EUROPEAN UNIVERSITY AT ST. PETERSBURG

Green Factor Influence on the Yield of Stocks and Bonds in the Russian Financial Market

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Abstract: In this paper we test whether environmental characteristics of assets influence their returns for the case of Russian financial market. Our main hypothesis based on the relevant literature is that if a spread between "green" and "brown" assets' yield exists, it should be in favour of the brown assets. We employ relevant econometric models separately for stocks and for bonds. For the stock market we used realized returns and estimated the role of the green factor in the yield using the three-factor Fama–French model. While the resulting coefficient was not significant, on the whole we have observed that the realized return of the climate-risk hedge portfolio had a negative value over a nearly ten-year observation period. We have also demonstrated the applicability of the green factor calculations for estimating the degree of climate risk exposure for individual companies. Using data on a number of green bonds and their chosen "twin" bonds, we calculate the difference in the premium in the yield to maturity over that of a similar government bond for all pairs of "twin" bonds and proceed to check if this difference is significant, and if it can be attributed to the Greenium factor. We find that over the stable period in Russian financial markets (allowing for the most stable results) "green" bonds have lower yield to maturity — a result that is in line with previous results for other markets and suggests that green financing might be cheaper for companies. On the whole our results suggest that environmental considerations might be relevant in the Russian financial market during stable macroeconomic periods.

Keywords: ESG, sustainable investing, Greenium, Russia

JEL classification: G10, G12

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Abstract[1]

In this paper we test whether environmental characteristics of assets influence their returns for the case of Russian financial market. Our main hypothesis based on the relevant literature is that if a spread between 'green' and 'brown' assets' yield exists, it should be in favour of the brown assets. We employ relevant econometric models separately for stocks and for bonds. For the stock market we used realized returns and estimated the role of the green factor in the yield using the three-factor Fama-French model. While the resulting coefficient was not significant, on the whole we have observed that the realized return of the climate-risk hedge portfolio had a negative value over a nearly ten-year observation period. We have also demonstrated the applicability of the green factor calculations for estimating the degree of climate risk exposure for individual companies. Using data on a number of green bonds and their chosen 'twin' bonds, we calculate the difference in the premium in the yield to maturity over that of a similar government bond for all pairs of 'twin' bonds and proceed to check if this difference is significant, and if it can be attributed to the Greenium factor. We find that over the stable period in Russian financial markets (allowing for the most stable results) 'green' bonds have lower yield to maturity – a result that is in line with previous results for other markets and suggests that green financing might be cheaper for companies. On the whole our results suggest that environmental considerations might be relevant in the Russian financial market during stable macroeconomic periods.

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Introduction

Environmental problems and climate change are considered to be among the most important global problems. The pressure to take action against corresponding negative externalities leads to changes in behavioural patterns and regulations followed by changes of supply and demand in various markets. Russia follows this general trend as well. A ban on importing certain goods, production technology limitations, and new recycling requirements are among measures listed in local and international legislative acts such as the Strategy of Ecological Security of the Russian Federation until 2025[2] or the Proposal for Establishing a Carbon Border Adjustment Mechanism announced by the European Commission in 2021[3]. According to KPMG's estimates, "an additional financial burden on goods exported from Russia"[4] could amount to 37.7 billion euros in the period 2026 to 2035 if the latter plan is approved.

Society-driven requirements concerning productions processes and new legal restrictions change cost-revenue structure of companies and affect investors' preferences. The latter can be traced best in the behaviour of institutional investors. The number of signatories to the United Nations Principles for Responsible Investment has quadrupled in the last decade. According to a survey conducted among investors, approximately 93% of the respondents reported that they use at least one approach to reduce climate risks when structuring their portfolios[5]. When setting investment targets with a reference to non-financial goals or hedging climate risks, investors have to evaluate asset returns accounting for the environmental characteristics of the respective companies. This imposes additional costs on all parties involved, namely: the cost of verification of financial assets by a regulatory authority or a non-governmental rating agency to ensure that the assets meet environmental standards as well as the cost of subsequent taxonomy and audit of non-financial reports.

Existence of such costs theoretically imply a yield spread between financial assets depending on their environmental characteristics as obtaining and maintaining ecological assessment is costly for the company. If such a spread exists, it poses a question of whether the state should provide support to either issuers or holders of ecologically graded assets, and whether such assets are instrumental in reducing negative environmental impact. Existence of such a spread is an empirical question, and while this issue has been studied for some countries, we are not aware of an in-depth analysis of this issue for the case of Russia.

The paper starts with hypotheses setting on the basis of existing literature. We proceed by discussing separately stocks and bonds – in both parts we start with the choice of a suitable empirical methodology from the literature and any changes that we have to make in our case, followed by descriptive analysis of our data, results of empirical analysis and discussion. Our main findings are summarized in the concluding section.

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[2] 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.

[3] European Commission. Proposal for a establishing a carbon border adjustment mechanism 14 .07.2021, COM(2021) 564 final 2021/0214(COD).

[4] KPMG. URL: https://mustread.kpmg.ru/articles/bezuglerodnaya-dieta-kak-rossiyskiy-biznes-gotovitsya-k-vvedeniyu-transgranichnogo-uglerodnogo-regul/

[5] Krueger P, Sautner Z, Starks LT. The importance of climate risks for institutional investors // The Review of Financial Studies 2020. V.33. P.1070

Literature review and hypotheses

Redistribution of risks is one of the main functions of financial markets. A risk-averse investor can decrease risks at the cost of lower expected return. If investor's space of potential states of the world includes environmentally negative ones (with associated environmental risk), then financial markets contribute to their reduction, performing their insurance function, and, moreover, they mitigate climate risks "by facilitating the flow of investment capital toward 'green' projects[6], and away from 'brown' industries and firms"[7]. If that is the case, financial assets can be grouped into two classes depending on how they perfume when environmental risks are realized. According to this logic, investments in assets "that pay off primarily when climate damages are realized — will have negative risk premium since these assets provide an insurance against bad (high marginal utility) states of the world"[8]. Thus, environmental risk premium can be defined as the expected excess return of the respective hedging portfolio. In addition to the risk premium concept, Baker et al. (2018) suggested another theoretical approach to explain the yield spread between green and brown assets. They identify a subset of investors holding underperforming green assets in their portfolios and having "a nonpecuniary component of utility, such as a sense of social responsibility… in addition to standard portfolio mean and variance"[9].

In view of the above, the main hypothesis of our paper is twofold: there should be a return spread between assets depending on their environmental characteristics, and, moreover, green assets should have a lower expected return than brown assets. In other words, a portfolio hedging environmental risks should have a negative risk premium.

If one accepts the importance of environmental threats to portfolio holders, then the question is how financial markets can hedge such risks. As noted by Giglio et al (2020), "many of the effects of climate change are sufficiently far in the future that neither financial derivatives nor specialized insurance markets are available to directly hedge those long-horizon risks"[10]. In this case, investors construct their portfolios on their own from the assets available at financial markets with a view of solving the hedging problem.

Another important issue is related to the way the assets for an environmental hedging portfolio are selected. An independent analysis of climate risks exposure and examination of highly specialized environmental indicators of the relevant companies could become a rather laborious procedure requiring additional costs and inaccessible to private investors. The problem of selecting assets to green portfolios by investors themselves can be solved if they could rely on the companies' environmental performance assessment, or *E-score*, awarded by various rating agencies, non-governmental organizations, or regulatory governmental bodies.

