), who did not find green premium in either Chinese or global markets. However, global market models showed that issuing green bonds in CNY could reduce the premium, unlike in USD or EUR. Kapraun *et al*. (2021) analysed the pricing of green bonds on the primary and secondary markets

and concluded that in both markets only certain types of green bonds exhibit lower yields relative to their conventional counterparts.

In most cases, empirical research focuses on the evidence of the existence and size of GBPs and comparison with previous findings, leaving aside the reasons that caused particular results. Only a few of them pointed out that GBP in the secondary market exists because of a combination of supply-demand imbalances (Maltais & Nykvist, 2021), investor preferences (Zerbib, 2019), and regulatory incentives (Azhgaliyeva & Kapsalyamova, 2023). According to Maltais and Nykvist (2021), one common explanation for the GBPs difference is the high demand for and limited supply of green bonds. Although investors' preferences for green financial instruments and their impact on pricing have been intensively documented in the literature, the existing literature does not establish whether and to what extent the pricing difference is determined by non-financial motives (Zerbib, 2019). Tax-exempt green bonds are issued at a premium because the primary investors take additional benefits. Policies (grants, tax incentives) stimulate the issuance and reduce the cost of green bonds (Azhgaliyeva & Kapsalyamova, 2023) and increase their demand.

There are multiple arguments regarding the non-existence of GBP in the secondary market. The prevailing among them are liquidity, market inefficiency, credit risk, policy towards greening the economy, and policy related to holding green bonds. Green bonds often have lower liquidity than conventional bonds (Koziol *et al*., 2022). One of the reasons is their limited supply (Bachelet *et al*., 2019; Febi *et al*., 2018). Liquidity is an important factor of GBPs, however, its impact on bond pricing is underexplored (Yan *et al*., 2025). Market inefficiency creates uncertainty among investors. Information asymmetry widens the gap between the market price and fair value of bonds and causes mispricing. For example, Adekoya *et al*. (2021) disclosed that the U.S. green and conventional bond market is inefficient. The other argument is that green bonds and conventional bonds have identical credit risks. Usually, business risk is assigned to a specific project, but financial risk is not accounted for separately. According to Caramichael and Rapp (2024), the coupon and principal payments from green bonds are rarely paid out from cash flows generated by green projects. Even if the issuance of green bonds reduces credit risk by lowering the company's exposure to environmental risk factors, it would not necessarily improve the risk-adjusted returns (Caramichael & Rapp, 2024). Recently greening the economy and ESG investing has become mainstream, however, the

pace and methods of each country are different. GBPs depend on the issuer country's environmental performance and are more typical for issuers located in non-green economy countries (Arat *et al*., 2023). Finally, regulatory benefits or tax advantages are important not only at the moment of green bond issuance but also in the secondary market. Tax-based incentives are an important type of policy incentive (Wu, 2022).

Several studies have been conducted to determine the performance of sustainable financial instruments over unsustainable ones during the COVID-19 pandemic (Albuquerque *et al*., 2020; Intonti *et al*., 2023; Arat *et al*., 2023). Albuquerque *et al*. (2020) found that stocks with higher environmental and social (ES) ratings generated significantly higher returns and lower return volatility. Intonti *et al*. (2023) showed that the negative COVID-19 shock increased GBP, especially for governmental issues. Arat *et al*. (2023) explained why investors shift their investments towards more sustainable financial instruments. First, these instruments offer detailed reporting and high transparency. Second, investors have better awareness of the potential risks associated with environmental degradation and social inequality. The empirical study of Arat *et al*. (2023) was focused on GBP and showed that the geographic effect on the GBP persists only during the financially stable period.

The analysis and synthesis of previous research revealed that scholars applied different methods with or without liquidity control. For example, Ehlers and Packer (2017) used comparison method without the liquidity control; Karpf and Mandel (2018) applied Oaxaca-Blinder decomposition method with the liquidity control through the number of transactions; Baker *et al*. (2018) chose OLS regression with the liquidity control through the issue amount; Hachenberg and Schiereck (2018) used panel regression with the liquidity control through the issue amount; Zerbib (2019) applied fixed-effects panel regression with the liquidity control through the bid-ask spread; Caramichael and Rapp (2024) based their study on fixed-effects panel regression with the expected liquidity differential. In summary, recent studies have focused on liquidity control to capture GBPs. According to Zirek and Unsal (2023), the liquidity spread is a significant driver of the yield spread between green and conventional bonds, indicating that liquidity differences account for some differences between green and conventional bonds.

