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GREEN MUNICIPAL BONDS IN THE ENERGY TRANSITION PROCESS

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ABSTRACT: In this article, we focus on green bonds issued by local authorities for the energy transition of cities. Using bonds listed on public markets, we compared the yields of municipal energy bonds with those of other bonds of the same issuer at the same time. The comparison was made using the Wilcoxon signed-rank test. The study aimed to establish the presence of greenium, which can significantly reduce the cost of financing green energy projects implemented by urban centres. The study included selected agglomerations from almost every continent with different financial market experiences. The results indicate a wide variation in the occurrence of greenium, both in terms of value and stableness over time. This may imply that other non-financial factors influence its properties. However, the study results show the potential for reducing the cost of financing energy transition implemented by cities and may have practical relevance.

KEYWORDS: green bond, municipal, energy transition, energy efficiency, financial management

Introduction

Green bonds are widely seen as an essential financial tool for reversing the environmental deficit and enabling climate change mitigation and adaptation (Jones et al., 2020). Such debt instruments are classified as 'green' based on assessing whether the funds raised from their issuance are allocated to new or existing projects that are expected to have a positive environmental or climate impact. Green financing supports mobilising funds and investments to implement sustainable business and social and environmental projects in various countries worldwide (Zhang & Wang, 2021). This enables a more progressive way of thinking, in which environmental and social aspects are as important as simple wealth creation.

There are many ways of green financing, but they often do not have clear demarcations in terms of standards that distinguish them from other financial products. A solution to this problem is the activity of the Climate Bonds Initiative (CBI), an international organisation that certifies and classifies investment bonds issued for environmental projects. This provides information on the eligibility of the business projects for which the bonds are issued.

Green bonds are playing an increasingly important role in financing projects that support the green transformation of economies. Year on year, the value of instruments issued is increasing, reaching nearly USD 0.5 trillion by the end of 2022 (Climate Bonds Initiative, 2023). Green financing initiatives are higher in countries with strict environmental commitments and sustainable development goals (Tolliver et al., 2020). This is manifested in mobilising funds to support sustainable business and social projects that aim to achieve zero carbon emissions and promote green growth (Taghizadeh-Hesary & Yoshino, 2019). While governments and international financial organisations were initially dominant among issuers, corporate and local government offerings began to emerge in the financial market over time. The expansion of the range of issuers beyond was largely determined by the credibility of green bonds. This problem affects all green bond issuers and is related to the concept of greenwashing, i.e., creating the misleading impression that an investment project is environmentally friendly while the issuance is de facto motivated by obtaining economic benefits. However, this does not mean that green investment projects are notoriously suspected of having unethical intentions. Green energy investments are often based on sophisticated knowledge and advanced technology. They are often innovative and, therefore, hitherto unverified in practice. As a result, such projects are often accompanied by insufficient support and confidence in their success and are treated with distrust by investors.

In this article, we have addressed the issue of financing green investment projects aimed at the energy transition implemented by large urban areas. They are a natural ally in halting climate change and improving energy efficiency. What is at stake here is not only energy savings and funding but also environmental quality in highly urbanised areas. An additional challenge for the managers of large cities is to maintain or improve the functionality of the city for its inhabitants, e.g., in the area of public transport. However, the evaluation of financial instruments issued by large cities to finance pro-energy investment projects can be mixed and inconclusive with other municipal instruments issued for non-green reasons.

The aim of this article is to analyse the premium of green bonds issued by municipalities for the implementation of the energy transition process. This premium, known as greenium, expresses investor acceptance of pro-environmental projects. It allows issuers to reduce the cost of financing the project. Due to the diverse purposes that green bond issues can address, the focus has been exclusively on bonds dedicated to energy projects: alternative or renewable energy sources, energy efficiency as well as clean transport, therefore reducing the impact of the purpose of the issue on the investment attractiveness of the municipal bond.

For research purposes, the following research hypothesis was formulated:

- Municipal green energy bonds have a lower yield than similar non-green municipal bonds due to the non-monetary benefits to investors of an identifiable green project.

The hypothesis was verified by comparing the changes in yields of municipal green bonds earmarked for energy projects with corresponding non-green bonds of the same issuer over the same time. The positive verification of the hypothesis makes it possible to conjecture non-financial investor support for the energy transition process implemented by urban centers. This may be important

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for the management of this process. Identifying geranium and its possible determinants would allow the optimisation of energy investment financing strategies for municipalities and cities.

The article is divided into five parts. The first one analyses the rationale for issuing green municipal bonds based on existing research on these instruments. The next part presents the methods used so far to study the problem of green bonds and how the study was conducted in this article. In the third part, the sample of municipal bonds is characterised. The most important issue parameters and the method of bond selection for the research objective are presented. The fourth part of the article presents the results of the research. Some of them, in the authors' opinion – the most interesting ones, are additionally illustrated with charts. The last, fifth part of the article contains the conclusions from the research, general statements related to the raised issue of financing the energy transformation of cities, perceived limitations of the conducted research, and suggestions for further work in this area.