The verification of assets as 'green' by a third-party may prove to be an additional burden for investors. Hyun et al (2021) have found evidence that "labelled green bonds are traded at 24-36 basis points lower in bond yields compared to unlabeled green bonds that share similar common

[6] That is, more environmentally friendly projects as opposed to brown ones that are more environmentally problematic.
[7] Giglio S., Kelly B., Stroebel J. Climate Finance// NYU Stern School of Business Forthcoming, 26.10.2020. P. 2.
[8] Ibid., P. 7.
[9] Baker M., Bergstresser D., Serafeim G., Wurgler J. Financing the response to climate change: The pricing and ownership of US green bonds // NBER Working paper. 2018. 25194. P. 2.
[10] Giglio S., Kelly B., Stroebel J. Climate Finance// NYU Stern School of Business Forthcoming, 26.10.2020. P. 17.

pricing factors"[11]. Similar conclusions are drawn by Avramov et al. (2021): "rating uncertainty leads to higher perceived market risk, higher market premium, and lower investor demand"[12]. Both of these findings play an important role in the examination of our hypothesis, in which we consider *green-labelled* environmental risk-free assets.

Admittedly there are numerous works evaluating impact of environmental sustainability on the performance of various financial assets, such as stocks (Pastor et al., 2021)[13], bonds (Flammer, 2021)[14], commodities (Dutta et al., 2021)[15], and real estate (Bernsten et al., 2019)[16]. In this paper we limit ourselves with considering stocks and bonds only. Consequently, the purpose of this paper is to verify if there is a difference in the yield of financial assets – stocks and bonds – in view of the environmental characteristics assigned by an independent rating agency or a regulatory body.

Methodology for stock market

Existing studies of the connection between environmental characteristics and stock performance consider returns based on two approaches: realized return (calculated using stock prices) and expected return. In the second case, the proxy variable has to be chosen since the expected stock return is not observable[17] in the market. As it has been shown that forecasts of expected stock returns in the Russian market are poor[18], we consider in this paper realized returns for the stock market.

When analyzing how environmental characteristics affect stocks' excess return, the result bias caused by an unsystematic risk can be reduced if, instead of considering individual stocks, the portfolio approach is used (see e.g. Bolton and Kacperczyk (2021)[19] and Lioui and Tarelli (2022))[20]. In this case, stocks are ranked according to environmental characteristics of the issuing companies, and portfolios, formed on the basis of these characteristics, are compared in terms of their average return.

The reliability of results can be enhanced in case a zero-cost portfolio is constructed. For this purpose, we consider the investment strategy where a long position is taken in stocks of green companies, and a short position is taken in stocks of brown companies. The weights of assets in the portfolio are determined according to the environmental characteristics of the issuing

[11] Hyun S., Park D., Tian S. Pricing of Green Labeling: A Comparison of Labeled and Unlabeled Green Bonds // Finance Research Letters. 2021. Vol. 41. P.4.
[12] Avramov. D., Cheng Si., Lioui A. Tarelli A. Sustainable investing with ESG rating uncertainty // Journal of Financial Economics. Article in press. P. 22-23.
[13] Pastor L., Stambaugh R.F., Taylor L.A. Dissecting Green Returns // Working paper NO. 2021-70. 10.06.2021.
[14] Flammer C. Corporate green bonds // Journal of Financial Economics. 2021. Vol. 142. P. 499-516.
[15] Dutta A., Bouri E., Noor M.H., Climate bond, stock, gold, and oil markets: Dynamic correlations and hedging analyses during the COVID-19 outbreak // Resources Policy. 202. V.74. 102265
[16] Bernstein A., Gustafson M., Lewis R. Disaster on the horizon: The price effect of sea level rise // Journal of Financial Economics. 2019. Vol.34 (2). P. 253-272.
[17] Pastor L., Stambaugh R.F., Taylor L.A. Dissecting Green Returns // NBER Working paper NO. 28940. June 2021. P. 3.
[18] Болотин Г. В. Анализ прогнозирующей способности финансовых аналитиков на российском фондовом рынке // Вестник Чувашского университета. 2010. № 4. С. 313.
[19] Bolton P., Kacperczyk M. Do investors care about carbon risk? // Journal of Financial Economics. 2021. Vol. 142. PP. 517–549.
[20] Lioui A., Tarelli A. Chasing the ESG Factor // Journal of Banking and Finance, Forthcoming. 24.02.2022. https://ssrn.com/abstract=3878314

companies[21]. Furthermore, we use a factor model for our analysis of stock excess returns as it "dominates empirical asset pricing research"[22].

Pastor et al. (2021) (further – PST) use the concept of tastes. They provide theoretical basis for green and brown stock pricing via CAPM: if investors prefer green stocks, then they "are willing to pay more for greener firms, thereby lowering the firms' costs of capital"[23]. An investor with a portfolio of green stocks is settling for a lower expected return.

The PST model expands CAPM into a two-factor model consisting of a market factor and an *ESG factor* (i.e. zero-cost portfolio return). The ESG betas represent environmental characteristics of the stocks' in the portfolio: green stocks have positive ESG betas, and brown stocks have negative betas. The ESG factor can be understood as the return of the portfolio consisting of a long position in green stocks and a short position in brown stocks[24]. In other words, if ESG factor is an important part of an investor's decisions, there is a return spread between the green and the brown assets.

This paper considers the return spread only with relation to the environmental characteristics[25]. Therefore, the *green factor* is calculated similarly to the ESG factor using the PST methodology.

The two-factor PST model with market and green factors can be presented as follows[26]:

$$r_t - r_{ft} = \beta_{m,t-1}\left(r_{mt} - r_{ft}\right) + g_{t-1} f_{gt} + \varepsilon\ , \tag{1}$$

where the left-hand side of the equation is the vector of excess stock returns; $\beta_{m,t-1}$ is the vector of market betas in the previous period; $\left(r_{mt} - r_{ft}\right)$ is the excess market return; g_{t-1} is the vector of environmental characteristics in the previous period or the green factor betas; f_{gt} is the estimated green factor.

By moving the first term to the left-hand side of the equation, we get the vector of market-adjusted excess stock returns, $\tilde{r}_t^e$.

$$\tilde{r}_t^e = g_{t-1} f_{gt} \tag{2}$$

The green factor or the return spread between green and brown stocks can be estimated separately for each observation month by the cross-sectional regressions of the vector of market-adjusted excess stock returns on the environmental characteristics of the companies without a constant. The slope of such a regression is characterized by the following equation:

$$\hat{f}_{gt} = \frac{g'_{t-1}\tilde{r}_t^e}{g'_{t-1} g_{t-1}} \tag{3}$$

We have chosen the yield of 10-year Russian government bonds in rubles or the corresponding point on the zero-coupon yield curve of the Moscow Exchange as a risk-free rate, r_{ft}. A similar

[21] Pastor L., Stambaugh R.F., Taylor L.A. Dissecting Green Returns // NBER Working paper NO. 28940. June 2021. P. 3.
[22] Giglio S., Kelly B., Stroebel J. Climate Finance// NYU Stern School of Business Forthcoming, 26.10.2020. P.15.
[23] Pastor L., Stambaugh R.F., Taylor L.A. Sustainable investing in equilibrium // Journal of Financial Economics. 2021 Vol.142. P.2
[24] Pastor L., Stambaugh R.F., Taylor L.A. Sustainable investing in equilibrium // Journal of Financial Economics . Article in press. P.2
[25] We opted to concentrate on environmental factor only since we believe that this part of the ESG-triad is more likely to be important for Russian companies and investors in the Russian financial market.
[26] Pastor L., Stambaugh R.F., Taylor L.A. Dissecting Green Returns // Working paper NO. 2021-70. 10.06.2021. P. 11.

risk-free return is considered in Ozornov (2015) for the factor model evaluation[27]. We have taken the return of the Moscow Exchange Russia Index (IMOEX) as a market return, r_{mt}. Market betas have been calculated monthly, using a rolling regression of the excess stock returns from the index excess return based on 24 previous months. All stock prices needed to calculate the stock return r_t have been taken from CBonds.ru[28].