The literature review revealed the controversial findings related to the assessment of GBPs because the studies are different in the context of in-

vestigated markets and periods, the scope of issuers, the measurement of yield and liquidity spreads, the methods applied, and other conditions. The existence and non-existence of GBPs are frequently explained by transparency, uniform standards, and external certification. According to Kapraun *et al*. (2021), investors do not trust green labels without additional verification. Meanwhile, Zirek and Unsal (2023) did not observe a statistically significant relationship between bond-level certification and the GBPs. Similar insights are presented by Caramichael and Rapp (2024), who stated that although green bond governance and external certification appear to matter for the green premium, the credibility of the major projects has little impact. The scholars also determined various characteristics of green bond issues influencing the GBPs. In addition to the assessment of GBP and its determinants, they focused on the green premium differences in financially stable and crisis periods.

The literature review allowed us to identify the most common empirical challenges and problems related to the development and operation of the green bond market. Until now, liquidity, as one of the most important factors, has not been included in all empirical studies. This fact led to the controversial findings. Previous studies were focused on different geographical scopes: global, regional, and local. Nordic countries as one region have not been investigated yet. This region is worth attention because of two main reasons. First, Nordic countries have a transformative model for greening the economy with the active role of governments and strong cooperation with all stakeholders. Second, some scholars proved the relationship between companies' greenium, credit rating and ESG performance of countries in which companies are located. The sample of green bonds covers the period of 2014–2023 with a sharp increase in issuances in 2019 and a peak in 2023. This increase almost coincides with the start of the COVID-19 pandemic and later — the Russian-Ukrainian war. Investors may restructure their portfolios to reduce risk by shifting towards green bonds as they have better reporting and higher transparency. Following the problems and limitations of previous studies we close the research gap by choosing the issuers of green bonds in Nordic countries as the leaders in greening the economy, controlling the liquidity as the main factor of GBP, and focusing on the influence of financial turmoil on GBP.

We raised two hypotheses for empirical research:

H1: *Green bonds in Nordic countries exhibit a premium in the secondary market during the entire study period*.

H2: *Green bonds in Nordic countries exhibit a higher premium in the secondary market during the different sub-periods.*

Data and methods

The research examines the green bond market of Nordic countries: Norway, Sweden, Finland, Denmark, and Iceland. The sample of green bonds covers the period of 2014–2023, as green bond standards were approved only in 2014. In total, there are 1047 green bond issues of non-financial companies, financial institutions, and governments in the Nordic countries. Of all 1047 green bond issues only 240 issues met the matching criteria and were included in the study. Each of these bonds is matched with two conventional bonds, which are most similar in characteristics to a green bond. In total, the study assesses 240 green bonds and 480 conventional bonds. Daily research data is taken from the Bloomberg database.

Figure 1 shows the distribution of green bond issues according to the countries and years in absolute terms. The largest shares of the green bond issues are in Sweden and Norway. Green bonds of Finnish and Dannish issuers account only for 4.5% of the total sample. The significant growth of green bond issues has been influenced by European Commission regulation. In 2018, the EU Sustainable Finance Action Plan was approved. One year later, work began on preparing a report on an EU Green Bond Standard. These regulations pushed the actions in Nordic countries. In 2019, the Swedish government issued an instruction to the Debt Office. In the same year, the Norwegian government updated the criteria for green bonds. Policy implementation contributed to the development of the green bond market. The activity of the issuers in the primary green bond market peaked in 2023.

We chose a matching method for the measurement of GBP applied by Zerbib (2019) because the exact matching method applied by Bachelet *et al*. (2019) and Larcker and Watts (2020) is difficult to use due to the small sample. According to Zerbib (2019), two conventional bonds with the clos-

est maturity to the green bond and the same characteristics of the issue are chosen for the study. Table 1 presents the criteria according to which green and conventional bonds are matched. This study is based on the research of Hyun *et al*. (2020) and Zerbib (2019) and collects bonds with a maturity of no more than 2 years since the terms usually do not coincide. In this way, we limit the maturity differences to calculate the most accurate synthetic bond yields. Liquidity is also an important factor in bond pricing. The scholars claim that the amount and date of the issue at least partially limit the liquidity of the bonds. Due to the effect of liquidity on the yield, the following restrictions are applied: the amount of the issue of conventional bonds is neither lower nor higher than 4 times the amount of the green bond issue. Meanwhile, the conventional bond issuance date is no earlier and no later than 2 years than the date of the green bond issue.