An overview of the literature

The development of the green bond market has resulted in a growing number of studies on the topic. Most of them focus on comparing the returns of green and conventional bonds (Karpf & Mandel, 2018; Kapraun et al., 2019; Bachelet et al., 2019; Zerbib, 2019) or the greenium (Partridge & Medda, 2018). There is conflicting evidence of a greenium (lower credit spread) over non-green issuance, reflecting the green status of the bond. Flammer (2021) finds that investors react positively to green bond issuance, which is consistent with signalling the issuer's commitment to the environment, but also notes that there is no difference in yield between green and non-green bonds. Larcker and Watts (2020) analysed the risk and difference between green and non-green bonds of the same issuer on the same day and found no greenium. Zerbib (2019) showed a mostly negative greenium, which is particularly high in specific market segments, arguing that rating and issue amount are the main determinants of the premium. On the other hand, Karpf and Mandel (2017) document a green bond yield discount of eight basis points, while Baker et al. (2018) found evidence of a premium for these bonds of six basis points. Wulandari et al. (2018) showed that the greenium was 70 bps in 2016 and found that, in general, green bonds were more liquid than conventional bonds. Liquidity was positively related to the yield spread, but this effect diminished over time, so according to the authors, liquidity risk is negligible for green bonds. On the other hand, Bauer and Hann (2010) observed that environmental concern was positively correlated with higher cost of debt and lower credit ratings. Reboredo (2018), in contrast, observed that green bond returns are closely correlated with corporate and government bond returns, while they correlate little with equities or energy assets.

A possible factor that may influence the market performance of green bonds is the type of issuer. The results of Bachelet et al. (2019) indicate that green bonds have a surprisingly higher yield combined with higher liquidity while being slightly less volatile than their closest brown bond counterparts. At the same time, institutional green bonds show a negative greenium and are much more liquid, while private green bonds have a positive greenium and much less liquidity. In the authors' opinion, green bonds can enjoy a negative greenium; therefore, green investments can be financed at a discount. This indicates investors' willingness to pay for environmental sustainability or their lower-risk exposure to green investments. The greenium, however, requires either an established reputation for institutional issuers or green vetting of the project to reduce information asymmetries and provide investors with guarantees against greenwashing. Sharfman and Fernando (2008) showed that lower environmental risk is associated with a lower cost of capital. If bonds do not have a green certificate, the risk of greenwashing is higher, and investors may require a premium.

The above research results identify three reasons issuers want to certify their bonds as green (Flammer, 2021). Firstly, the green certification of a bond increases the credibility of the commitment and sends a valuable signal to the environment, such as the issuer's stakeholders. This argument assumes that issuers can expose their commitment to the environment by allocating significant amounts to green projects. If the issuer's shareholders perceive this to be important, there should be a positive impact on goodwill resulting from the non-monetary utility of such an investment. In the case of municipal companies, concerned citizens may demand that local companies switch to green energy generation. However, many issuing companies are publicly owned, so increasing the value to owners by increasing the share price is of little importance.

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A second rationale for certifying bonds as green is greenwashing, i.e., misrepresenting or exaggerating environmental commitment. This can be achieved through selective disclosure or misleading narratives. The issuer pretends to be materially committed to environmental protection to gain the benefits of such a stance. In the case of municipal projects, the risk of greenwashing appears to be lower due to the often non-commercial nature of investment projects. There is, therefore, no solid reason to mislead stakeholders. Projects are identifiable, and their benefits are more visible. The exception to this rule is greenwashing to achieve political objectives.

A third argument for using green bonds is the possibility of issuing debt at a lower yield, thus lowering the cost of capital for the borrower. Indeed, investors may accept a lower yield in exchange for the benefit of combating climate change.

Much less attention has been paid to the municipal bonds greenium. Bhanot et al. (2022), examining all municipal bonds issued between 2010 and 2021 by U.S. municipalities, showed that green energy bonds command a greenium of 11 basis points over other green municipal bonds of similar risk. In their view, this reduction in the cost of capital translates into a benefit for U.S. municipal stakeholders. These benefits are distinct from other long-term environmental benefits associated with municipal services. Larcker and Watts (2020) showed a slight greenium but found no significant difference in liquidity or price difference for those green bonds that are certified by local governments. In their view, municipalities de facto increase their borrowing costs by issuing green bonds.

The analysis of the greenium is also conducted by the primary and secondary bond markets. The presence of greenium in the primary market promotes lower financing costs for green infrastructure. The difference in bond prices in the secondary market can, in turn, put pressure on prices in the primary market (Zerbib, 2016). One of the first studies on the topic was published by Karpf and Mandel (2018), who analysed the price premium in the secondary market for green municipal bonds. They found an overall average spread of 23 basis points but failed to find any signal for greenium until 2016. A similar analysis was conducted on the U.S. green municipal bond market. Partridge and Medda (2020), based on a yield and benchmarking analysis of municipal bonds, noted that there is evidence of greenium in secondary markets, but it is less pronounced in primary markets. This difference may be because the primary market for municipal bond issues is relatively enclosed, and the secondary market is more accessible to smaller investors. They also noted that green municipal bonds came to market at a discount compared to their vanilla counterparts. This indicates that green bonds are competitive with their brown counterparts and experience greater price appreciation in the secondary market after issuance. They also perceived signs of a trend, with more green bonds being issued at a premium than vanilla bonds. A reason for the problematic identification of greenium in the primary market may also be the so-called 'green halo effect', in which the issuance of green bonds lowers the overall yield curves of an issuer's bonds, not just green bonds (Hale, 2023).