The companies' environmental characteristics are not constant and change over time. Hence, it is necessary to rebalance the portfolio for each month according to the newly identified environmental characteristics. The portfolio profit is calculated without the transaction costs for the rebalancing[29]. We have considered the MSCI ESG Research LLC (MSCI) rating as a source of the companies' integrated environmental scores. The available data contains observations on Russian companies, both public and not listed on stock exchanges, for the period of 2011-2021.

The calculation of the variable g_t from equation (1) based on the MSCI data can be carried out according to the PST methodology, which uses the same data base. We have used the following two MSCI variables. First, the "Environmental Pillar Score" (ES) is a number from zero to ten. The environmental score is a weighted average of all 13 environmental indicators (energy efficiency, climate change impact, carbon footprint, and others). Secondly, the "Environmental Pillar Weight" (EW) is a number from zero to one hundred, indicating a weight that reflects the importance of the environmental component in the E-S-G structure. EW is constant for all companies in the industry over the same period[30]. Then, the environmental score of the *i*-company at the beginning of the *t*-period is determined as:

$$G_{i,t-1} = -(10 - ES_{i,t-1}) \cdot EW_{i,t-1}/100 \tag{4}$$

We can get the E-score or the green factor betas centering the value obtained in the previous equation:

$$g_{i,t} = G_{i,t} - \bar{G}_t \,, \tag{5}$$

where $\bar{G}_t$ is the weighted average of $G_{i,t}$ for all companies in the t-period.

Equations (4) and (5) are used to calculate the green factor betas for non-missing values of the MSCI ESG Ratings for all Russian companies traded on the Moscow Exchange. In addition, we have considered foreign companies with Russian origin or doing business in Russia and having depositary receipts listed on the Moscow Exchange and traded in rubles (for example, Petropavlovsk PLC registered in the UK or RosAGRO PLC registered in Cyprus). We have replaced missing values with previous available observations if the gap between values in the MSCI database was less than 11 months.

The total number of companies with the calculated E-score value according to the MSCI data is shown in Fig. 1.

[27] Ozornov S. Validity of Fama and French Model on RTS Index // Review of Business and Economics Studies. Vol.3(4). 2015. PP. 22-43. P.28.
[28] Russian stocks. CBonds.ru. URL: https://cbonds.ru/stocks/?emitents_country_id=0-2&.
[29] In S.Y., Park K.Y., Monk A. Is 'Being Green' Rewarded in the Market?: An Empirical Investigation of Decarbonization and Stock Returns // Stanford Global Project Center Working Paper. 2019. https://ssrn.com/abstract=3020304. P.22.
[30] Pastor L., Stambaugh R.F., Taylor L.A. Dissecting Green Returns // Working paper NO. 2021-70. 10.06.2021. P. 9.

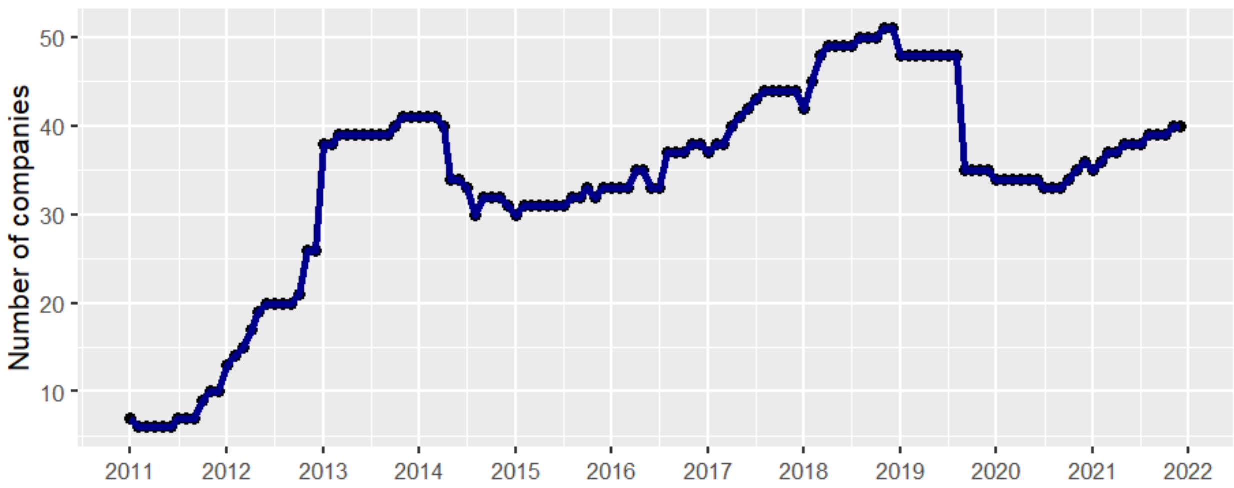

Fig.1. Number of Russian companies with an estimated E-score

The monthly number of companies ranges from 6 to 51. The total number of companies with the calculated environmental characteristic is 70. The observation period is 132 months.

After calculating the vector of market betas, $\beta_{m,t}$, the time series $\tilde{r}_t^e$ were reduced by 24 observations for each stock. In addition, observations are used for stocks only from the moment when both time series – $\tilde{r}_t^e$ and g_t – are available. 4234 cross-sectional observations remain in the sample.

Results for the Stock Market

Based on the results of the overall cross-sectional regression without a breakdown by months, the green factor score is 2.64 bps, and the positive slope contradicts the research hypothesis. However, as can be seen in Fig. 2, the slope of the regression is not significant.

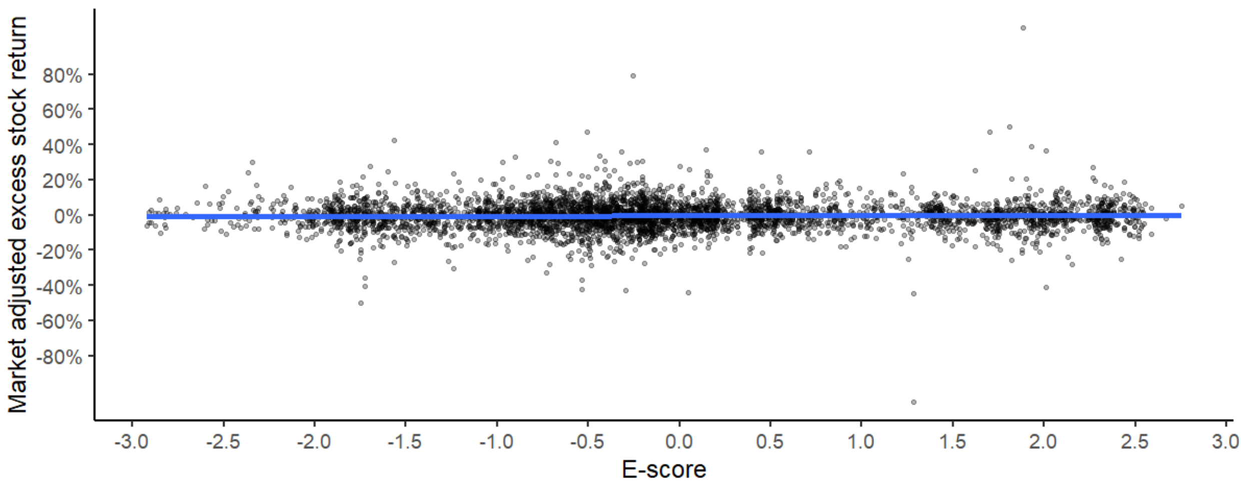

Fig.2. Slope of the regression or the green factor $\hat{f}_g$estimation for all individual observations

We present results of a similar regression for individual companies in the appendix. Fig. A provides examples for companies from the oil and gas (SIBN), coal mining (RASP), telecommunications (MTSS) and financial services (SBER) sectors.