Table 2 presents the structure of green and conventional bond issues according to the issuer type, currency, and credit rating. Nearly two-thirds of green bond issues were issued by financial institutions, about 25% — by governments, and the rest — by non-financial companies. The green and conventional bond issues are dominated by Swedish kroner (SEK) and Norwegian kroner (NOK). Credit rating is one of the main determinants that influence GBPs. Unfortunately, most bonds are unrated and only about 30% of issues have credit ratings. The majority of green bonds are rated AAA and AA+.

The empirical study includes two steps. GBP for the total period is determined in the first step. GBPs for sub-periods is determined in the second step. The first step is searching for the two conventional bonds which meet the matching criteria and constraints. Then the synthetic conventional bond for each green bond is built using the method of interpolation and extrapolation. The yield of the synthetic conventional bond was then compared to the yield of the green bond. The yield of the synthetic bond is calculated by establishing a linear relationship between the maturities of the two conventional bonds and the yield:

$$y_{SB} = y_{CB_1} + \frac{(y_{CB_2} - y_{CB_1})}{(X_{CB_2} - X_{CB_1})}(X_{GB} - X_{CB_1}) \quad (1)$$

where:

y_{SB} the synthetic bond yield;

y_{CBi} the conventional bond yield;

X_{GB} the number of days the green bond is until maturity;
X_{CBi} the number of days the conventional bond is until maturity; i=1,2.

The yield spread per bond at time t is measured as the difference between the yield of the green bond and the yield of the synthetic bond:

$$\Delta\tilde{y}_{i,t} = y_{i,t}^{GB} - y_{i,t}^{SB} \quad (2)$$

where:
$\Delta\tilde{y}_{i,t}$ the yield spread;
$y_{i,t}^{GB}$ the GB_i yield at time t;
$y_{i,t}^{SB}$ the SB_i yield at time t.

Green bonds and conventional bonds have different issuance and maturity dates. The average difference between the issuance dates of green and conventional bonds is 90 days and between the maturity dates — 101 days. Differences in issuance and maturity dates may affect the results, so the liquidity is controlled in the fixed-effects panel regression model. Liquidity is measured as the difference between the bid and ask price, divided by their average (Zerbib, 2019; Febi *et al*., 2018; Fong *et al*., 2017):

$$\text{Liquid}_{i,t} = \frac{\text{AskPrice}_{i,t} - \text{BidPrice}_{i,t}}{(\text{AskPrice}_{i,t} + \text{BidPrice}_{i,t})/2} \quad (3)$$

Since the synthetic bond is composed of two conventional bonds, the liquidity of the synthetic bond is measured in the following way (Zerbib, 2019):

$$\text{Liquid}_{i,t}^{SB} = \frac{d_2}{d_1 + d_2}\text{Liquid}_{i,t}^{CB1} + \frac{d_1}{d_1 + d_2}\text{Liquid}_{i,t}^{CB2} \quad (4)$$

where:

$$d_1 = |GB_{maturity} - CB1_{maturity}|;\ d_2 = |GB_{maturity} - CB2_{maturity}|.$$

A matching method selects identical bonds, except for greenness and liquidity, so all other factors should not affect the obtained results. According to Hyun *et al*. (2020), the liquidity criterion is removed, i.e., liquidity is

fixed by the difference between demand and supply. A variable $\Delta\text{Liquid}_{i,t}$ captures the liquidity spread:

$$\Delta\text{Liquid}_{i,t} = \text{Liquid}_{i,t}^{GB} - \text{Liquid}_{i,t}^{SB} \quad (5)$$

where:

$\text{Liquid}_{i,t}^{GB}$ the green bond liquidity;
$\text{Liquid}_{i,t}^{SB}$ the synthetic bond liquidity.

We perform Wooldridge and Breusch-Pagan tests before choosing the panel regression model for the determination of GBPs. Wooldridge's test for autocorrelation in panel data allows us to indicate the existence of serial correlation in the idiosyncratic error term. Test results ($p > 0.05$) showed that autocorrelation does not exist. Breusch-Pagan test is an important diagnostic tool for detecting heteroscedasticity in regression models. Identifying and addressing heteroscedasticity ensures that the model's estimates are efficient and that inference based on these estimates is valid. The p-value of coefficients is below a certain threshold (0.05), so the models with identified heteroscedasticity are estimated using robust standard errors:

$$\Delta\tilde{y}_{i,t} = p_i + \beta\Delta\text{Liquid}_{i,t} + \epsilon_{i,t} \quad (6)$$

where:

$\Delta\tilde{y}_{i,t}$ the yield difference between the green bond and the synthetic bond;
p_i an intercept for bond i (green bond premium);
$\Delta Liquid_{i,t}$ liquidity spread;
β a parameter;
$\epsilon_{i,t,}$ the error term.

