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Green bonds in the Russian market: Assessing environmental influence on returns

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Abstract

In this paper, we study whether the environmental characteristics of assets influence their returns in the case of the Russian bond market. Our main goal for this study was to research this issue for Russia using the same methodology as in studies for developed markets to allow for comparison of results. We use the twin bond methodology and consider expected returns. Our main hypothesis is that brown (i.e., non-green) assets should have a higher yield compared to green ones. Indeed, we find, predictably, that green bonds have a lower yield to maturity. This result is in line with previous results for other markets and suggests that green financing might be cheaper for companies.

Keywords: green bonds, ESG, sustainable investing, Greenium.
JEL classification: G10, G12, O5.

1. Introduction

Environmental problems and climate change remain among the most important global issues. The pressure to take action against expected negative consequences leads to changes in social norms and government regulations, resulting in changes in the cost-revenue structure of companies and investors' preferences. Approximately 93% of the respondents reported using at least one approach to reduce climate risks when structuring their portfolios (Krueger et al., 2020).

Stimulated by environmentally concerned investors, financial markets should help mitigate climate risks by reallocating investment capital towards green projects[1] at the expense of brown ones (Giglio et al., 2020). If this holds true, financial assets can be categorized into two classes based on their performance when environmental risks materialize: those with a negative risk premium

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[1] Green projects are more environmentally friendly as opposed to brown ones that are more environmentally problematic.

(as a type of insurance against undesirable world states) and the rest (Giglio et al., 2020). Therefore, the environmental risk premium can be defined as the expected excess return of the corresponding hedging portfolio. Baker et al. (2022) propose another theoretical approach to explain the yield spread between green and brown assets by identifying a subset of investors who retain underperforming green assets in their portfolios due to a specific component in their utility function related to a sense of social responsibility. This approach directly considers societal norms and values by incorporating them into the investors' utility function.

If one acknowledges the significance of environmental threats to portfolio holders, the next question is how financial markets can help hedge such risks. As pointed out by Giglio et al. (2020), the impacts of climate change are uncertain and will materialize at some unspecified moment(s) in the distant future, suggesting that neither financial derivative markets nor insurance products can offer hedging solutions. Investors are then tasked with constructing their own portfolios that hedge climate risks by connecting asset returns to the environmental attributes of companies.

Independently analyzing climate risk exposure and evaluating highly specialized environmental indicators of various companies could be a labor-intensive process entailing additional costs, potentially inaccessible to individual investors. The issue of asset selection for green portfolios by investors can be addressed if they could rely on environmental performance assessments or E-scores assigned by rating agencies, non-governmental organizations, or regulatory bodies. This incurs additional costs for all involved parties, including the expense of third-party verification of financial assets to ensure they meet environmental standards, along with the costs of subsequent classification and auditing of non-financial reports. Hyun et al. (2021) discovered evidence that bonds with verified green labels offered a lower yield (24–36 basis points) than non-verified green bonds. This outcome underscores the significance of third-party verification that financial market investors can trust. Avramov et al. (2022) arrive at a similar conclusion, indicating that rating uncertainty correlates with a higher market premium and reduced demand from investors.

Identifying a yield spread between green and brown assets in the financial market helps address the question of the advisability of government support for either the issuers or holders of environmentally graded assets, thereby enabling them to play a role in reducing negative environmental impacts. There is a wealth of literature assessing the influence of environmental sustainability on the performance of various financial assets, including stocks (Pástor et al., 2021; In et al., 2019; Bolton and Kacperczyk, 2021), bonds (Flammer, 2021; Hachenberg and Schiereck, 2018; Nanayakkara and Colombage, 2019; Haciomeroglu et al., 2022), commodities (Wang et al., 2023; Dutta et al., 2021; Ferraro et al., 2005), and real estate (Bernstein et al., 2019; Eichholtz et al., 2019). However, most research in this area focuses on either well-developed markets (such as the U.S., Germany, China, OECD) or global financial markets.

We investigate the presence of such a yield spread in Russia, which, until recently, has been deeply integrated into the global trade and financial system, and is characterized by an underdeveloped financial market. Russia's global integration meant that stricter environmental regulations in foreign markets impacted its busi-

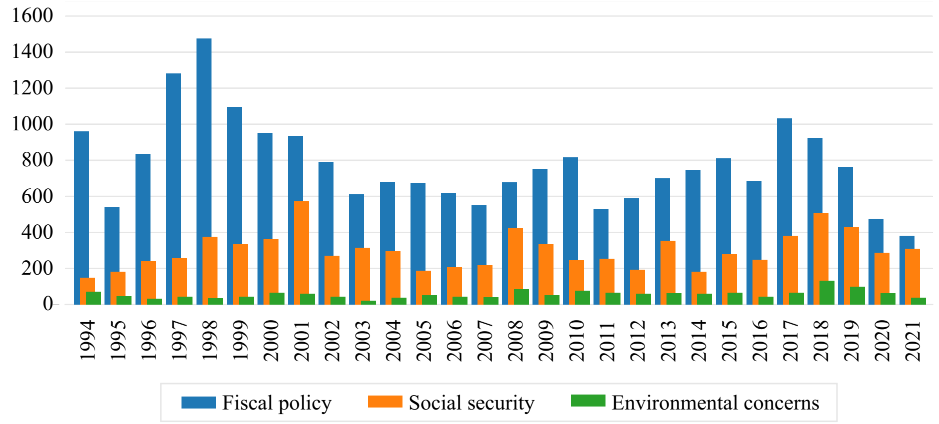

Fig. 1. Number of mentions of the issues of fiscal policy, social security and environmental concerns in the State Duma.

Source: Authors' estimate based on Dekoder.org (2021).

nesses. Under a Carbon Border Adjustment Mechanism,[2] Russian exports were projected to incur adjustment costs of nearly 38 billion euros from 2026–2035.[3] Russia has developed the Strategy of Ecological Security of the Russian Federation until 2025,[4] and despite increasing isolation, ESG is listed among its long-term priorities for financial market development.