According to In et al. (2019), it is necessary to determine the minimal number of stocks sufficient to construct an appropriate portfolio before starting to test the hypothesis about the presence of a return spread between green and brown stocks[31].

We have considered this issue in terms of achieving the minimal risk with a certain number of stocks in the portfolio. According to Campbell et al. (2001) and given the size of the sample, we have set a minimum limit for securities numbers in the portfolio of twenty stocks[32]. As can be seen from Fig. 1, the sample reaches this number of observations for the first time in June 2012. The time series are reduced to 115 observations with the introduction of this threshold.

The estimated time series of the green factor, or the return spread between green and brown stocks, turned out to be volatile (see Fig. 3), not allowing for unambiguous conclusions at this stage.

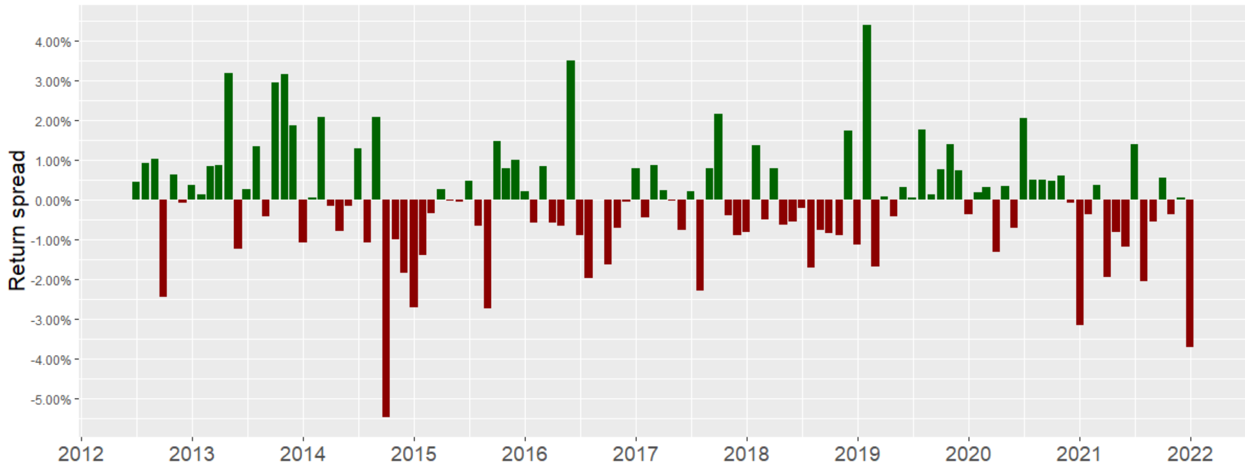

Fig.3. The green factor time series estimated according to equation (3)

A more general conclusion regarding the performance of the green factor can be drawn if we calculate the cumulative return for the whole observation period (see Fig. 4).

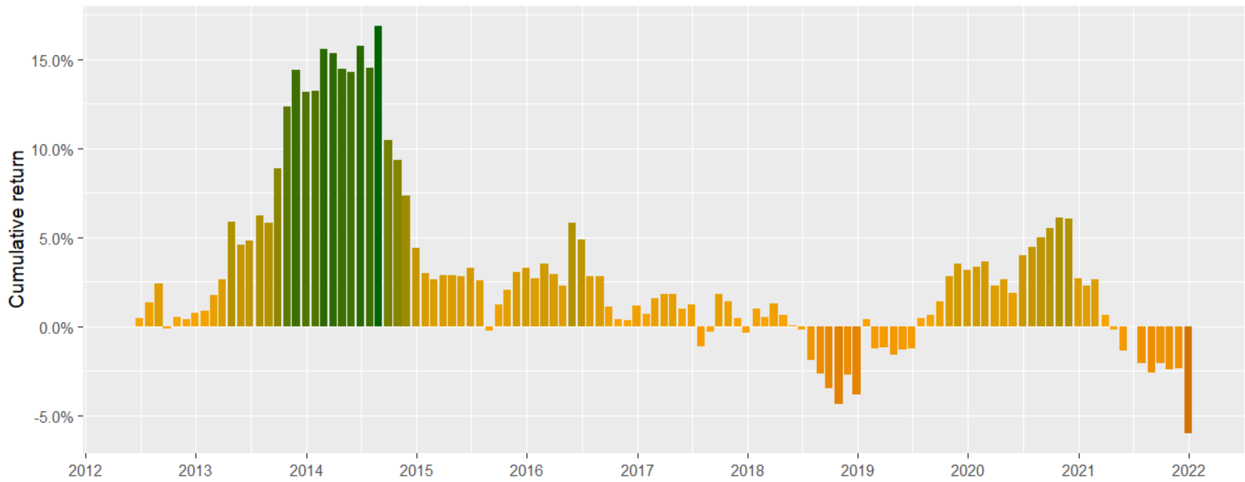

Fig.4. Cumulative green factor return

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[31] In S.Y., Park K.Y., Monk A. Is 'Being Green' Rewarded in the Market?: An Empirical Investigation of Decarbonization and Stock Returns // Stanford Global Project Center Working Paper. 2019. P.15.
[32] Campbell J. et al. Have Individual Stocks Become More Volatile? An Empirical Exploration of Idiosyncratic Risk // The Journal of Finance. 2001. Vol. 56 (1). PP. 25-26.

Figure 4 shows that the green factor, represented as a cumulative return, leads to a negative total return. The factor's cumulative return constituted about minus 6% by December 2021, with an average monthly return of minus 5.39 bps and the average annual return of minus 64.5 bps This fact is consistent with the research hypothesis, although it does not confirm it. The bar chart also clearly shows two long periods of decline in cumulative returns: from August 2014 to December 2018 and from October 2020 to December 2021.

The factor models consider return as a combination of various risk premiums. If we construct a model with the green factor as the dependent variable, and factors reflecting premiums for other risks as the explanatory variables, then the constant of such a model (the alpha coefficient) will show the excess return that other risk factors cannot provide. In addition to the green factor, we have included three other factors: the market factor, the SMB and HML factors from the three-factor Fama-French model (FF3). According to a study of the Russian stock market by Aistov and Kuzmichev (2013), the FF3 model most fully characterizes the asset pricing in the Russian market[33].

$$f_{gt} = \hat{\alpha} + \hat{\beta}_1 \tilde{r}_{mt} + \hat{\beta}_2 SMB_t + \hat{\beta}_3 HML_t \quad (6)$$

According to the FF3 methodology, we have made our own calculations of the SMB and HML factors on the basis of the stock returns[34]. However, we have included in the calculation only those stocks that had been used in the green factor estimation.

We have verified that the factors' time series are stationary using the unit root tests: augmented Dickey-Fuller test (ADF) with automatic lag selection based on the modified Schwartz information criterion and the Phillips-Perron (PP) test with the Bartlett kernel and the Newey-West bandwidth. The results of the regression of the obtained green factor on a constant, on a constant and a market factor, and on all three factors are presented in the table 1.