In the second step, we determine the GBPs in three sub-periods: pre-COVID-19 (until 31/12/2019), COVID-19 (01/01/2020–23/02/2022), and the Russian-Ukrainian war (from 24/02/2022). According to the World Health Organization, the pandemic period lasted from the first quarter of 2020 to the first quarter of 2023. So, there is one-year overlapping of COVID-19 and the Russian-Ukrainian war. However, the S&P index sharply declined after the Russian-Ukrainian war. The pandemic subsided and geopolitical risks increased, which undoubtedly overshadowed the impact of the pandemic.

Results

The estimates of the fixed-effects regression model are presented in Table 3. They show that liquidity spread is not a statistically significant determinant of yield spread in the total sample and all sub-samples. R^2 in all cases is close to zero. Liquidity spread has no explanatory power and the step used for its control could be discarded.

After controlling the liquidity spread, we calculate GBPs and their distribution (Table 4). The results show that the GBP for the total sample ranges from negative 541.1 basis points (b.p.) to positive 100.5 b.p. The mean for the total sample is -5.93 b.p. The results by the issuer type show that the mean of GBP for non-financial companies is -10.24 b.p. and for governments is -0.12 b.p. A positive GBP (1.25 b.p.) was found only for financial institutions. The medians and means show the data asymmetry. The medians are greater than the means in all cases except for financial institutions and identify the skewness to the left.

The distribution of GBPs revealed that 25% of GBPs in the total sample are less than -6.58 b.p. and 75% are less than 3.95 b.p. Half of GBPs in the total sample are within the 0.11 wide interval. Even though the GBPs are not large, two-thirds of the values are within a relatively narrow interval. In the case of non-financial companies, a quarter of the results are less than -21.75 b.p., and three-quarters of the results are less than 1.52 b.p. The sample interval is equal to 0.23, which is more than twice as long as that of the total sample. Data asymmetry is also observed for financial institutions, and governments: the values of width interval (0.10 and 0.04, respectively) are more similar to the total sample. The different distribution of data in the total sample and sub-samples is determined by the number of observations. Figure 2 shows the relative distribution of the GBPs. The graph shows that the distribution of the green premium for both the total sample and sub-samples is similar. The total sample has more negative outliers. Financial institutions have a positive outlier. Significant outliers were not found for other sub-samples. Despite the identified data outliers, the yield spread between green and conventional bonds dominates from -0.4 to 0.4. Most of the distribution of values is close to 0.

The Wilcoxon signed-rank test with continuity correction is applied to assess whether the GBPs are statistically significant (Table 5). The results obtained showed that there are no statistically significant GBPs either for the total sample or for sub-samples by the issuer type. We can conclude

that investors in the Nordic countries invest in green bonds at the same or even lower prices compared to conventional bonds. The findings allow us to reject the H1.

The scatter plot shows the distribution of the yield spread from 2014 to the end of 2023 (Figure 3). It can be seen that the yield spread increased after the onset of COVID-19. However, the increase in the yield spread is short-lived and quickly returns to normal. The largest expansion in the yield spread is observed from the beginning of 2022.

Further, we discuss the estimates of the fixed-effects regression models for three sub-periods (Table 6). It should be pointed out that the total number of observations was quite small during the pre-COVID-19 sub-period while 40 times larger during the Russian-Ukrainian war. The liquidity spread does not influence the yield spread in all sub-periods. R^2 is close to zero in all cases. After controlling the liquidity spread, we calculate GBPs and present their distribution (Table 7). The results in all sub-periods are different. The means of GBP were positive during the pre-COVID-19 period (16.15 b.p.) and the Russian-Ukrainian war period (6.66 b.p.), while negative — during the COVID-19 period (-3.32 b.p.). The difference between the medians and means shows the data skewness to the right except for the COVID-19 period. The distribution of GBPs revealed that 25% of GBPs are less than the identified negative values in the first quartile. Values are similar during the pre-COVID-19 and COVID-19 periods. Meanwhile, the third quartile showed the values are closer during COVID-19 and the Russian-Ukrainian war periods. As in the total sample, a Wilcoxon test with continuity correction was performed to test the statistical significance of GBPs. The test results showed that no statistically significant difference was found between green and conventional bonds under study (Table 8).