Without excluding the possibility of some positive impacts from the use of municipal green bonds in financing the energy transition, new research on this issue has emerged that addresses not so much the financial benefits but rather the socio-ecological relationships underlying green financing. Castree and Christophers (2015) consider how financial capital can support the energy transition by allocating capital to new climate-friendly socio-economic and socio-ecological infrastructures. Looking at green bonds issued for climate change adaptation through the prism of the financialisation of nature, racial capitalism, and savings, Bigger and Millington (2019) conclude that green debt ultimately fits into existing inequalities. In other words, green climate bonds do not contribute to transformative urban change but rather threaten to exacerbate the risk of racism in financial and environmental terms. The cited research alludes to the concept of post-politics, a kind of 'third way' that seems to transcend class divisions between left and right. Through consensus-building, good governance, and cooperation, this new form of politics makes it possible to sidestep political issues. The absence of ideological conflicts and underlying political interventions means that the remaining activities are relegated to managerial, procedural, and/or technical activities (Mouffe, 2005; Swyngedouw, 2008). The concept of an urban sustainability agenda has many practical examples. Decision makers may differ in their world view, but most often, they agree on goals, e.g. clean and emission-free public transport, increasing the share of green areas in the city, or improving the energy efficiency of urban infrastructure. Such 'agreements across boundaries' are real and demonstrate the possibility of post-politics, although it should also be remembered that this concept is negated by populist groups that refer to 'alternative facts' and truths (Escobar, 2019; Hempel, 2018) for their own politi-

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cal purposes. Further doubts are raised by the conclusions of the case study analysis of the very active municipal green energy bond issuer – the City of Gothenburg (García-Lamarca & Ullström, 2022). In this study, the interviewed administrative staff admit that despite being active in the green financial market and delegating project management to professionals, green bonds do not stimulate green transformation at all. In their opinion, this is despite the conclusions of official municipal reports and the good reputation among investors. However, this does not change the fact that green bonds serve as a financial tool to support a consensual, post-political order that becomes completely and deliberately absent from ideological struggles. From this perspective, they serve to strengthen consensus politics and the socio-ecological status quo rather than actually contribute to a deeper socio-ecological transformation.

The worldview factor in the energy transition financing process is related to the conditions the local authority creates for investors and the quality of the projects they want to develop. Hu and Chang (2023), for example, that municipalities in U.S. counties leaning towards the Democratic Party, identified by votes in the U.S. presidential election, are more likely to issue green municipal bonds compared to regular bonds than those in counties leaning towards the Republican Party. The authors find no significant greenium in a sample of green and regular municipal bonds issued by the same issuer.

Research methods

As mentioned in the literature review, a major component of the green bond analysis is the study of the greenium. The greenium is the difference between a green bond yield and a corresponding 'twin' brown bond with the same characteristics. Rejecting a difference equal to zero in the analysis allows the hypothesis of a premium between green and brown bonds to be accepted. In the case of a greenium, the difference between green and brown bond yields is expected to be negative. This implies that investors are willing to pay more for the environmental characteristics of green bonds, or, if judged another way, it could be argued that they are driving higher demand for bond classes that have less environmental and regulatory risk than traditional brown bonds.

According to MacAskill et al. (2021), the methodological heterogeneity of studies is one of the reasons for doubts about the consensus on the existence of a greenium in the green bond market. Studies assessing the greenium in the secondary market most commonly use ordinary least squares (OLS) and generalised least squares (GLS) regression with fixed effects (F.E.). An alternative approach to analysing the correlation of variables over time is the dynamic conditional correlation (DCC) method. The DCC method is used to analyse daily data. Bond yield, maturity, the amount issued, rating, and currency are often used as independent variables in OLS and GLS regressions. In studies of the greenium in the primary market, a basket of comparable issues is used. This allows price differences to be determined for green bonds and brown bonds in the same basket. Many studies focus on the relationship of the greenium to bond characteristics such as rating, the amount issued, government and non-government issuer, liquidity, or volatility. Attention is drawn to data limitations, which makes it difficult to compare different studies difficult (MacAskill et al., 2021).

For example, Preclaw and Bakshi (2023) studied a global set of green bonds issued in 2014-2015 using OLS regressions. Baker et al. (2018) also analysed a large sample of green municipal bonds from 2010-2016 using OLS regressions. Hachenberg and Schiereck (2018) analysed spreads via a yield curve using a global sample of matched bonds. Karpf and Mandel (2018) studied a large sample of 1880 municipal bonds using the Oaxaca-Blinder decomposition method. Bachelet et al. (2019) studied a global sample of bonds using the least squares (OLS) method and fixed effects. Nanayakkara and Colombage (2019) used a global set of matched bonds and compared them using panel data regressions. Zerbib (2019) also used a two-stage regression after the matching procedure, accounting for fixed and cross-sectional effects. Partridge and Medda (2020) analysed and, conducted an analysis of matched pairs of green and brown bonds. The paired bonds in the study were issued at the same time and under the same statement, had the same issuer, the same use of proceeds, the same issue date, maturity date, and coupon. In the primary and secondary market studies, price differences were divided into annual averages to analyse the greenium over time and market growth. Larcker and Watts (2020), using a strict matching procedure for green and non-green bonds, calculated the inci-

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dence of mean greenium using t-tests and Wilcoxon tests and the methodological approach used by Baker et al. (2018).

In our analysis, we focus on issuers of municipal green-energy bonds. Green bonds were dedicated to financing alternative energy, clean transport, eligible green projects, and energy efficiency. This is a small and specialised asset class. Our research sample comprises only 44 bond issues, 16 municipal issuers, and a total issue size of just under USD 4.5 billion. The limited size of the surveyed bond base and, in many cases, the shortlisting history in the Reuters database did not allow for a cross-sectional study of the greenium using the least squares method.