Table 1. Monthly time series regression of green factor, f_{gt}

Variables	**Models**		
	(1)	**(2)**	**(3)**
$\boldsymbol{\alpha}$	-0.000435 (-0.323)	-0.000478 (-0.353)	-0.000197 (-0.145)
$\tilde{\boldsymbol{r}}_{\boldsymbol{mt}}$	—	0.016039 (0.523)	-0.001769 (-0.057)
$\boldsymbol{SMB_t}$	—	—	-0.001397 (-0.055)
$\boldsymbol{HML_t}$	—	—	-0.028646 (-1.279)

t-statistics in parentheses

The green factor (the regression constant) has showed the expected negative value in all evaluated models: from minus 4.78 bps to minus 1.97 bps of monthly return. However, the statistically insignificant *t*-statistics for the regression constants do not allow us to confirm the research hypothesis. Such results can be explained both by the specific features of the Russian stock market and by the limited sample of companies in this research.

[33] Aistov A.V., Kuzmichev K.E. Empirical Analysis of Asset Pricing Models in the Russian Stock Market // Financial Analytics: Science and Experience. 2013. 5 (143). P. 44.
[34] Fama E., French K. Common risk factors in the returns on stocks and bonds // Journal of Financial Economics. , 1993. Vol. 33 (1). P. 7-10.

However, it should be noted that the insignificance of the regressions' coefficients does not necessarily indicate that the green factor's calculations were incorrect. The insignificance of the regression only on the constant (1) demonstrates the absence of a stable trend in the green factor realization during the whole observation period, which was already noted in the comments to Fig. 3-4. The insignificance the market premium beta indicates a weak correlation between the return of the portfolio that hedges the environmental risks and the market portfolio return (corr ≈ 0.049). Finally, the non-significant coefficients of the factors from the FF3 model suggest that the green factor does not depend on the phenomenon of the outperformance of small-cap stocks and growth stocks.

Robustness tests for the stock market

To verify that our results are robust, two assumptions in the return calculations have been changed. First, we have considered another risk-free rate to calculate the excess returns in equation (1). We have used the one-month government bond rate. This rate is also used in the original FF3 model[35] as well as in a number of studies of the Russian stock market[36]. We have chosen the one-month bond rate since all other returns are monthly. The results of this regression are presented in the second column of table 2.

Second, we have considered a shorter prior period for calculating the market betas. Estimating market betas based on just one previous year performance would inevitably lead to higher volatility of betas. However, we think that such a reduction is justified since emerging markets tend to be characterized not only by increased volatility, but also by shorter business cycles with changing trend characteristics[37]. In this case, a shortened period for estimating the market betas will give a more accurate result characterizing the current stage of the business cycle. In addition, this will increase the number of observations for each stock by 12 months. The results of this regression are presented in the third column of table 2.

Table 2. Results of evaluating equation (6) for various calculation methods of β_m and r_f. f_{gt} is dependent variable

	$\beta_m[t = 24m]$, $r_f[t = 10y]$	$\beta_m[t = 24m]$, $r_f[t = 1m]$	$\beta_m[t = 12m]$, $r_f[t = 10y]$
$\boldsymbol{\alpha}$	-0.0002 (-0.145)	-0.000 (-0.023)	-0.00016 (-0.129)
$\tilde{r}_{mt}$	-0.0018 (-0.057)	0.0013 (0.041)	-0.0143 (-0.496)
SMB_t	-0.0014 (-0.055)	0.0028 (0.103)	0.0084 (0.351)
HML_t	-0.0286 (-1.279)	-0.028 (-1.221)	-0.0222 (-1.058)
f_{gt} return			
cumulative	-6.01%	-7.07%	-9.2%
average monthly	-5.39 bps	-6.85 bps	-8.39 bps
average annual	-64.5 bps	-81.91 bps	-100.24 bps

t-statistics in parentheses

35 Fama E., French K. Common risk factors in the returns on stocks and bonds // Journal of Financial Economics. 1993. Vol. 33 (1). P.5

36 Fedorova E.A., Sivak A.R. Comparison of CAPM and Fama-French Models on the Russian Stock Market // Finance and Credit. 45 (222). 2012. P. 43.

37 Aguiar M., Gopinath G. Emerging Market Business Cycles: The Cycle Is the Trend // Journal of Political Economy. Vol. 115 (1). 2007. PP.69-102. P.70

All the coefficients remain insignificant despite changes made in calculating excess returns. The conclusions about the absence of a relationship between the green factor and other factors are valid. Similar non-significant regressions in estimating FF3 models were obtained, for example, by In et al. (2019)[38] on a sample of more than 700 US companies, and statistically significant alphas were obtained only by splitting the sample and increasing the number of factors. Our changes did not affect the sign of the cumulative returns of the green portfolio: the final returns are negative, and differences in percentages can be explained by the different composition of the sample.

Application of the obtained return factors on the stock market

We can apply the PST model or its extended version with SMB and HML factors to evaluate performance of individual stocks. Thereby, the environmental risk premium reflected in the green factor would be taken into account. Such usage of the PST model also allows for evaluating the consistency of all calculated factors.

As this part is intended mostly for demonstration purposes, we have chosen out of our sample of 70 shares only two groups of stocks with extreme values of environmental characteristics and capitalization have been estimated. The stocks in the first group have been selected according to the calculated E-score. The minimum E-score value in our sample belongs to the coal mining company Raspadskaya PJSC (RASP): minus 2.143 points. The median value pertains to the PJSC Tatneft (TATN) from the oil and gas industry: minus 0.39 points. The maximum value of E-Score is observed for the telecommunications company Mobile TeleSystems PJSC (MTSS), it approximately equals 2.318 points.

Since the Green Factor was calculated using the companies' environmental scores, its reverse application in the return explanation was expected to give negative Green Factor betas for brown companies and positive betas for green ones. The Green Factor coefficient for an environmentally neutral company or a company with a median E-score was expected to be close to zero or insignificant.

All factors are also excess returns. In such a case, the excess stock returns can be estimated by time-series OLS regressions of previously calculated factors. It was expected that "if the model is well specified, then in such regressions the constants should be indistinguishable from zero" [39]. White's heteroscedasticity-consistent standard errors are used to estimate stock returns.

Table 3. Estimation of the stock performance with the minimum, median and maximum E-score. Estimation period: July 2012 – December 2021

	RASP		TATN		MTSS	
α	0.009 [0.963]	0.009 [0.884]	-0.0005 [-0.087]	-0.0005 [-0.085]	-0.006 [-1.257]	-0.006 [-1.199]
$\tilde{r}_{mt}$	1.714 [7.014]***	1.720 [6.264]***	1.076 [8.605]***	1.077 [8.674]***	1.073 [5.532]***	1.071 [5.350]***
SMB_t	0.843	0.847	-0.123	-0.123	0.060	0.059

[38] In S.Y., Park K.Y., Monk A. Is 'Being Green' Rewarded in the Market?: An Empirical Investigation of Decarbonization and Stock Returns // Stanford Global Project Center Working Paper. 2019. https://ssrn.com/abstract=3020304. P.47.

[39] Fama E., French K. Common risk factors in the returns on stocks and bonds // Journal of Financial Economics. 1993. Vol. 33 (1). P.5.