The results of the first step of the study showed that there were no statistically significant GBPs in the Nordic market. The data was analysed by the total sample and by issuers' type. Considering the previous studies on the changes of GBPs during financial turmoil we divided the total period into three sub-periods. However, we got the same results and rejected the H2. The main arguments for our findings are presented in the next section.

Discussion

We studied the existence of GBPs of the issuers in Nordic countries in the secondary market. The choice of Nordic countries and secondary markets was based on several reasons. First, previous empirical studies were controversial. Some of the studies confirmed the existence of GBPs in the secondary market (Fiorillo *et al*., 2024; Intonti *et al*., 2023; Hu *et al*., 2022; Immel *et al*., 2021; Gianfrate & Peri, 2019; Nanayakkara & Colombage, 2019; Zerbib, 2019), however, other studies denied it (Wu, 2022; Flammer, 2021; Kapraun *et al*., 2021; Hyun *et al*., 2020; Larcker & Watts, 2020; Bachelet *et al*., 2019; Karpf & Mendel, 2018). Among them, studies confirming the existence of negative GBPs in the secondary market dominate (MacAskill *et al*., 2021). Second, scholars have explored green bonds either globally, regionally, or within a single country. Nordic countries as one region have not been investigated yet. This is the region having a transformative model for greening the economy with the active role of governments and strong cooperation with all stakeholders. Third, liquidity is a crucial factor that should be controlled and measured correctly to determine GBP. However, the summary of empirical studies (Zerbib, 2019) revealed that liquidity was not always controlled. Finally, a sample of green bonds covers the period of 2014–2023 with a sharp increase in issuance in 2019 and a peak in 2023. So, does financial turmoil influence the behaviour of investors and GBP? This last point is worth noting.

Our findings allowed us to deny the existence of GBP for the total period, chosen sub-periods, total sample, and sub-samples by the issuers. The sample of green bonds covers the period of 2014–2023 while previous empirical studies often covered the periods of 2013–2019. Recently, greening the economy and ESG investing has become mainstream. The period of 2020–2024 is characterised by robust growth in green investments and a notable shift toward sustainable economic practices, despite encountering policy and market challenges. Global energy investments, geopolitical dynamics, and China's leadership have an influence not only on the "level of greenery" at the macro level but also on the environmental sustainability of companies. This is why investors view green and conventional bonds as almost exact substitutes (Larcker & Watts, 2020), consider their identical credit risk (Caramichael & Rapp, 2024), and apply similar pricing principles with conventional bonds (Yan *et al*., 2025). Therefore, it is not surprising that scholars note decreasing negative GBPs over time (Fiorillo *et al*.,

2024; Zerbib, 2019) and growing investor scepticism (Poggensee, 2025). These investors' behavioural tendencies lead to the disappearance of negative GBPs. The green bond principle "Use of proceeds" recommends that issuers provide an estimate of the share of financing the green projects and clarify which investments or project portfolios may be refinanced. However, financial risk is not accounted for on a separate project. Coupon interest and principal payments from green bonds are rarely paid out from cash flows generated by green projects. The "Use of proceeds" plays a significant role in the pricing of green bonds by influencing investor's demand, enhancing transparency, reducing perceived risk, and contributing to a positive market reputation. These factors will likely become even more prominent in their pricing dynamics. The question is for how long the divide between green and non-green investments, and between green and conventional bonds will remain in the future.

Other arguments for the non-existence of GBP are related to the specifics of Nordic countries. These countries are at the forefront of greening the economy due to strong government policies, innovation, and public support for sustainability. Their transformative models provide guidelines and plans for other nations aiming to transition toward a low-carbon and circular economy. Nordic companies actively adopt ESG principles. Their CSR (Corporate social responsibility) and especially environmental disclosure scores increase over time (Aleknevičienė & Stralkutė, 2023). Our findings support the statements that GBP is moderated by the issuer country's environmental performance and is more pronounced for issuers from non-green countries (Arat *et al*., 2023; Stellner *et al*., 2015). These arguments lead to the future research directions. One direction is related to controlling the environmental sustainability of countries through various indices such as the Environmental Performance Index, Global Green Economy Index, etc. The other direction would allow us to capture the environmental performance of companies incorporating ESG scores.