We chose to analyse the greenium by examining the differences in yields between individual matched pairs of municipal green bonds and municipal brown bonds. By calculating the average bond yields over the periods under analysis, we used the yield levels published by Reuters for each day. The Wilcoxon signed-rank test was used to test the significance of bond yield differences. The test considers the sign of the differences, their magnitude, and their order. After arranging the differences into an ascending series, the test assigns ranks to the differences. Then, it sums up the ranks of positive and negative differences separately. The smaller of the resulting totals is the Wilcoxon test value, which decides whether or not to reject the null hypothesis when compared with the corresponding theoretical value. The null hypothesis is that there is no difference between the variables under study. The Wilcoxon test was prompted by the lower requirements that needed to be met than parametric tests, and its indication was the strongest alternative to the Student's t-test for related variables.

One of the research methodology's key challenges is matching green bonds to their closest brown counterparts appropriately. Matching methods are widely used in the financial literature to compare environmentally responsible assets with conventional assets (Bachelet et al., 2019; Larcker & Watts, 2020). We searched the dataset for a brown bond with the best matching key characteristics for each green bond. Both bonds had to have the same issuer, the same currency, and the same rating. The bonds also had to have the same coupon type – only fixed-rate bonds were used. The other characteristics of the bonds, i.e., maturity date, coupon rate, and amount issued, caused problems in a close match with such a limited database. A trade-off had to be made between the number of bonds matched and the accuracy of the match. In matching the bonds, we were primarily guided by the maturity date. We assumed that investors investing for the same period would expect the same return. This would imply that investors would not be willing to accept a lower return to support environmentally friendly projects, and the greenium is zero. Our approach, which mainly considered the maturity date, did not, for example, meet the recommendations for the coupon rate differential of matched bonds proposed by (Bachelet et al., 2019), for example, but this allowed the analysis to be carried out and ten pairs of green and brown bonds to be identified.

Results of the research

The average issue value is USD 101.9 million, which is quite a high number. This shows that the issues may not be too numerous, but they are for quite significant amounts. The municipal green-energy market is growing, but it is not an exponentially strong growth. The number of issues and the value is increasing, but we can see some regression in 2022. The amount of financing raised is clearly lower. This may be due to an increase in global interest rates. The increase in the cost of financing may somewhat limit the willingness for new issues.

The summary of issues by specific municipal green-energy bond issuers consists of 16 cities or municipalities. New Zealand's Auckland certainly stands out, having issued almost ¼ of all green-energy issues. It is very active and also issues in foreign markets and currencies. Swedish cities, especially Gothenburg, Malmo, and Ostersund, are also very active. Shenzhen, Paris, and Ottawa also attract attention. Issues are few, but the amounts of bonds sold are significant.

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Table 1. Value and number of municipal green-energy bond issues by year

Year	Bonds	Amount (million USD)
2014	5	332.55
2015	2	439.74
2016	2	73.58
2017	4	261.85
2018	4	257.30
2019	5	328.88
2020	4	798.53
2021	9	1,336.68
2022	8	605.76
2023*	1	49.06
Total	44	4,483.93

* 2023 includes only January.
Source: Reuters Eikon database.

Table 2. Value and number of municipal green-energy bond issues by issuer

Issuer	Bonds	Amount (million USD)
AUCKLAND	6	967.90
GOTHENBURG	6	623.99
SHENZHEN	2	545.45
PARIS	2	448.96
MALMO	8	416.98
OTTAWA	1	400.49
OSTERSUND	6	336.03
STOCKHOLM	1	137.36
LUND	3	127.55
TORONTO	1	114.43
JOHANNESBURG	1	81.38
OREBRO	2	73.58
VASTERAS	2	73.58
CAPE TOWN	1	55.82
LINKOPING	1	49.06
REYKJAVIK	1	31.37

Source: Reuters Eikon database.

The Swedish krona stands out in terms of the currencies in which green-energy bonds are issued. It accounts for almost 40 percent of the bonds issued. This shows the importance of Swedish city issuances in this market. Furthermore, issuances in CHF are noteworthy, even though Swiss agglomerations have not chosen to seek such financing. These are the issues of Auckland, which raises funding in foreign markets by issuing bonds in foreign currencies as well. However, by far, the most common issuance is in national currencies.

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Table 3. Value and number of municipal green-energy bond issues by currency of issue

Currency	Bonds	Amount (million USD)
SEK	29	1,838.13
NZD	4	734.97
CNY	2	545.45
CAD	2	514.91
EUR	2	448.96
CHF	2	232.94
ZAR	2	137.20
ISK	1	31.37

Source: Reuters Eikon database.

Finally, there is one more summary, considering the features of bonds. In terms of design, fixed-rate bonds dominate. Floating-rate bonds are mainly issued by Swedish entities. If we look at the market where green-energy bonds are placed, it is dominated by the domestic market (55 percent share) and the euro market with 26 percent. However, we can conclude that green-energy bond issuers raise a significant proportion of their funding in the domestic market. In the case of municipally issued green-energy bonds, clean transport financing dominates the purpose of raising financing, as much as 83 percent of the total funds obtained.

Table 4. Value and number of municipal green-energy bond issues by bond characteristics

Characteristic	Bonds	Amount (million USD)
Coupon Class		
Fixed Coupon	27	3,505.27
Floating Coupon	17	978.67
Market of Issue		
Domestic	25	2,527.22
Eurobond	15	1,178.33
Foreign	4	778.39
Use of Proceeds		
Alternative Energy	1	78.49
Clean Transport	37	3,752.31
Eligible Green Projects	4	513.32
Energy Efficiency	2	139.81

Source: Reuters Eikon database.