	RASP		TATN		MTSS	
	[3.852]***	[3.359]***	[-1.096]	[-1.095]	[0.535]	[0.559]
HML_t	-0.282 [-1.561]	-0.184 [-0.887]	0.027 [0.318]	0.036 [0.422]	0.091 [1.198]	0.058 [0.691]
f_{gt}	**-3.443** [-4.618]***	—	**-0.317** [-0.968]	—	**1.146** [3.052]***	—
N	114	114	114	114	114	114
R^2	0.463	0.338	0.445	0.442	0.488	0.438
F-stat	23.495***	18.735***	21.842***	28.987***	26.000***	28.540***
AIC	-1.723742	-1.532261	-2.863654	-2.875069	-3.071137	-2.994437
SC	-1.603734	-1.436254	-2.743645	-2.779062	-2.951128	-2.898430
HQC	-1.675037	-1.493297	-2.814949	-2.836106	-3.022432	-2.955473

*Robust t-statistics in parentheses. *** p<0.01, ** p<0.05, * p<0.1*

The second group includes companies selected by extreme values of capitalization in the last sampling period, i.e. December 2021. During this period, PJSC RN-Western Siberia (CHGZ) had the minimum capitalization of less than 1.14 billion rubles. PJSC Rosseti (RSTI) had the median capitalization of about 272 billion rubles. Finally, in December 2021 PJSC Sberbank (SBER) had the maximum capitalization of more than 4.56 trillion rubles. According to the FF3 hypothesis, the SMB coefficient should decrease as the capitalization of the consideration companies grows[40].

Table 4. Estimation of the stock performance with the minimum, median and maximum capitalization in December 2021. Estimation period: July 2012 – December 2021

	CHGZ		RSTI		SBER	
α	0.012 [0.606]	0.012 [0.606]	-0.012 [-1.363]	-0.012 [-1.333]	0.0014 [0.282]	0.0013 [0.275]
$\tilde{r}_{mt}$	0.099 [0.289]	0.097 [0.286]	1.825 [7.937]***	1.827 [8.057]***	1.581 [13.655]***	1.580 [12.889]***
SMB_t	0.021 [0.072]	0.0196 [0.066]	0.654 [3.179]***	0.656 [3.227]***	0.293 [3.008]***	0.293 [2.93]***
HML_t	0.440 [1.589]	0.404 [1.490]	-0.226 [-1.639]	-0.185 [-1.328]	-0.150 [-1.861]*	-0.168 [-2.044]**
f_{gt}	**1.230** [0.917]	—	**-1.444** [-2.015]**	—	**0.631** [1.811]*	—
N	114	114	114	114	114	114
R^2	0.020	0.014	0.440	0.414	0.657	0.647
F-stat	0.558	0.510	21.391***	25.911***	52.185***	67.080***
AIC	-0.202308	-0.213390	-1.839217	-1.811881	-3.077563	-3.065308
SC	-0.082300	-0.117383	-1.719208	-1.715874	-2.957554	-2.969301
HQC	-0.153604	-0.174426	-1.790512	-1.772917	-3.028858	-3.026344

*Robust t-statistics in parentheses. *** p<0.01, ** p<0.05, * p<0.1*

According to the Breusch-Godfrey LM test, there is no evidence of serial correlation in the residual terms of the stock returns regressions. The null hypothesis of the serial correlation absence is not rejected in all cases, except for the CHGZ stocks. But the cause of the problem can be explained by the misspecification of the model in this case.

[40] Fama E., French K. Common risk factors in the returns on stocks and bonds // Journal of Financial Economics. 1993. Vol. 33 (1).

Results presented in the tables 3 and 4 demonstrate that only the regression of the CHGZ return is insignificant. The reason for this result might be a weak trade liquidity of this stock. The insignificance of even the market premium beta is explained by the low correlation with the Moscow Exchange index ($\text{corr} \approx 0.005$). The factor model should either be expanded or revised in this case.

The other five estimated stock return models are consistent and significant. The insignificance of the constants in all regressions proves correct specification of the factor model. The general conclusions also include the significance of the market factor at the 1% level. The SMB factor, which is responsible for the excess return of small-caps companies, is significant at the 1% level in the regressions for three stocks, and its coefficient decreases as the capitalization increases (0.656 for RSTI shares and 0.293 for SBER), confirming theoretical expectations.

The HML factor representing the excess returns of companies with a high book-to-market ratio is significant only in one case. The weak explanatory power of this factor in our regressions corresponds to the findings of Fedorova and Sivak (2012), who could not confirm significance of the HML factor for the six portfolios they have evaluated in the Russian stock market[41].

The green factor estimates are significant in four out of five regressions. The value of the f_{gt} coefficient demonstrates expected relationship with the calculated E-score. This suggests that our green factor calculations are correct. TATN, with a median E-score, received a non-significant Green Factor beta, as expected. According to at least two out of three information criteria, the model specifications with the green factor explain the stocks' performance better than without it, except for the stocks of TATN and CHGZ mentioned above.

Although the expected results of the green factor evaluation for our selection of stock do not necessarily apply to the entire sample or the whole population, they seem indicative that the green factor is important for practical purposes. The green factor reflecting the environmental risk premium in the factor model can show the degree of exposure to this risk of various public companies. In other words, the evaluation of the beta coefficients of the green factor calculated in advance provide an opportunity to obtain an environmental score of a listed company in relation to which there is no public ESG reporting.

Our results suggest at least one possible line for further research. It would be interesting to find an explanation for the change of sign of the green factor in time as well as the reasons for a stable negative return of the green factor in the period from August 2014 to December 2018. Public attention could one be one explanation for this phenomenon as it stands as a proxy variable for the public's climate concerns prompting investors to buy green assets[42].

Methodology for bond market

Bonds, unlike stocks, allow for calculating of the expected return through yield to maturity. Therefore, our hypothesis becomes more specific: increased demand for environmentally friendly – green – bonds leads to a higher price of these assets and, as a result, a lower yield to

[41] Fedorova E.A., Sivak A.R. Comparison of CAPM and Fama-French Models on the Russian Stock Market // Finance and Credit. 45 (222). 2012. P. 47.
[42] Engle R.F., Giglio S., Kelly B., Lee H., Stroebel J. Hedging climate change news // NBER Working paper. 2019. 25734. P. 2.

maturity. According to Flammer (2021), this hypothesis, if confirmed, might have 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)”[43].

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) should be negative. This difference is now known as the *Greenium*. It is convenient to evaluate the Greenium for the so-called *twin bonds*, i.e., two issues with the same credit rating, issuer, volume size, coupon rate, issue date, and maturity date. This allows for comparison of “identical streams of cash flows with identical credit risk but different greenness”[44].

One of the classic examples of twin bonds is the case of two German federal issues of 10-year zero-coupon bonds (ISIN: DE0001030708, DE0001102507). Though these bonds are not exactly identical (the issue dates and issue volumes differ, which theoretically could affect their liquidity), a stable negative Greenium was found: the yield spread between green and non-green bonds of these two issues ranged from -2 to -6.5 bps for the period from September 2020 to September 2021[45], i.e., conventional bonds outperformed green bonds. A similar performance 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 (and identifying the Greenium). Hachenberg and Schiereck (2018) offer a way to estimate the yield spread of green and non-green bonds through *i*-spreads, which are “noted in basis points (bps) above a risk-free benchmark, usually the swap rate” and hence “consist of the difference between the yield in question and the interpolated swap rate at the same maturity”[46].

The authors mention two advantages of their method: the ease of cross-country comparison in different currencies and the availability of the swap curve without additional estimation in constrast to the government bond curve. Both are not relevant for the purposes of our research. As we are looking only at rouble-denominated bonds and do not consider Eurobonds, the first advantage is not applicable. The second advantage is also irrelevant since both the Moscow Exchange (and the Bank of Russia with a reference to it) publishes data of the zero-coupon government curve on a daily basis.

The disadvantage of this approach includes the need to find two non-green bonds with different number of days to maturity for each green bond issue, which could become a serious problem in our case. This point will be further discussed in our *Data* section.