An additional focus of this research was on the effect of crises on GBPs as green bond issues in the 2019–2023 period accounted for 96% of the total sample. Usually, green bonds offer better returns during crisis periods (so-called "crisis premium"). However, the findings neglected the effect of crises on GBPs as they were insignificant in all sub-periods. These results contradict the findings of Kanamura (2025), Arat *et al*. (2023) and Intonti *et al*. (2023). Considering the contradiction, we should point out that the scholars found negative GBPs and proved the increase of them during fi-

nancial turmoil. In addition, their empirical investigations were done globally. Our empirical study was carried out regionally and we did not find negative GBPs at all.

We did not find evidence of the statistically significant effect of liquidity on yield spread. Hu *et al*. (2022) assessed the liquidity of green bonds compared to conventional bonds and did not find a difference in the liquidity level of green bonds. Febi *et al*. (2018) noticed that recently the impact of liquidity risk on yield spread has become negligible and explained this phenomenon by the growing maturity of green bonds markets. The green bond market is expanding with increasing liquidity and diversity. As the market matures, the yield differential between green and non-green bonds tends to narrow. Initially, green bonds may have faced liquidity issues, but as the market grows and liquidity improves, the yields on green bonds align more closely with those of conventional bonds.

Finally, despite the dominating existence of GBPs in the secondary markets in previous studies, we should keep in mind the following aspects: (i) different methodologies were applied; (ii) different measures for liquidity control were chosen (in some cases — without the control); (iii) different research periods were investigated; (iiii) different green bond samples at the global, regional, and country levels were chosen. The geographical scope is sensitive to regulatory and policy support for greening the economy, so it is worth capturing this factor in future research.

Conclusions

The fast development of green bond markets encourages scholars to focus on GBPs studying the issues in various countries, regions, or at a global level. This research is dedicated to the green bond issues in Nordic countries which are the leaders in boosting the green economy. We chose to study the secondary market because the existence and size of GBPs may be one of the most important drivers in green bond market development. The findings denied the existence of GBPs for the total sample and sub-samples by the issuer type (non-financial companies, financial institutions, and governments). The division of the total period (2014–2023) into three subperiods (pre-COVID-19, COVID-19, and the Russian-Ukrainian war) did not change the results.

Our study contributes to the theory of rational option pricing. This theory provides a methodological foundation for valuing investments, including green attributes. The green premium reflects market participants' willingness to pay more for environmentally friendly investments, which can be incorporated into pricing models through adjustments for risk, preference, and regulatory impacts. Growing demand for sustainable and socially responsible investments, policies and incentives that promote green investments, and the belief that green investments may have lower long-term risks due to regulatory changes, societal shifts, and physical impacts of climate change should lead to the existence of GBP. However, the results are the opposite. It does not mean that the abovementioned tendencies are not true. Nevertheless, all stakeholders should rethink the dynamics of market demand and supply, the development of the green bond market, the role of regulatory and policy support, and the long-term perspective of investors. The key question is whether the investors differentiate between future green projects or green companies in their decision-making.

The findings have important policy implications for issuers, investors, market regulators and policymakers towards the drive for environmental sustainability. Issuers of green bonds should consider strategies to enhance liquidity when structuring their offerings to maximise the benefit-to-cost ratio. Investors should consider that green bonds do not always offer financial markets sufficient diversification, safe haven, and hedging opportunities neither during stable nor financial turmoil periods. GBPs may depend on the issuer country's environmental performance and the "level of greenery". While Green Bond Principles are voluntary, market regulators should rethink green bond compliance through investor expectations, third-party verifications, stock exchange listing requirements, and national regulations. Liquidity is a crucial factor of green bond market development, so market regulators could involve efforts to expand secondary market trading and increase information availability. Policymakers could increase the attractiveness of green bonds for investors by not taxing coupon interest received from holding green bonds.

This paper has certain limitations that can be addressed in future research. The main limitation of this study arises from the theory of rational option pricing which assumes market efficiency. Since bonds are not frequently traded, a bond yield does not precisely reflect its fair value. Secondly, we controlled the liquidity by applying bid-ask spread while other measures can also be used. Thirdly, the matching method relies on finding

nearly identical conventional bonds for comparison, but not all green bonds have a perfect match. A limited number of matched pairs can reduce statistical robustness. Applying this method, it is difficult to control issuer-specific differences for potentially skewing the estimated GPB.