While attention to environmental issues at the state level in Russia has increased over time (Fig. 1), it still remains relatively limited. In the past two years, climate policy issues have continued to be relevant for Russian policymakers, as evidenced by research activity at the Bank of Russia[5] (see Andreyev and Nelyubina, 2024; Turdyeva, 2024).

Russia's financial market can be characterized as 'thin' or underdeveloped (with a score of 0.44 out of 1.00 in the IMF Financial Development Index 2020,[6] compared to 0.6 for the banking system). This indicates limited opportunities for hedging environmental risks within the Russian financial market. However, the importance of hedging such risks may increase in the near future, given the predominance of small private investors in number and their restricted trading options elsewhere due to ongoing sanctions and counter-sanctions.

Existing studies on environmental issues in the Russian financial market predominantly consist of literature reviews (e.g., Kiseleva, 2021) or focus on a limited number of companies (Filimonova et al., 2020). One notable exception is a study that examines the accurate measurement of climate risk ratings using input-output tables to properly identify credit risks (Penikas and Vasilyeva, 2023). Our objective is to investigate whether there is a disparity in bond yields

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[2] European Commission. Proposal for establishing a carbon border adjustment mechanism. COM(2021) 564 final, 2021/0214(COD). https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A52021PC0564

[3] Kept. https://mustread.kept.ru/articles/esg/bezuglerodnaya-dieta-kak-rossiyskiy-biznes-gotovitsya-k-vvedeniyu-transgranichnogo-uglerodnogo-regul/ (in Russian).

[4] Order of the Government of the Russian Federation No. 1124-r *On the approval of the plan for the implementation of the Strategy for Environmental Security of Russia until 2025*, dated 29 May 2019. http://static.government.ru/media/files/8JZnJlTgyjhYA9AyYoDVKBmD9jLi8yGK.pdf (in Russian).

[5] We are grateful to the anonymous reviewer for drawing our attention to these recent working papers.

[6] https://data.imf.org/?sk=f8032e80-b36c-43b1-ac26-493c5b1cd33b

based on the environmental characteristics designated by a regulatory body in the Russian financial market. Additionally, we seek to replicate methodologies utilized in larger financial markets to enhance the comparability of our findings with previous research.

Building on existing literature, we categorize green-labeled assets as devoid of environmental risk. As a result, our main hypothesis consists of two parts: (1) a return differential should be expected among assets based on their environmental attributes, and furthermore, (2) green assets are anticipated to yield lower returns compared to brown assets. Consequently, a portfolio designed to hedge environmental risks is expected to exhibit a negative risk premium. Our findings concerning bonds are robust and indicate a Greenium of approximately 30–40 basis points over our 10-month study period.

Our contribution to the literature is twofold. Firstly, we expand upon existing research by examining the yield spread between green and brown bonds across various countries. Specifically, we explore an emerging market economy — Russia — which has not been extensively studied in this context. By employing methodologies used in prior studies of advanced financial markets, we ensure the comparability of our results. Secondly, we investigate a financial market where environmental considerations are secondary, meaning they were not initially driven by societal factors but rather by two predominant groups. The first group comprises large Russian companies with bonds traded in foreign financial markets or engaged with foreign clients, thereby necessitating alignment with heightened environmental standards. The second group consists of major institutional investors in the Russian financial market who created demand for green assets. Notably, these dual factors contribute to observable distinctions.

The paper examines the selection of empirical methodology, the data available for analysis, the outcomes of empirical modeling, and conducts robustness checks. A recap of our discoveries and remaining questions are presented in the concluding section.

2. Methodology

Bonds, unlike stocks, allow for direct calculation of expected return through yield to maturity. Thus, we have a specific hypothesis: increased demand for green (environmentally friendly) bonds leads to their higher prices and lower yields to maturity. If confirmed, this hypothesis has practical implications: “if green bond investors are willing to trade off financial returns for societal benefits, companies may issue green bonds to obtain cheaper financing (cost of capital argument)” (Flammer, 2021, p. 1).

A positive price premium leads to a negative yield-to-maturity premium, i.e., the difference in yields between green and non-green bonds with equal or, at least, similar other characteristics (*Greenium*) should be negative. The best way to evaluate the Greenium is through *twin bonds*, i.e., two issues with the same credit rating, issuer, volume size, coupon rate, issue date, and maturity date. This allows for a comparison of two bonds that are identical in everything except for their greenness (PST). A classic example of twin bonds is the case of two German federal issues of 10-year zero-coupon bonds (identical in all respects except for dates and volumes). For them a stable negative Greenium was found ranging from –2 to –6.5 basis points for the period from September 2020 to September 2021 (Deutsche Bundesbank, 2021). A similar result was shown by two other pairs of German twin bonds, namely by 5-year and 30-year issues.

In most cases, however, finding twin bonds is a difficult task. A significant difference in one of the characteristics of the two issues requires a special methodology for comparing them to identify the Greenium. Hachenberg and Schiereck (2018) offer a way to estimate the yield spread of green and non-green bonds through *i*-spreads that compare the bonds' yield with a risk-free benchmark (specifically, the swap rate at the same maturity) and then look at how these differ. Two advantages of this method are: the ease of cross-country comparison in different currencies and the availability of the swap curve without additional estimation, in contrast to the government bond curve. However, they are irrelevant for us, as we only deal with rouble-denominated bonds and the data on the zero-coupon government curve are available from the Moscow Exchange. The disadvantage of this approach is the need to find two non-green bonds with a different number of days to maturity for each green bond issue, and this could become a serious problem in our case (we discuss this point further in the Data section).

An alternative way to estimate Greenium was proposed by Diaz and Escribano (2021). They use a sample of US energy company bonds for 2005–2014 and calculate the yield spreads as the yield-to-maturity difference between an empirically observed bond and a theoretically constructed government bond with similar cash flows. Prices for synthetic government bonds are obtained by discounting cash flows by spot rates derived from a zero-coupon government yield curve. The main advantages of this approach include: (1) yield spread estimation is not affected by potential differences in bond features, such as a coupon rate (Diaz and Escribano, 2021); and (2) yield spread is not dependent on the cash flow specifics or the settlement date of the bonds in question (Gurkaynak et al., 2007). This means that this method is suitable for comparison of the bonds with different durations and different dates of coupon payments. Both points are crucial for our case, as the required data for the Russian fixed income market are scarce.