The bonds studied were matched in green-energy bond – brown bond pairs. Each of the bond pairs compared has a different research period due to the limitations of the database, but it is also in line with the purpose of the study. In the analysis carried out, we wanted to determine whether green-energy bond financing was accompanied by greenium versus other debt instruments of the municipal issuer at the same time. The study ultimately used ten pairs of bonds: 2 pairs of green-energy bonds offered by the local governments of Paris, Shenzhen, and Malmo. An analysis of bond pairs from Ottawa, Toronto, Stockholm, and Auckland complemented the study. Green-energy bonds are denoted as (G) and their brown counterparts as (B). Details of the parameters of the compared bonds are shown in Table 5.

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Table 5. Characteristics of the analysed pairs of municipal bonds

Couple	ISIN	Issue Date	Maturity Date	Fixed Coupon	Amount	Currency
PARIS1(G)	FR0013054897	18/11/2015	25/05/2031	1.75	300,000,000	EUR
PARIS1(B)	FR0012030526	17/07/2014	17/07/2031	2.51	70,000,000	EUR
PARIS2(G)	FR00140070G1	06/12/2021	06/12/2051	0.963	100,000,000	EUR
PARIS2(B)	FR0013516259	08/06/2020	08/06/2050	0.963	180,000,000	EUR
TORONTO(G)	CA891288DZ29	21/12/2021	21/12/2031	2.20	150,000,000	CAD
TORONTO(B)	CA89119ZAP86	18/10/2021	20/10/2031	2.47	150,000,000	CAD
SHENZHEN1(G)	HK0000778479	19/10/2021	19/10/2024	2.70	1,500,000,000	CNY
SHENZHEN1(B)	CND100059TP1	09/10/2021	12/10/2024	3.32	3,000,000,000	CNY
SHENZHEN2(G)	HK0000778487	19/10/2021	19/10/2026	2.90	2,400,000,000	CNY
SHENZHEN2(B)	CND100059Q02	21/10/2021	25/10/2026	3.59	1,500,000,000	CNY
OTTAWA(G)	CA689551FG93	11/05/2020	11/05/2051	2.50	525,000,000	CAD
OTTAWA(B)	CA689551ED71	30/07/2013	30/07/2053	4.20	360,000,000	CAD
MALMO1(G)	XS1913339690	21/11/2018	17/09/2024	0.875	500,000,000	SEK
MALMO1(B)	XS2457008493	15/03/2022	15/03/2024	0.478	700,000,000	SEK
MALMO2(G)	XS2072775765	29/10/2019	14/03/2025	0.250	250,000,000	SEK
MALMO2(B)	XS2136688624	17/03/2020	17/09/2025	0.294	500,000,000	SEK
STOCKHOLM(G)	XS2382242092	01/09/2021	01/09/2026	0.228	1,400,000,000	SEK
STOCKHOLM(B)	XS2159897391	22/04/2020	22/04/2026	0.600	1,650,000,000	SEK
AUCKLAND(G)	NZAKCDT484C5	10/07/2019	10/07/2025	2.013	150,000,000	NZD
AUCKLAND(B)	NZAKCDT363C1	24/03/2015	24/03/2025	4.176	125,000,000	NZD

Source: Reuters Eikon database.

The selected green-energy bond – brown bond pairs were analysed in order of daily yields, and the Wilcoxon signed-rank test was used to test the significance of the differences in bond yields. All differences tested were found to be statistically significant. However, the magnitudes of the differences are quite variable in terms of value and stability over time. The signs of the differences also vary, indicating both the presence or absence of greenium. The results obtained are shown in Table 6.

For the first bond pair, in which Paris is the issuer, a low (6.7 basis points) statistically significant greenium could be observed over the period studied. The analysis period was relatively long, from 12/11/2015 to 30/06/2023, and allowed for observations in a changing economic environment. At the beginning of the study period, the bond yield differential took on positive values, with a clear decrease in the differential only occurring in the second part of the study period, when interest rates on global markets began to rise, caused by increases in inflationary pressures. This would indicate that the green bond reacted more weakly to changing market conditions than the brown bond. The second pair of bonds, also issued by Paris, showed a low positive spread of less than two basis points. The bonds analysed are long, with 27 years to maturity. In this case, one could argue that perceptions of the green and brown bonds are similar for such long-term instruments.

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Table 6. Characteristics of yields (Y) and average yield differential of selected municipal bonds in the examined period