The comparison analysis of previous empirical studies and our findings revealed the importance of the environmental sustainability of countries in which issuers are located and the environmental performance of companies on GBP. So, there could be a niche for future research.

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Compliance with ethical standards

This article does not contain any studies with human participants or animals performed by the authors. Extracting and inspecting publicly accessible files (scholarly sources) as evidence, before the research began no institutional ethics approval was required.

Data availability statement

All data generated or analyzed are included in the published article. The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation. The raw anonymized data can be provided by emailing the primary author.

Author contributions

All listed authors have made a substantial, direct and intellectual contribution to the work, and approved it for publication. The authors take full responsibility for the accuracy and the integrity of the source analysis.

Conflict of interest statement

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Annex

Table 1. Matching criteria and constraints of the green and conventional bonds

Matching criteria	Matching constraints
Issuer	Match
Currency	Match
Credit rating	Match
Maturity date	Not longer and not shorter than 2 years
Issuance date	Not earlier and not later than 2 years
Amount issued	No more and no less than 4 times

Table 2. Structure of the sample of green and conventional bond issues

Criterion and structure		Green bond issues		Conventional bond issues	
		Number	Percentage	Number	Percentage
Issuers	Financial institutions	155	64.58	310	64.58
	Governments	59	24.58	118	24.58
	Non-financial companies	26	10.84	52	10.84
	Total sample	240	100	480	100
Currency	SEK	126	55.76	252	55.76
	NOK	80	30.85	160	30.85
	EUR	28	10.40	56	10.40
	USD	6	2.99	12	2.99
	Total sample	240	100	480	100
S&P 100 credit rating	Unspecified rating	188	78.33	376	78.33
	BBB-	1	0.42	2	0.42
	BBB	7	2.92	14	2.92
	BBB+	4	1.66	8	1.66
	A-	9	3.75	18	3.75
	A	5	2.08	10	2.08
	A+	1	0.42	2	0.42
	AA-	1	0.42	2	0.42
	AA	1	0.42	2	0.42
	AA+	12	5.00	24	5.00
	AAA	11	4.58	22	4.58
	Total sample	240	100	480	100

Table 3. Estimates of the fixed-effects regression models

Estimates	Dependent variable $\Delta\tilde{y}_{i,t}$			
	Total	**Non-financial companies**	**Financial institutions**	**Governments**
$\Delta Liquid_{i,t}$	3.0159	1.0799	4.2079	-3.6558
t-statistic	1.2510	0.5157	1.3640	-0.3905
Total observations	85 815	9 867	48 171	27 777
R^2	0.0116	0.0018	0.0154	0.0008

Note: The table gives the estimates of the regression $\Delta\tilde{y}_{i,t} = p_i + \beta\Delta Liquid_{i,t} + \epsilon_{i,t}$.
Significance level: *** 1%; ** 5%; * 10%.

Table 4. Distribution of the estimated GBPs

	Min	**1st quartile**	**Median**	**Mean**	**3rd quartile**	**Max**
Total	-5.4108	-0.0658	-0.0013	-0.0593	0.0395	1.0050
Non-financial companies	-0.5657	-0.2175	-0.0078	-0.1024	0.0152	0.1654
Financial institutions	-0.9684	-0.0458	0.0058	0.0125	0.0538	2.9073
Governments	-0.3119	-0.0240	-0.0003	-0.0012	0.0169	0.5646

Note: The table gives the distribution of the estimated green bond premiums in the regression $\Delta\tilde{y}_{i,t} = p_i + \beta\Delta Liquid_{i,t} + \epsilon_{i,t}$.

Table 5. Mean, median, and the level of significance of GBP

	Mean	**Median**	**Statistical significance**	**Number of green bonds**
Total	-0.0593	-0.0013	not statistically significant	240
Non-financial companies	-0.1024	-0.0078	not statistically significant	26
Financial institutions	0.0125	0.0058	not statistically significant	155
Governments	-0.0012	-0.0003	not statistically significant	59

Note: Wilcoxon signed-rank test with continuity correction is applied.