An alternative way to estimate the Greenium was proposed by Diaz and Escribano (2021). They use the 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 theoretical

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[43] Diaz A., Escribano A. Sustainability premium in energy bonds // Energy Economics. 2021. Vol.95. 105113. P.1.
[44] Pastor L., Stambaugh R.F., Taylor L.A. Dissecting Green Returns // Working paper NO. 2021-70. 10.06.2021. P.6.
[45] Deutsche Bundesbank. Green Bond Monitor. Zentralbereich Märkte September 2021. P.28. URL: https://www.bundesbank.de/resource/blob/879938/e4bf4ffdce6b9368b3167f3eb2695a42/mL/green-bond-monitor-data.pdf.
[46] Hachenberg B., Schiereck D. Are green bonds priced differently from conventional bonds? // Journal of Asset Management. 2018. Vol. 19. P. 4.

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 are: (1) yield spread estimation is not affected by potential differences in bond features, such as a coupon rate; and (2) yield spread "does not depend on the settlement date or the specific cash flow profile of the bond"[47], enabling comparison of bonds that are traded on different dates. These advantages are crucial for our case, as the relevant data for the Russian fixed income market are scarce.

Hence, we rely primarily on Diaz and Escribano (2021) approach for the first stage of our research, and we describe below its main steps in details.

Stage 1 – computing yield spreads for green and non-green bonds.

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

$$G(t) = \beta_0 + (\beta_1 + \beta_2)\frac{\tau}{t}\left[1 - \exp\left(-\frac{t}{\tau}\right)\right] - \beta_2 \exp\left(-\frac{t}{\tau}\right) + \sum_{i=1}^{9} g_i \exp\left(-\frac{(t-a_i)^2}{b_i^2}\right), \tag{7}$$

where $G(t)$ is the instantaneous forward rate in bps, $\beta_0, \beta_1, \beta_2, \tau, g_i$ are the government zero-coupon yield curve parameters, t is the term to maturity in years, a_i, b_i are parameters.

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

$$D(t) = \exp\left(-\frac{G(t)}{10\,000}t\right) \tag{8}$$

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

$$P_{G\_th} = \sum_{T=t_1}^{t_n} C_T \cdot D(T) \tag{9}$$

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 given by the following equation:

$$P_{G\_th} + A = \sum_{i=1}^{n}\left(\frac{C_i}{(1+YTM_{G\_th})^{\frac{t_i}{365}}} + \frac{N}{(1+YTM_{G\_th})^{\frac{t_i}{365}}}\right) \tag{10}$$

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 (10) is solved with respect to YTM_{G_th} by Newton's method (Uniroot function in R was used).

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

$$YS_G = YTM_G - YTM_{G\_th} \tag{11}$$

[47] Diaz A., Escribano A. Sustainability premium in energy bonds // Energy Economics. 2021. Vol.95. 105113. P.6.

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

6. Calculations (7) – (11) are repeated for the non-green bond to obtain the yield spread YS_B in a similar way to get:

$$YS_B = YTM_B - YTM_{B\_th} \tag{12}$$

where $\mathrm{YTM_B}$ is the effective yield to maturity of the non-green bond, $\mathrm{YTM_{B\_th}}$ is the effective yield to maturity of the synthetic government bond with similar cash flows as 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 (11) and (12):

$$Greenium = YS_G - YS_B \tag{13}$$

Stage 2 – comparing yield spreads

First using the *t*-test for mean values, the bond yield spreads obtained in equations (11) and (12) are checked for being statistically different. Secondly, after comfirming that there is, indeed, a difference in yield spreads, we consider if this difference can be explained by factors other than 'green/non-green' taxonomy. The base model is defined as follows:

$$\begin{aligned} Spread_{it} = {} & \alpha + \beta_1 \cdot Green_i + \beta_2 \cdot Liquidity_{it} + \beta_3 \cdot Bank_i + \beta_4 \cdot Rating_i + \\ & + \beta_5 \cdot lrRUABITR_t + \beta_6 \cdot RVI_t + \beta_7 \cdot KIR_t + \beta_8 \cdot RPUI_t + \varepsilon_{it} \end{aligned} \tag{14}$$

where $Spread_{it}$ is the dependent variable (from equations (11) and (12)), $Green_i$ is a dummy variable, taking value one if the bond has a green label and zero otherwise, $Liquidity_{it}$ is the measure of the bond liquidity. The latter is estimated as a weighed Bid-Ask spread using the following equation:

$$Liquidity = \frac{P_{Ask} - P_{Bid}}{(P_{Ask} + P_{Bid})/2} \tag{15}$$

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 an ordinal variable that equals 13, 17, 18 and 22, which corresponds to the scale BBB-, A, A+ and AAA; $lrRUABITR_t$, 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 Russian economic policy uncertainty index.

$\alpha, \beta_1, \ldots \beta_8$ 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.

Our choice of control variables is explained by 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 'bank' dummy. Emission's rating is important as it stresses the bond's overall credit quality and influences 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. Finally, changes in the policy rate have a direct influence on the bond market by changing the discount rate.

Our baseline model (14) is estimated using a variety of models: pooled, fixed effects, random-effects, between-effects, population averaged panel regression and hybrid model with the bond ISIN as the cluster variable. These alternative estimations are checked for consistency using Wald test, the Hausmann test and the Breusch-Pagan test.

Bonds' data description

According to the International Capital Markets Association's (ICMA) definition and that of 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"[48]. ICMA also restricts projects that can be funded by green bonds to be those involving "renewable energy, energy efficiency, pollution prevention and control, environmentally sustainable management of living natural resources and land use, terrestrial and aquatic biodiversity conservation, clean transport, sustainable water and wastewater management, climate change adaptation, eco-efficient and/or circular economy adapted products, production technologies and processes, [and] green buildings"[49]. Thus, investor can rely on a third-party verification of the issuer or the bond instead of carrying out his/her own analysis of the goals and objectives of the issue.

As of February 12th 2022, 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 liquidity level (the number of days traded, with a cut-off set as at least a third of total days of the trading history) for the purposes of this research. The remaining seven bonds meet the requirements of *plain vanilla bonds*, i.e., the simplest bonds with basic fixed features including coupon, maturity date, and face value. The total volume of seven issues exceeds 218 billion rubles. The history of trading varies from 56 to 544 trading 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) certain level of trade liquidity (the number of trading days is more than 1/3 of the trade history);

(6) the guarantees (or lack of them) is similar to 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 5.

48 Moscow Exchange. Bond preparation process. URL: https://bondguide.moex.com/articles/bond-preparation-process/42.

49 ICMA. The Green Bond Principles (GBP). P.4.URL: https://www.icmagroup.org/sustainable-finance/the-principles-guidelines-and-handbooks/green-bond-principles-gbp/.

Table 5. Green and non-green bonds

	Company	Issue	Terms		coupon		Economy Sector	Credit rating
			Placement	Maturity	Rate	Freq. per year		
1	Atomenergoprom	001P-01	25.06.2021	19.06.2026	7.5	2	En	AAA
	VTB	Б-1-231	02.07.2021	28.06.2024	7.5	4	B	AAA
2	Garant-Invest	001P-06	17.12.2019	13.12.2022	11.5	4	CD	BBB-
		002P-01	09.12.2020	23.11.2022	10.5	4	D	BBB-
3	Moscow	74	27.05.2021	18.05.2028	7.38	2	Mun	AAA
		73	09.07.2021	21.04.2026	7.2	2	Mun	AAA
4	Sinara	001P-02	28.07.2021	22.07.2026	8.7	2	ME	A
		001P-01	28.05.2021	24.05.2024	8.1	2	ME	A
5	Sberbank	002P-01	12.11.2021	10.11.2023	8.8	2	B	AAA
		001P-SBER32	11.08.2021	04.08.2023	7.3	2	B	AAA
6	Garant-Invest	002P-02	12.01.2021	25.12.2023	10.0	4	CD	BBB-
		002P-03	09.04.2021	26.03.2024	10.5	4	CD	BBB-
7	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: E – energy, B – banks, CD – Construction and development, Mun – municipal, ME – Mechanical engineering, VP – Vehicle production.