Couple	Mean (Y)	Median (Y)	Min. (Y)	Max. (Y)	SD (Y)	Difference
Research Period 12/11/2015 – 30/06/2023						
PARIS1(G)	1.1177	1.1487	-0.0724	3.5095	0.8519	-0.0670***
PARIS1(B)	1.1846	1.1976	-0.0184	3.7564	0.8994	
Research Period 08/12/2021 – 30/06/2023						
PARIS2(G)	2.7753	2.9486	0.8516	3.9978	0.9206	0.0181***
PARIS2(B)	2.7572	2.9285	0.8216	3.9778	0.9196	
Research Period 09/03/2022 – 30/06/2023						
TORONTO(G)	3.7866	3.7920	2.7110	4.4900	0.3057	-0.4657***
TORONTO(B)	4.2523	4.2640	3.0410	4.9980	0.3225	
Research Period 19/10/2021 – 30/06/2023						
SHENZHEN1(G)	2.9748	2.9820	2.4824	3.3035	0.1584	0.1640***
SHENZHEN1(B)	2.8108	2.8364	2.3407	3.3695	0.2415	
Research Period 26/10/2021 – 30/06/2023						
SHENZHEN2(G)	3.1225	3.1188	2.8315	3.6573	0.1313	-0.0389***
SHENZHEN2(B)	3.1614	3.1987	2.7537	3.5888	0.2041	
Research Period 15/07/2020 – 30/06/2023						
OTTAWA(G)	3.4273	3.0590	2.2620	5.0430	0.8134	0.0429***
OTTAWA(B)	3.4703	3.1560	2.2180	5.0200	0.7900	
Research Period 06/04/2022 – 30/06/2023						
MALMO1(G)	3.2013	3.2924	1.5276	4.3139	0.6496	0.0884***
MALMO1(B)	3.1130	3.1611	1.3780	4.1917	0.7305	
Research Period 16/09/2022 – 30/06/2023						
MALMO2(G)	3.5747	3.5584	3.0360	4.1907	0.2797	0.0701***
MALMO2(B)	3.5045	3.4900	2.9434	4.1160	0.2356	
Research Period 27/10/2021 – 30/06/2023						
STOCKHOLM(G)	2.6696	3.1708	0.5660	3.9403	1.0874	-0.0288***
STOCKHOLM(B)	2.6984	3.2366	0.5727	3.9926	1.1173	
Research Period 17/07/2019 – 30/06/2023						
AUCKLAND(G)	2.6699	1.9201	0.4916	5.8225	1.6928	0.0072***
AUCKLAND(B)	2.6627	1.9033	0.5076	5.9515	1.7238	

*** ($p < 0.01$).

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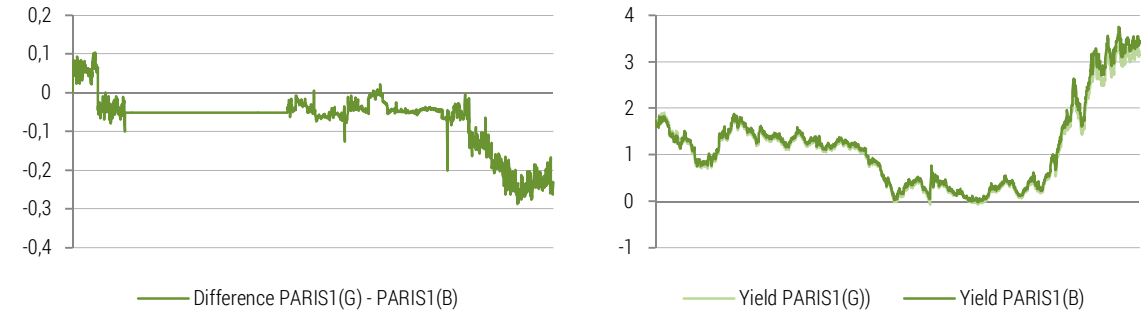

Figure 1. **(a)** Yield differences (in %) between the PARIS1(G) green bond and the PARIS1(B) brown bond over the period 12/11/2015 – 30/06/2023. **(b)** Yields (in %) of the PARIS1(G) green bond and PARIS1(B) brown bond for the period 12/11/2015 – 30/06/2023

The third pair involves bonds issued by Toronto. For the analysed pair, there is a clear statistically significant greenium throughout 46 basis points. However, it should be noted that the analysis period is relatively short, covering the range from 9.03.2022 to 30.06.2023.

The issuer of the fourth pair of bonds is Shenzhen. We can observe that during the period under study, the green bond reacts to market changes in yields with a lag. Declines or increases in yields occur first for the brown bond. The average yield difference between the bonds is positive, there is no greenium, but the difference fluctuates over the period under study in a wide range of plus or minus about 60 basis points. The fifth pair of bonds was also issued by Shenzhen. In this case, there was a low greenium, at less than four basis points. As with the fourth pair of bonds, there were significant fluctuations in the yield differential of the bonds. The changes in yields show a delayed response of the green bond, with yields rising later and falling later than the brown bond. With a relatively short analysis time, such large fluctuations may have some impact on the level of the yield spread recorded.

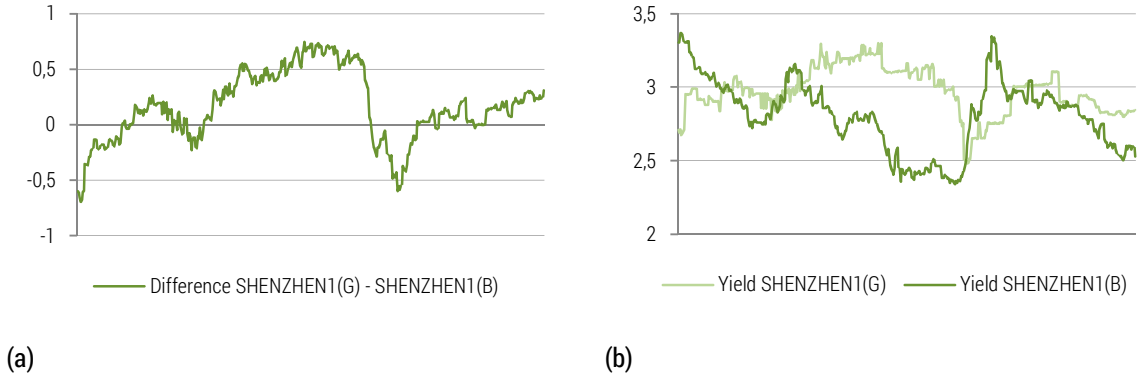

Figure 2. **(a)** Yield differences (in %) between the SHENZHEN1(G) green bond and the SHENZHEN1(B) brown bond over the period 12/11/2015 – 30/06/2023. **(b)** Yields (in %) of the SHENZHEN1(G) green bond and SHENZHEN1(B) brown bond for the period 12/11/2015 – 30/06/2023

The sixth bond pair is issued by Ottawa. In this case, there was a low significant greenium of just over four basis points. Over the period under review, it can also be observed that the greenium disappears as interest rates and bond yields rise in the market. However, it should be highlighted here that there are some problems with adequately matching green and brown bonds, which may not be without impact on the comparison results.