Hence, we rely on the methodology suggested by Diaz and Escribano (2021) for the first stage of our research, and the description of its main steps below follows closely their work.

Stage 1: computing yield spreads for green and non-green bonds

1. The instantaneous forward rates are calculated for each observation day for all payment terms of the green bond cash flows based on the daily data of 13 parameters of the government zero-coupon yield curve published by the Moscow Stock Exchange, using the following formula:

$$G(t) = \beta_0 + (\beta_1 + \beta_2)\,\frac{\tau}{t}\left[1 - \exp\left(-\frac{\tau}{t}\right)\right] - \beta_2 \exp\left(-\frac{\tau}{t}\right) + \\ + \sum\nolimits_{i=1}^{9} g_i \exp\left(-\frac{(t-a_i)^2}{b_i^2}\right), \tag{1}$$

where $G(t)$ is the instantaneous forward rate in basis points, β_0, β_1, β_2, τ, g_i, are the government zero-coupon yield curve parameters, t is the time to maturity in years, a_i, b_i are parameters.

2. These rates are used to produce the discount function $D(t)$ through:

$$D(t) = \exp\left(\frac{-G(t)}{10000}t\right). \tag{2}$$

3. The price of the synthetic government bond $P_{G_t h}$ is calculated by discounting the cash flows of the real green bond with the function obtained in the previous step:

$$P_{G_t h} = \sum\nolimits_{T=t_1}^{t_n} C_T D(T). \tag{3}$$

where C_T is a cash flow (coupon or face value), n is the number of cash flows.

4. The effective yield to maturity $YTM_{G_{th}}$ of the synthetic government bond based on its price is calculated using the following equation:

$$P_{G_t h} + A = \sum\nolimits_{i=1}^{n}\left(\frac{C_i}{\left(1 + YTM_{G_{th}}\right)^{\frac{t_i}{365}}} + \frac{N}{\left(1 + YTM_{G_{th}}\right)^{\frac{t_i}{365}}}\right). \tag{4}$$

where A is the accrued interest, N is the face value, t_i is the number of days until the payment of the i^{th} coupon or the face value. Equation (4) is solved with respect to $YTM_{G_{th}}$ by using Newton's method (we used the Uniroot function in R).

5. The yield spread YS_G is calculated as the difference between the yield of the real green bond and the yield of its theoretically constructed counterpart, i.e., the government synthetic bond with the same cash flows:

$$YS_G = YTM_G - YTM_{G_{th}}, \tag{5}$$

where YTM_G is the effective yield to maturity of the green bond.

6. Calculations (1)–(5) are repeated for the non-green bond to obtain the yield spread YS_B in a similar way:

$$YS_B = YTM_B - YTM_{B_{th}}, \tag{6}$$

where YTM_B is the effective yield to maturity of the non-green bond, $YTM_{B_{th}}$ is the effective yield to maturity of the synthetic government bond with cash flows similar to the non-green bond.

7. The final yield spread between the green and the non-green bond, or the Greenium, is calculated as the difference between the spreads obtained in equations (5) and (6):

$$Greenium = YS_G - YS_B, \tag{7}$$

Stage 2: comparing yield spreads

To test our main hypothesis—that green bonds have a lower yield to maturity—we compare as a first step the mean values of the spreads from equations (5) and (6) using the *t*-test and Wilcoxon test. However, we are also interested in whether this difference can really be attributed to the environmental characteristics of the bonds or to some other factors. Therefore, in the second step of this stage, we consider the model that has spread as the dependent variable and a number of factors that might explain this spread as independent variables. The base model is defined as follows:

$$Spread_{it} = \alpha + \beta_1 Green_i + \beta_2 Liquidity_{it} + \beta_3 Bank_i + \beta_4 Rating_i +$$
$$+ \beta_5 lrRUABITR_t + \beta_3 RVI_t + \beta_7 KIR_t + \beta_8 RPUI_t + \varepsilon_{it}, \tag{8}$$

where $Spread_{it}$ is the dependent variable (from equations (5) and (6)), $Green_i$ is a dummy variable that takes the value of one if the bond has a green label and zero otherwise, $Liquidity_{it}$ is the measure of the bond liquidity which is estimated as a weighed Bid-Ask spread using the following equation:

$$Liquidity = \frac{P_{Ask} - P_{Bid}}{(P_{Ask} + P_{Bid})/2}. \tag{9}$$

Controls include: $Bank_i$, which is a dummy variable that equals one if the issuer of the bond is a bank; $Rating_i$, which is a set of dummy variables taking value of one for each of the relevant credit rating grades (BBB–, A, A+ or AAA) in our sample; $lrRUABITR_t$, which is the logarithmic return of the Moscow Exchange Aggregate Bond Index RUABITR; RVI_t, which is the New Russian Volatility Index of the Moscow Exchange; KIR_t, which is the policy rate (key rate) of the Bank of Russia; $RPUI_t$, which is the economic policy uncertainty index for Russia. $\alpha, \beta_1, ..., \beta_8$ are regression coefficients. According to our hypothesis, β_1 should be negative (and significant). Positive values are expected for the coefficient β_2 since larger Bid-Ask spread (lower liquidity) leads to the higher return spread.

We have chosen control variables on the basis of the following considerations: industry might be important for the bond yield, and as 3 out of 14 bonds in our sample are banks, we include the "bank" dummy. The emission's rating is important as it stresses the bond's overall credit quality and influences the bond's yield. Excess yield to maturity might follow the index and change in line with the general tendencies in the market, so we control for the index and the market's volatility. Changes in the policy rate have a direct influence on the bond market by changing the discount rate. Finally, changing levels of uncertainty related to economic policy might reflect general expectations of the market that are not captured by the bond index.

Our baseline model (8) is estimated using a variety of specifications: pooled, fixed effects, random-effects, between-effects, population averaged panel regression and hybrid model with the bond ISIN as the cluster variable. These alternative specifications are checked for consistency using the Wald test, the Hausmann test and the Breusch–Pagan test.