Table 6. Estimates of the fixed-effects regression models for sub-periods

Estimates	Dependent variable $\Delta\tilde{y}_{i,t}$		
	Pre-COVID	**COVID**	**The Russian-Ukrainian war**
$\Delta Liquid_{i,t}$	0.5739	-0.1913	3.1559
t-statistic	0.2126	-0.9444	1.1941
Total observations	1 673	17 937	66 198
R^2	0.0000	0.0206	0.0000

Note: The table gives the estimates of the regression $\Delta\tilde{y}_{i,t} = p_i + \beta\Delta Liquid_{i,t} + \epsilon_{i,t}$.
Significance level: *** 1%; ** 5%; * 10%.

Table 7. Distribution of the estimated GBPs in sub-periods

Sub-periods	Min	1st quartile	Median	Mean	3rd quartile	Max
Pre-COVID-19	-0.2406	-0.0456	-0.0134	0.1615	0.2963	1.4865
COVID-19	-0.7322	-0.0474	-0.0095	-0.0332	0.0081	0.3457
The Russian-Ukrainian war	-2.0189	-0.0842	-0.0009	0.0666	0.0540	11.7480

Note: The table gives the distribution of the estimated green bond premiums in the regression $\Delta\tilde{y}_{i,t} = p_i + \beta\Delta Liquid_{i,t} + \epsilon_{i,t}$.

Table 8. Mean, median, and the level of significance of GBPs in sub-periods

Sub-periods	Mean	Median	Statistical significance	Number of green bonds
Pre-COVID	0.1615	-0.0134	not statistically significant	13
COVID	-0.0332	-0.0095	not statistically significant	91
The Russian-Ukrainian war	0.0666	-0.0009	not statistically significant	238

Note: Wilcoxon signed-rank test with continuity correction is applied.

Figure 1. Distribution of the number of green bond issues by countries and years

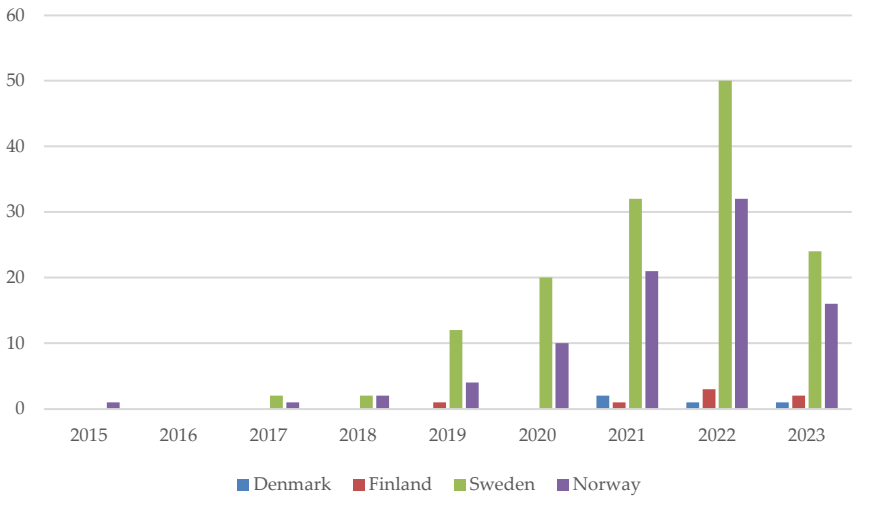

Figure 2. Distribution of the GBPs for the total sample and sub-samples

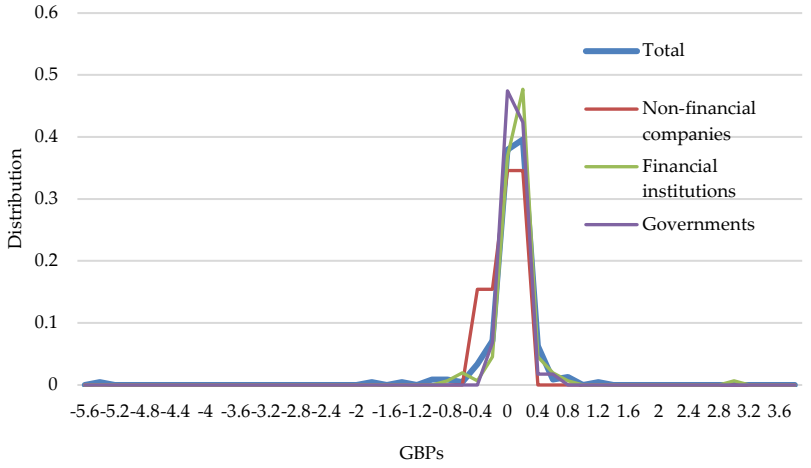

Figure 3. Distribution of yield spread