The seventh bond pair issued by Malmo did not show the presence of greenium. However, the possibility of using a short period of analysis and the existence of significant fluctuations in the yield

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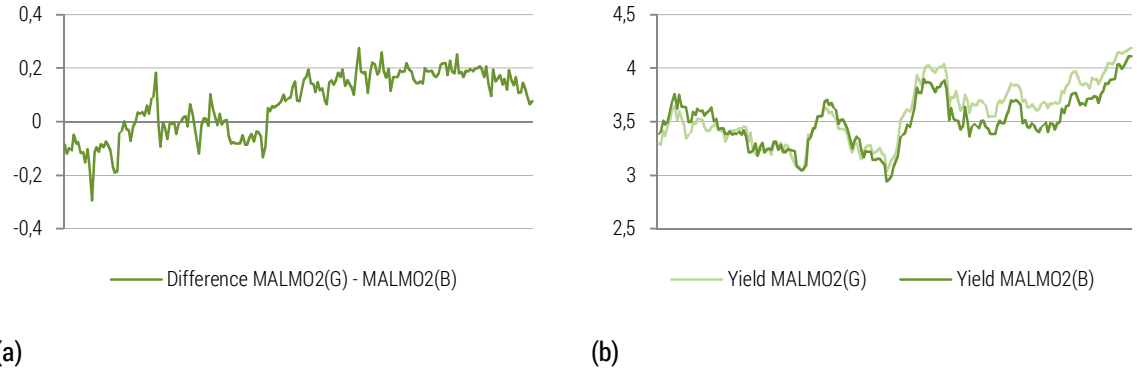
spread from almost +40 basis points to -30 basis points should be highlighted. The eighth pair of bonds were also issued by Malmo, and in this case, no greenium was observed. During the analysis period, the differential was first negative (greenium was observed), but as bond yields rose in the market, the differential became positive, and the greenium disappeared.



(a) (b)

Figure 3. **(a)** Yield differences (in %) between the MALMO2(G) green bond and the MALMO2(B) brown bond over the period 12/11/2015 – 30/06/2023. **(b)** Yields (in %) of the MALMO2(G) green bond and MALMO2(B) brown bond for the period 12/11/2015 – 30/06/2023

The ninth pair of bonds was issued by Stockholm. A low greenium of less than three basis points was recorded in this case. However, it is important to emphasise the short period of analysis and the occurrence of a sharp increase in bond yields due to changes in monetary policy, which may have influenced the final result. We did not observe a stable greenium here, but rather an oscillation of the yield spread around the zero level.

The tenth bond pair analysed was issued by Auckland. In this case, no greenium was recorded, and there was a positive differential of 7 basis points, but we did observe some fluctuations. There was a stable positive differential in the first part of the research period. However, after the bond yields rose sharply and then stabilised at a high level, there was a more substantial decline in the green bond yields compared to the brown bond, resulting in a negative differential of 10-15 basis points.

Discussion/Limitation and future research

To summarise the review of the difference analysis of the ten bond pairs, it is not easy to come to a clear conclusion regarding greenium observations in the sample. In five cases, there were statistically significant average positive yield differences between green and brown bonds, and, at the same time, in five cases, the differences were negative, indicating a greenium. Furthermore, it should be noted that the bond yield differences examined were sometimes subject to significant fluctuations, even by tens of basis points, and the final results of average differences were low in the order of a few basis points. A strong and stable greenium, at around 50 basis points, was recorded in only one case, bonds issued by Toronto. Therefore, given the significant limitations of the sample and the results obtained, a sustained and significant greenium effect could not be observed due to the high propensity of investors to finance environmentally friendly projects. Therefore, the research hypothesis posed in the article should be rejected.

However, this does not imply a lack of progress in research on applying green bonds in the urban energy transition. Firstly, the yield differential between urban green and brown bonds was observed to be relatively stable. Only in the case of Shenzhen was a sharp turbulence of yields perceived. This applies to both green and brown bonds. Secondly, the yield differential, regardless of the presence or absence of greenium, is small and rarely reaches 0.5 percent (50 bps), indicating limited opportunities to reduce the cost of green energy project financing, but also not generating risks for the unexpected excess cost of financing for such projects. Thirdly, the change in yield differentials (greenium

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values) intensifies with changes in the interest rate market. This area requires further research since green bonds have so far not been analysed over a more extended period of cost of capital changes. There was no adequate environment for this. Identifying the strength and direction of interest rate changes on greenium seems to be important information for local governments planning green energy projects. Knowledge also seems important in other pro-environmental investments.