3. Data

According to the International Capital Markets Association's (ICMA) definition and the Issuer Guidelines published by the Moscow Exchange, "Green Bonds are any type of bond instrument where the proceeds will be exclusively applied to finance or re-finance, in part or in full, new and/or existing eligible Green Projects... and which are aligned with the four core components of the Green

Bond Principles."[7] Thus, investors can rely on third-party verification of the issuer or the bond instead of carrying out their own analysis of each particular issue.

As of February 12, 2022,[8] there were twenty issues of green bonds quoted on the Moscow Exchange, but thirteen of them are non-marketable or do not have a sufficient level of liquidity (measured as the number of days traded, with a cut-off set at least one-third of the total trading history) for the purposes of this research. The remaining seven bonds meet the requirements of *plain vanilla bonds*, meaning they are the simplest bonds with basic fixed features including coupon, maturity date, and face value. The total volume of the seven issues exceeds 218 billion rubles. The trading history of these bonds varies from 56 to 544 days, depending on the date of the bond placement.

To compare the yield spreads, non-green counterparts for these seven bonds were selected on the basis of the following criteria:

(1) the same issuer,
(2) the same rating of the issue,
(3) the same issue currency (Eurobonds are not considered),
(4) unstructured issues (without options, convertibility, or a floating coupon),
(5) a certain level of trade liquidity (the number of trading days is more than one-third of the trading history),
(6) similar guarantees (or lack thereof) as the green bond.

If a non-green bond with the above-listed features is absent, then criterion (1) is excluded, and the procedure is repeated for another issuer with the same rating. The details of the resulting sample of 14 bonds divided into 7 pairs are presented in Table 1. As can be seen from Table 1, only one bond (Atomenergoprom) has no pair among non-green bonds of the same issuer. Therefore, a VTB PJSC bond was selected as a counterpart for this bond. The choice of that particular bond is explained by the fact that both issuers — VTB and Atomenergoprom — are largely government-owned, and the other characteristics of the selected bonds are similar.

Bond prices (indicative prices for calculating yields and Bid-Ask prices for calculating the liquidity level), as well as the time terms, the structure, and values of cash flows, are taken from the CBonds information agency database,[9] a reliable source of information on everything related to the fixed-income part of the Russian financial market. The zero-coupon yield curve parameters for each trading day are taken from the Moscow Stock Exchange. As shown in Table 2, the minimum yield to maturity was recorded for the City of Moscow non-green bonds (5.79%), while the maximum was for the Garant-Invest green bonds (21.5%).

Data on the daily values of the Moscow Exchange Aggregate Bond Index (RUABITR), the New Russian Volatility Index (RVI)[10] measured as the market's expectation of the 30-day volatility, and the policy rate (key rate) are taken from the CBonds information agency database. The monthly values of the Economic Policy Uncertainty Index for Russia, based on newspaper articles, are taken from the website of the Economic Policy Uncertainty Project[11]. The bond credit rating

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[7] https://www.icmagroup.org/assets/documents/Regulatory/Green-Bonds/Green-Bonds-brochure-150616.pdf

[8] We have chosen this as a cut-off date in our study in order to finish our sample before the sanctions and counter-measures changed pricing mechanisms in the Russian financial market.

[9] https://cbonds.ru/bonds/?emitent_country_id=0-2 (in Russian).

[10] https://www.moex.com/en/index/RVI/

[11] Details of the index construction and data can be found at https://www.policyuncertainty.com/russia_monthly.html

Table 1
Green and non-green bonds.

Company	Issue	Terms		Coupon		Economy sector	Credit rating
		Placement	Maturity	Rate	Freq. per year		
Atomenergoprom	001P-01	25.06.2021	19.06.2026	7.50	2	En	AAA
VTB	Б-1-231	02.07.2021	28.06.2024	7.50	4	B	AAA
Garant-Invest	001P-06	17.12.2019	13.12.2022	11.50	4	CD	BBB–
	002P-01	09.12.2020	23.11.2022	10.50	4	CD	BBB–
Moscow	74	27.05.2021	18.05.2028	7.38	2	Mun	AAA
	73	09.07.2021	21.04.2026	7.20	2	Mun	AAA
Sinara	001P-02	28.07.2021	22.07.2026	8.70	2	ME	A
	001P-01	28.05.2021	24.05.2024	8.10	2	ME	A
Sberbank	002P-01	12.11.2021	10.11.2023	8.80	2	B	AAA
	001P-SBER32	11.08.2021	04.08.2023	7.30	2	B	AAA
Garant-Invest	002P-02	12.01.2021	25.12.2023	10.00	4	CD	BBB–
	002P-03	09.04.2021	26.03.2024	10.50	4	CD	BBB–
KAMAZ	БО-П09	24.11.2021	22.11.2023	9.75	4	VP	A+
	БО-П08	12.07.2021	10.07.2023	8.30	4	VP	A+

Sectors: En — energy, B — banks, CD — Construction and development, Mun — municipal, ME — Mechanical engineering, VP — Vehicle production.
Source: Compiled by the authors.

Table 2
Yield to maturity descriptive statistics.

Company	Issue	Min	Mean	Max	SD
Atomenergoprom	001P-01	0.0736	0.0809	0.1007	0.0071
VTB	Б-1-231	0.0728	0.0803	0.0951	0.0056
Garant-Invest	001P-06	0.0913	0.1260	0.2147	0.0220
	002P-01	0.1011	0.1155	0.1623	0.0138
Moscow	74	0.0746	0.0827	0.1028	0.0089
	73	0.0579	0.0776	0.0915	0.0063
Sinara	001P-02	0.0886	0.0988	0.1176	0.0099
	001P-01	0.0807	0.0931	0.1252	0.0119
Sberbank	002P-01	0.0812	0.0896	0.1000	0.0033
	001P-SBER32	0.0723	0.0847	0.1061	0.0095
Garant-Invest	002P-02	0.0910	0.1123	0.1794	0.0145
	002P-03	0.1079	0.1189	0.1513	0.0143
KAMAZ	БО-П09	0.0492	0.0918	0.1001	0.0107
	БО-П08	0.0778	0.0879	0.1103	0.0089

Source: Authors' calculations.

values are based on the data of the ACRA rating agency (or Expert-RA, where ACRA does not provide data) and converted to corresponding dummy variables, taking values of one or zero, respectively, for each grade of credit rating in our sample. The bond credit rating and the bond green label remain unchanged for the whole duration of the sample for each issue.

4. Results

Visual analysis of the Greenium graphs does not provide consistent results. For four bond pairs, most of them in the middle of the investment rating scale, the yield spread remains consistently negative until autumn 2021, providing support for our main hypothesis (see Fig. 2, for example). For three bond pairs the spread is not stable over time (see Fig. 3, for example).

The results of the t-test and Wilcoxon non-parametric test comparison of the spreads obtained according to equations (5) and (6) are presented in Table 3. As can be seen from Table 3, the *t*-statistics are significant at the 1% level for almost all pairs of bonds, except the first two. This means that the mean yield spreads for green and non-green bonds are statistically different for five out of seven bond pairs in our sample. Wilcoxon tests show the same results, suggesting that proceeding with our baseline model (8) is reasonable.

The panel data for the dependent variable *Spread* and for the *Liquidity* variable were tested using Fisher-type panel tests on the basis of ADF or PP tests with

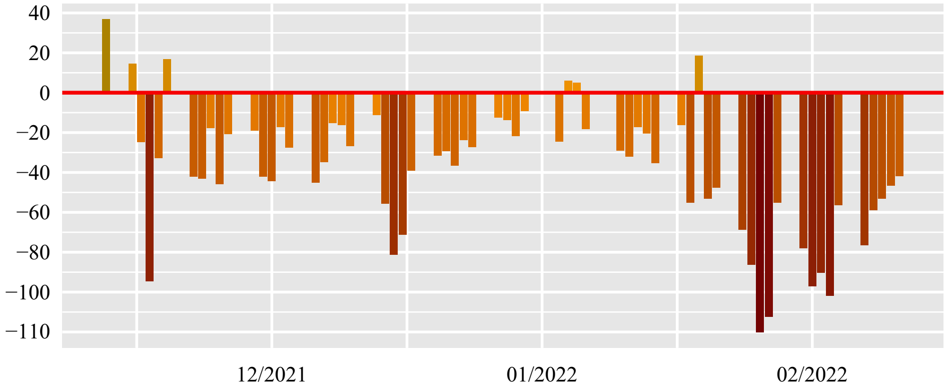

Fig. 2. Yield spread between Sberbank green and non-green bonds (basis points).

Source: Authors’ calculations.

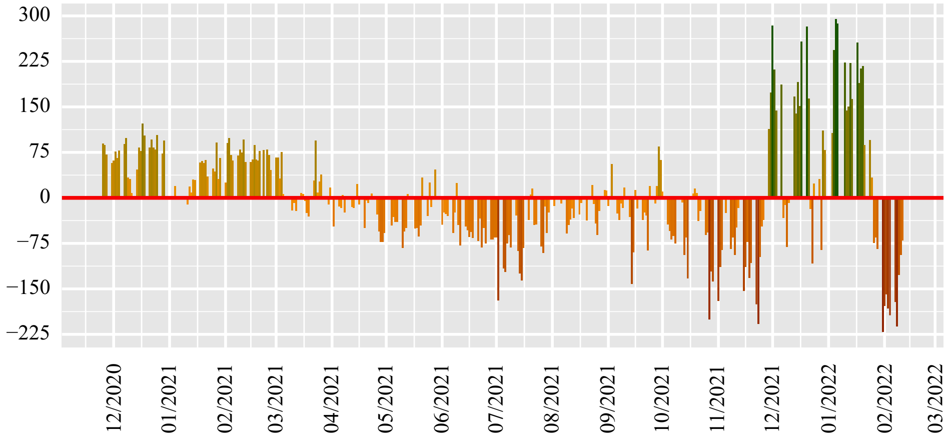

Fig. 3. Yield spread between the Garant-Invest (1st issue) green and non-green bonds (basis points).

Source: Authors’ calculations.

a preliminary subtraction of cross-sectional means. This type of test allows us to check for unit roots in unbalanced panels with different time intervals and gaps.

Table 4 presents the results of four different models on the full sample. The dependent variable $Spread_{it}$, is the spread between the yield of a bond and the yield of its synthetic government counterpart with the same cash flows.

Table 3
Mean values of spreads.

Bond	Mean of spread		*t*-stat (*p*-value)	*W*-stat (*p*-value)
	Green	Non-green		
Atomenergoprom / VTB	18.426	12.5481	1.0146	12139
			(0.3112)	(0.6732)
Garant-Invest (1-st issue)	502.168	500.5818	0.1647	47175
			(0.8692)	(0.695)
Moscow	47.221	–6.5797	10.696	23110
			(0.000)***	(0.000)***
Sinara	184.785	160.8924	5.8505	13550
			(0.000)***	(0.000)***
Sberbank	–0.536	37.9972	–6.4425	922
			(0.000)***	(0.000)***
Garant-Invest (2-nd issue)	408.149	446.1005	–5.1068	16319
			(0.000)***	(0.000)***
KAMAZ	16.370	74.0065	–4.302	775
			(0.000)***	(0.000)***

Note: p-value in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Source: Authors' calculations.

Table 4
Models on the full sample.