Another factor that may determine the research results is the issuer's geographical location and the related legal regulations for issuing green bonds. Despite the existing certification of these instruments, they are still perceived differently by investors and may be exposed to greenwashing even if issued by local or state governments. It was only in November 2023 that the European Union adopted a new regulation on European green bonds and optional disclosures for bonds marketed as environmentally sustainable and sustainability-linked bonds (Regulation, 2023), which introduced new requirements and standards for bond issuers wishing to label their offerings as 'European green bonds' in offerings to investors in E.U. member states. Until now, the standardisation of green bonds has been more accessible, which has entailed more significant risks for investors. Some European countries have made an effort to standardise on their own at the national level to reduce this risk. An example is the Swedish government, which in 2020 adopted a framework for issuing sovereign green bonds, setting out rules for the eligibility of expenditures that can be financed with green bonds. Municipal green bond issuances outside Europe are even more formally diverse and thus subject to the risk of greenwashing because countries and, thus, local governments are not obliged to adopt a unified law. In some cases, however, this can support the development of the green municipal bond market; China is an example of this. For several years, the country's government has played an active role in designing an enabling regulatory environment through law and policy, providing the necessary financial infrastructure and appropriate incentives for green bond investors and issuers. In a country so centralised, government support of green investments and municipal green issuance significantly reduces the risk for investors by increasing greenium.

Conclusions

In our article, we have applied the analysis method used in the existing literature to compare the findings with other studies. It is worth noting, however, that all the studies on greenium are based on the same assumption. It is presumed that, under the same characteristics and financial conditions, investors interested in greenium can accept a lower return on investment. This approach creates scope for greenium; consequently, the yield difference between a green bond and its brown counterpart should be negative. However, as noted by Basar (2023), an issuer's entire green debt curve often has a lower spread than the non-green curve, so comparing green and non-green issues from the same issuer may not provide enough difference to detect greenium. Furthermore, Michaelsen (2023) states that a true test of the difference in green bond prices would be to have two identical bonds priced on the same day. However, it is common in the municipal debt market for local governments to use green and brown bonds interchangeably, naturally making comparison difficult. A similar problem also occurred in our study.

Other studies often assume that green financing is the way to build a sustainable future, with little attention paid to what a sustainable future means within the existing system. This issue resonated loudly in the cited study by García-Lamarca and Ullström (2022). It is noteworthy, however, that despite the lack of realisation of the goals of green energy and sustainable development, the respondents surveyed do not evaluate such activities unequivocally negatively, pointing to social advantages. Understanding the nature of green energy projects is a separate issue. Profitability analyses mostly have a short perspective. Perhaps this viewpoint should be extended to a longer horizon. No doubt, such projects and the associated instruments should be easy to identify.

It is also worth noting that the investment policy of municipalities is often an extension of national policy, making it difficult to assess the impact of investments on the environment and thus determine greenium. In our study, there is no basis for the research hypothesis, which does not necessarily imply the absence of greenium as a financial market phenomenon. It seems that the key to explaining the ambiguity of the results of the studies, both those conducted in the article and the previous ones quoted in the text of the article, is not so much whether a particular bond is green or brown. Previous

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research, including ours, suggests that investors are aware of how pro-environmental an investment project is and the determination of the entity implementing it. Investors are then prepared to accept a lower yield on the bonds on offer, allowing greenium to emerge. The issuer's reputation seems to be of secondary importance because, as mentioned, municipalities often use green and brown bonds interchangeably, treating them as a collective source of capital. Difficulties in identifying greenium may also indicate the need to broaden the spectrum of the study to include the characteristics of the investments made, making the research process more difficult and sometimes even impossible. If, however, the mere comparison of green and brown bond yields is insufficient to identify greenium, then this raises the perplexing question of the study's validity. For it may turn out that it is not so much the type of bond that determines the appearance of greenium, but rather the investment project and its environmental consequences that result from it. The investors' reaction is then an assessment of the project's relevance to climate goals. This would have important implications for issuers, who would be forced to make pro-environmental investments fully transparent and rational in order to finance them more cheaply. Thus, as can be seen, our research, even though it does not solve the problem of identifying greenium in the municipal green bond market, seems to be another argument for continuing research on this financial phenomenon.

The contribution of the authors

Conceptualization, J.M. and P.S.; literature review, J.M.; methodology, P.S.; formal analysis, J.M. and P.S.; writing, J.M. and P.S.; conclusions and discussion, J.M. and P.S.

The authors have read and agreed to the published version of the manuscript.

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Jakub MARSZAŁEK • Paweł SEKUŁA

MUNICYPALNE ZIELONE OBLIGACJE W PROCESIE TRANSFORMACJI ENERGETYCZNEJ

STRESZCZENIE: W artykule skupiamy się na zielonych obligacjach emitowanych przez samorządy lokalne na potrzeby transformacji energetycznej miast. Wykorzystując obligacje notowane na rynkach publicznych, porównaliśmy rentowność komunalnych obligacji energetycznych z rentownością innych obligacji tego samego emitenta, w tym samym czasie. Porównania dokonano za pomocą testu kolejności par Wilcoxona. Celem badania było stwierdzenie obecności greenium, które może w znaczący sposób obniżyć koszty finansowania projektów zielonej energii realizowanych przez ośrodki miejskie. Do badania włączono wybrane aglomeracje z niemal każdego kontynentu, posiadające różne doświadczenia na rynku finansowym. Wyniki wskazują na duże zróżnicowanie w występowaniu greenium, zarówno pod względem wartości, jak i stabilności w czasie. Może to oznaczać, że na jego właściwości wpływają inne czynniki, pozafinansowe. Wyniki badania wskazują jednak na potencjał obniżenia kosztów finansowania transformacji energetycznej realizowanej przez miasta i mogą mieć znaczenie praktyczne.

SŁOWA KLUCZOWE: obligacje zielone, municypalny, transformacja energetyczna, efektywność energetyczna, zarządzanie finansami

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