Variables	(1) Pooled	(2) Fixed effects	(3) Random effects	(4) Between effects
Liquidity	–0.10***	0.01	0.00	–0.63
	(–3.15)	(0.26)	(0.15)	(–1.32)
Green	31.94***	–	4.70	10.59
	(6.80)		(0.21)	(0.31)
Bank	20.55**	–	4.26	31.85
	(2.47)		(0.12)	(0.57)
(A).rating	–282.25***	–	–273.45***	–297.94*
	(–37.19)		(–7.62)	(–3.03)
(A+).rating	–373.05***	–	–393.41***	–362.28**
	(–40.58)		(–10.81)	(–3.78)
(AAA).rating	–437.20***	–	–428.24***	–429.81**
	(–68.41)		(–13.46)	(–4.67)
$lrRUABITR$	0.36***	0.34***	0.34***	7.39
	(4.64)	(4.92)	(4.91)	(0.32)
ΔRVI	4.35***	3.94***	3.94***	–29.27
	(16.54)	(16.46)	(16.46)	(–1.07)
ΔKIR	–44.86***	–39.23***	–39.37***	149.53
	(–20.61)	(–19.58)	(–19.63)	(0.81)
$\Delta RPUI$	0.42***	0.35***	0.35***	4.15
	(18.02)	(16.63)	(16.66)	(1.46)
Constant	508.85***	322.33***	504.72***	–881.62
	(33.83)	(22.79)	(18.75)	(–0.70)
Observations	2,768	2,768	2,768	2,768
Number of id		14	14	14

Note: *t*-stat or *z*-stat (for RE-model) in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Source: Authors' calculations.

Statistical properties of model (1) make it a valid model, but the positive sign of the coefficient for the green bond label contradicts the research hypothesis and preliminary analysis. The main disadvantage of model (1) is that as a pooled model it does not account for differences in effects for individual clusters (bond issues). The fixed effects (FE) model presented in column (2) of Table 4 does not allow for the estimation of the coefficient of the variable *Green*, which aims to verify the main hypothesis, since the values of this variable are time-invariant for each of the bonds. However, the overall significance of the model indicates that the estimates for the control variables are correct and, statistically, this model is preferable to the pooled model.

The random effects (RE) model (column 3 of Table 4) is statistically significant, preferable to the pooled model, but inferior to the FE model according to the Hausman test statistics ($\chi^2 = 11.53$). We note that the t-statistic for the coefficient of the *Green* variable is significant and negative, as expected. The results of the between effects model (4) indicate the insignificance of most variables, except for some rating grades. We interpret this as the irrelevance of the between intergroup effects. The reason for this is our extremely limited sample (a narrow panel) and potentially significant idiosyncratic risks for all seven bond pairs.

The controversial results for Greenium can be explained by the fact that the spread changed its sign for most of the bond pairs in the fall of 2021. We examined the time series of the composite bond index of the Moscow Exchange (RUABITR) for structural changes in the bond market. For this purpose, we tested the RUABITR time series for the period of May 27, 2021 to February 11, 2022 for multiple structural breaks using the Bai–Perron test and identified a structural shift dated September 16, 2021. The index's fall, starting from this date (see Fig. 4), could have been caused by capital outflow from emerging markets due to potential COVID-19 threats, as well as rising inflation and tightening of central banks' monetary policies. As a result, riskier emerging market assets were discounted more than those of developed markets, which could have led to lower asset demand from investors.

A careful study of the second period requires adding factors into the model to reflect a change in the behavior of foreign institutional investors in relation to

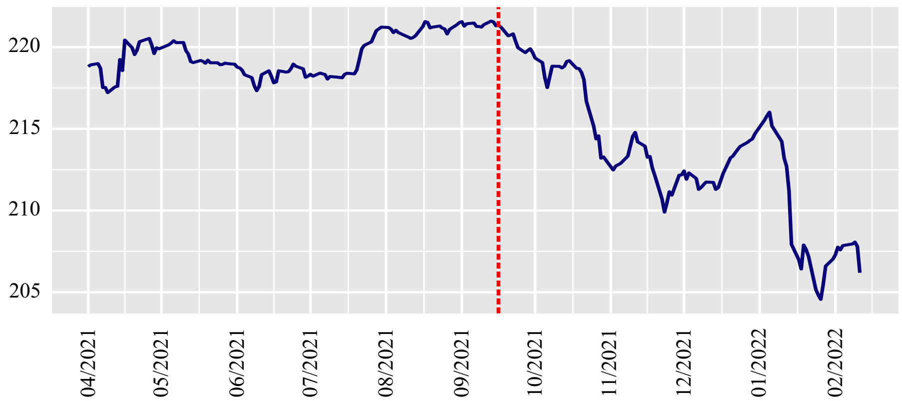

Fig. 4. Structural breakpoint of the composite bond index (RUABITR) of the Moscow Exchange (p.p.).

Source: Authors' calculations.

emerging markets. But as during such periods, the environmental agenda usually fades into the background, so we decided to focus on a more stable period (i.e., before September 16, 2021) in further research. Thus, the first (earlier) part of the sample counts 1,413 observations. The results of estimations on the shortened sample are presented in Table 5. The dependent variable remains $Spread_{it}$.

The re-estimated FE model (5) with the omitted main variable is estimated for the purpose of comparison with the RE model (6). However, the Hausman test gives preference to the fixed effects model (5) despite the 99% confidence interval of the *Green* coefficient estimate. The results of the between effects (BE) model (7) repeat the previous conclusion for the whole sample: the estimated coefficients of interest are not significant.

We also estimate the population-averaged model (model 8 in Table 5) with the unstructured correlation matrix based on the generalized estimating equations (GEE), which is a type of generalized linear models. According to Koziol (2015, pp. 40–41), “the GEE method accounts for variation of the random effects by specifying a more complex variance structure for [the dependent variable].” One of the important advantages of this approach is that its estimators are robust to misspecification. This model is statistically significant, but shows no significance of the *Green* coefficient and all other control variables except for rating and policy rate.

We also consider a hybrid model, or within-between random effects model (REWB), that combines two types of effects: RE and FE. According to Schunck et al. (2013, p. 67), “a decomposition into between and within effects can be used

Table 5
Models on the restricted sample.

Variables	(5) Fixed effects	(6) Random effects	(7) Between effects	(8) Population averaged	(9) Hybrid	(10) Hybrid HAC	(11) Hybrid HAC
Liquidity	0.14^{***}	0.15^{***}	–0.73	–0.04	0.15^{***}	0.02	0.02
	(2.93)	(2.95)	(–2.89)	(–0.52)	(3.00)	(1.43)	(1.39)
Green	–	50.10^{***}	–60.24	–0.58	-32.18^{***}	-35.45^{***}	-34.48^{***}
		(4.07)	(–2.57)	(–0.03)	(–3.64)	(–4.77)	(–4.57)
Bank	–	63.53^{***}	–134.63	13.12	-84.21^{***}	-87.12^{***}	-73.74^{***}
		(2.98)	(–3.06)	(0.39)	(–3.79)	(–5.76)	(–4.76)
(A).rating	–	-255.18^{***}	–181.78	-228.70^{***}	-183.9^{***}	-166.48^{***}	-139.37^{***}
		(–14.73)	(–3.55)	(–8.77)	(–6.01)	(–8.12)	(–6.61)
(A+).rating	–	-281.23^{***}	-337.77^{*}	-283.96^{***}	-325.60^{***}	-326.27^{***}	-313.44^{***}
		(–11.61)	(–6.65)	(–7.75)	(–11.58)	(–16.06)	(–15.31)
(AAA).rating	–	-400.55^{***}	–238.91	-350.39^{***}	-269.20^{***}	-269.44^{***}	-249.93^{***}
		(–27.64)	(–4.04)	(–16.22)	(–9.67)	(–12.46)	(–11.16)
lrRUABITR	0.36^{***}	0.38^{***}	11.77	–0.02	0.36^{***}	0.07^{**}	0.06^{**}
	(2.78)	(2.78)	(1.34)	(–0.05)	(2.78)	(2.41)	(2.18)
ΔRVI	8.88^{***}	9.10^{***}	73.79	2.89	8.88^{***}	2.51^{***}	2.31^{***}
	(19.81)	(19.63)	(4.73)	(1.43)	(19.79)	(9.50)	(8.66)
ΔKIR	-36.11^{***}	-35.42^{***}	11.19	-18.26^{***}	-36.09^{***}	-15.61^{***}	-14.99^{***}
	(–9.35)	(–8.93)	(0.24)	(–2.97)	(–9.34)	(–8.62)	(–8.24)
ΔRPUI	0.15^{***}	0.16^{***}	–1.89	–0.05	0.15^{***}	0.02	0.02^{*}
	(4.89)	(5.16)	(–2.18)	(–0.89)	(4.89)	(1.28)	(1.68)
Constant	322.37^{***}	374.90^{***}	–874.95	463.50^{***}	458.49	772.02^{***}	$1{,}261.20^{***}$
	(12.91)	(14.14)	(–3.25)	(11.19)	(0.97)	(2.65)	(4.10)
Observations	1,413	1,413	1,413	1,413	1,413	1,413	1,413
Number of id	12	12	12	12	12	12	12

Note: *t*-stat or *z*-stat (for RE and HM-models) in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Source: Authors’ calculations.

with generalized estimating equations, which enables us to specify less restrictive within-cluster error structures." Another advantage of this approach is that it represents an alternative to the Hausman test. As can be seen in column 9 of Table 5, all the coefficients in the hybrid model are significant and have the expected signs. The green label for a bond reduces the spread to the government yield curve by 32 basis points, all else being equal. It should also be noted that all variables in model (9) that change over time have very similar coefficient values to model (5). In other words, the hybrid model provides the same estimates as the FE model but with the estimates of time-invariant variables. As the hybrid model (9) showed heteroscedasticity (according to both the LR and the Wooldridge test), the hybrid model (10) in Table 5 accounted for the heteroscedastic structure of errors and the first-order within-group correlation (HAC), individual for each bond. In this model, the coefficients of *Liquidity* and *RPUI* variables become insignificant, but the Green variable is significant and negative.

5. Robustness tests and discussion

To check the robustness of our results, we substituted a part of our sample. As we had already taken into account all market issues of green bonds, we could not make any substitutions here. However, we could choose different non-green counterparts for some bonds in our sample. According to the selection procedure for green bond counterparts consisting of six criteria described in the Data section, the results of Table 1 changed in two cases.

For the green bond of Atomenergoprom, we chose an issue from another state-owned company, VEB.RF. This issue belongs to the banking industry, like the originally selected bond of the VTB company. The issuer is state-owned and has the highest national rating, although from a different rating agency. Besides, we chose another security of the same issuer for the green bond of Sberbank. The new non-green bond has a lower coupon and a longer circulation period of six months, but these differences are taken care of by the method used. For the remaining five green bonds mentioned in Table 1, it was impossible to find other non-green counterparts.

We limited the two new non-green issues by selecting a period commencing on the start date of trading of the originally used issues and finishing on the date of the structural shift, i.e., September 16, 2021. Thereby, we obtained a similar number of observations as in models (5)–(10) of Table 5. As a result of the revision of the two non-green counterparts, the total number of observations changed in 291 cases out of 1,413, which constitutes about 20% of the original sample.

We used the REWB model, which showed its consistency, to check the updated sample, accounting for heteroscedasticity and within-group autocorrelation (HAC). The sample change has not caused significant differences in the results according to model (11) from Table 5. All estimates of the control variables have shown the expected sign. For example, an increase in volatility or uncertainty indices also increases the spread to the risk-free yield. An important result of this test is that the coefficient estimation of the Green variable remained nearly unchanged and constituted minus 34.5. This means that green bonds are trading with a yield spread to government bonds that is 34.5 basis points less than for non-green bonds, other things being equal.

The hybrid models (9)–(11) showed a non-linear change in the rating variable estimates, which is counterintuitive. Therefore, we used a different approach to account for the ratings, using the logarithmic probability of default. We have also considered the exclusion of the Bond Index variable to ensure that there is no potential endogeneity problem. The results of these regressions are presented in Table 6. Our results are robust to these changes, and the variable of interest — the green indicator — remains negative and significant in three out of four new specifications with the value between –26.42 and –37.35 basis points.

Table 6

Models for the bond market on the restricted sample with probability of default variable (ln(*PD*)) and without Bond Index (*lrRUABITR*).

Variables	(10) Hybrid HAC	(12) Hybrid HAC	(13) Hybrid HAC	(14) Hybrid HAC
Green	-35.45^{***}	-26.42^{***}	-37.35^{***}	-7.31
	(–4.77)	(–3.31)	(–4.77)	(–0.86)
Liquidity	-0.66^{***}	-0.48^{***}	-0.52^{***}	-0.24^{**}
(between)	(–6.05)	(–4.10)	(–4.98)	(–1.96)
Liquidity	0.02	0.02	0.02	0.02
(within)	(1.43)	(1.43)	(1.23)	(1.08)
lrRUABITR	41.49^{***}	22.91^{***}	–	–
(between)	(5.79)	(3.05)		
lrRUABITR	0.07^{**}	0.07^{**}	–	–
(within)	(2.41)	(2.49)		
Δ*RVI*	117.32^{***}	94.30^{***}	79.47^{***}	85.62^{***}
(between)	(9.05)	(6.01)	(6.43)	(5.13)
Δ*RVI*	2.51^{***}	2.15^{***}	2.17^{***}	1.77^{***}
(within)	(9.50)	(7.98)	(8.03)	(6.30)
Δ*RPUI*	-5.28^{***}	-3.88^{***}	-2.81^{***}	-3.59^{***}
(between)	(–6.02)	(–3.75)	(–2.70)	(–3.14)
Δ*RPUI*	0.02	0.02^{*}	0.01	0.01
(within)	(1.28)	(1.68)	(1.10)	(1.00)
Δ*KIR*	-311.26^{***}	-342.80^{***}	-223.37^{***}	-358.17^{***}
(between)	(–6.48)	(–6.40)	(–3.64)	(–5.78)
Δ*KIR*	-15.61^{***}	-14.00^{***}	-13.06^{***}	-10.39^{***}
(within)	(–8.62)	(–7.30)	(–7.08)	(–5.42)
(*A*).*rating*	-166.48^{***}	–	-195.46^{***}	–
	(–8.12)		(–6.67)	
(*A*+).*rating*	-326.27^{***}	–	-313.04^{***}	–
	(–16.06)		(–12.31)	
(*AAA*).*rating*	-269.44^{***}	–	-283.35^{***}	–
	(–12.46)		(–10.40)	
ln(*PD*)	–	45.19^{***}	–	43.64^{***}
		(8.47)		(6.95)
Bank	-87.12^{***}	-46.03^{***}	-91.17^{***}	-40.21^{**}
	(–5.76)	(–2.63)	(–5.24)	(–2.01)
Constant	772.02^{***}	$1{,}364.26^{***}$	427.88	$1{,}532.30^{***}$
	(2.65)	(4.93)	(1.04)	(5.38)
Observations	1,413	1,413	1,413	1,413
Number of id	12	12	12	12
Wald χ^2	8562.45	6427.74	5887.74	4864.26

Note: z-statistics in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

(10) The model is re-estimated as model (10), Table 5.

(12) The logarithm of the probability of default has been used instead of a four-rating dummy variables as follows: $\ln(PD) = 1.3R - 11.2$, where R — rating (AAA = 1; A+ = 2.66; A = 3; BBB– = 4.33).

(13) Bond index has been removed from the dependent variables.

(14) Assumptions of models (12)–(13) apply jointly.

Source: Authors' calculations.

Comparable results on a sample of U.S. green and non-green bonds for the period 2005–2014 from Diaz and Escribano (2021) estimate an environmental risk premium of 66 basis points in terms of the yield spread, using a similar spread construction approach but a different regression model. Hachenberg and Schiereck (2018) also reported an environmental premium of 3.88 basis points on A-rated bonds using the *i*-spread approach on a worldwide sample from October 1, 2015, to March 31, 2016. However, other ratings in their analysis did not show statistically significant yield spreads. Haciomeroglu et al. (2022) found 25 basis points greenium for the sample of 643 green bonds on the secondary market. Thus, our results for bonds are in line with the findings of other papers — an environmental premium exists and is rather small in absolute value. Since green bonds in Russia were issued in accordance with international standards and in the period when ESG concerns infiltrated Russian business, our results seem to confirm that in such circumstances financing of green projects can be cheaper.

6. Conclusion

In this paper, our examination focused on the presence of a return differential between green and brown assets in the Russian bond market. Derived from the literature review, our principal hypothesis posited that if such a return spread does indeed exist, it would likely favor brown assets, leading to the expectation of a negative risk premium for a portfolio designed to mitigate environmental risks.

We tested our hypothesis on expected returns using Greenium estimation methodology. This approach involved identifying a non-green bond counterpart to each green bond, creating synthetic government bonds with cash flows resembling the selected bond pairs, and computing excess returns. The Greenium was derived for all listed green bond issues on the Moscow Exchange that exhibited adequate liquidity levels. Our findings suggest that the average excess return varies between bonds with and without the green label across the majority of examined issues. Employing a range of econometric models, we determined that green bonds yielded lower expected returns during a relatively stable period in the fixed income market. This implies that a green bond issuer in the Russian market could potentially reduce debt costs and partially offset additional expenses associated with non-financial reporting.

Our findings align with several other studies that have shown the presence of Greenium in developed financial markets (e.g., Diaz and Escribano, 2021; Hachenberg and Schiereck, 2018). This outcome is not unexpected, given that green bonds in Russia were issued based on similar principles as those in developed financial markets, with the majority of issuances occurring in recent years coinciding with Russian authorities, major companies, and institutional investors in the Russian financial market embracing the green economy trend. It would be intriguing to observe whether our results remain consistent in the future if Russia continues to be largely isolated from global financial markets and its exporters face restrictions on trading with environmentally conscientious countries.

It is important to note that our Greenium results are constrained by a small sample size both in terms of time and the number of bonds. For the entire sample (concluding before the end of February 2022), the direction of Greenium and its significance to investors may have undergone changes. We hypothesize that the variability in results for the complete sample could be attributed to the actions of major global institutional investors who tend to withdraw from emerging markets during periods of heightened volatility. Investigating this hypothesis presents another avenue for advancing our research. Additionally, exploring how the behavior of large institutional investors specifically impacts the returns of green versus non-green assets across different financial markets, including the most developed ones, would be a compelling area for further study.

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