As can be seen from table 5, only one bond (Atomenergoprom) has no pair among non-green bonds of the same issuer. Therefore, a VTB PJSC bond was selected for this bond as a counterpart. 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) and the time terms and the structure and values of cash flows are taken from the CBonds.ru database, a reliable source of information on everything related to bonds in the Russian financial market. The zero-coupon yield curve parameters for each trading day are taken from the Moscow Exchange. As can be seen from table 6, minimum yield to maturity was recorded for the City of Moscow non-green bonds (5.79%), and maximum was for the Garant-Invest green bonds (21.5%).

Table 6. Yield to maturity descriptive statistic

#	Company	issue	Min	Mean	Max	SD
1	Atomenergoprom	001P-01	0.073551043	0.080857996	0.100705249	0.007112367
2	VTB	Б-1-231	0.072816808	0.080289082	0.095038115	0.005572061
3	Garant-Invest	001P-06	0.09134812	0.12596879	0.21473756	0.02202050
4		002P-01	0.10105513	0.11548802	0.16234636	0.01375229
5	Moscow	74	0.074587524	0.082709072	0.102836520	0.008857476
6		73	0.057903339	0.077585707	0.091460337	0.006334741
7	Sinara	001P-02	0.088563605	0.098812631	0.117585216	0.009863389
8		001P-01	0.08067111	0.09314671	0.12524664	0.01188489
9	Sberbank	002P-01	0.081241810	0.089614243	0.099986436	0.003334117
10		001P-SBER32	0.072207409	0.084692741	0.106059296	0.009521088
11	Garant-Invest	002P-02	0.09099961	0.11227765	0.17943773	0.01451688

#	Company	issue	Min	Mean	Max	SD
12		002P-03	0.10791352	0.11889549	0.15132930	0.01428787
13	KAMAZ	БО-П09	0.04922025	0.09180487	0.10012460	0.01065770
14		БО-П08	0.077844095	0.087865629	0.110344676	0.008907904

Data on daily values of the Moscow Exchange Aggregate Bond Index (RUABITR), the New Russian Volatility Index (RVI), measured as "the market's expectation of the 30-day volatility"[50], and the policy rate (key rate) are taken from the Cbonds.ru database. The monthly values of the Economic Policy Uncertainty Index for Russia, based on newspaper articles, is taken from the website of the Economic Policy Uncertainty Project. The bond credit rating values are based on the data of the ACRA rating agency (or Expert-RA, where ACRA does not provide data) and converted to numbers as follows: the highest rating AAA equals 22 and the lowest rating D equals 1 with a step of 1 between the grades. The bond credit rating and the bond green label remain unchanged for the whole duration of the sample for each issue.

Results for the bond market

The Greenium, or the yield spread of green and non-green bonds, calculated according to equation (13), is displayed as Fig. 5 to 11.

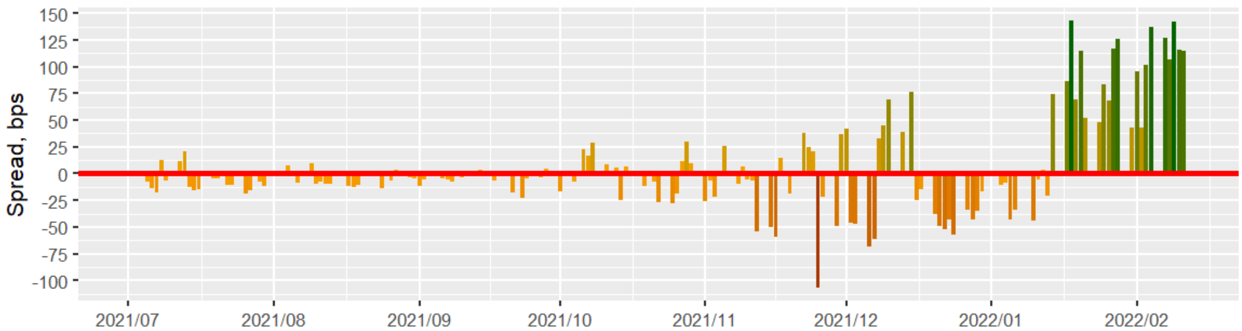

Figure 5. Yield spread between the Atomenergoprom green bond and the VTB non-green bond

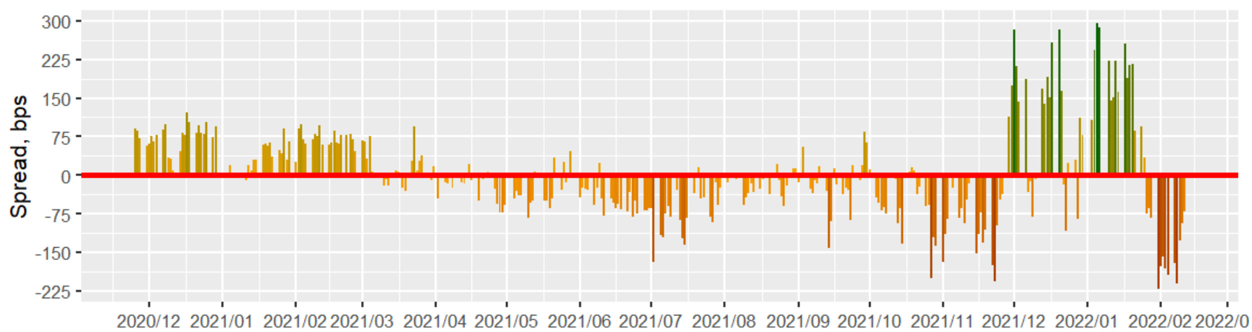

Figure 6. Yield spread between the Garant-Invest (1-st issue) green and non-green bonds

[50] The Moscow Exchange. The New Russian Volatility Index – RVI. URL: https://www.moex.com/en/index/RVI/.

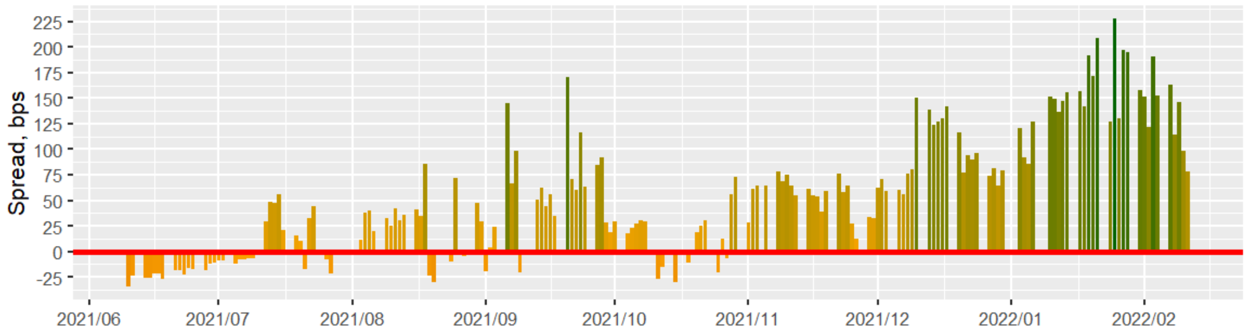

Figure 7. Yield spread between the City of Moscow green and non-green bonds

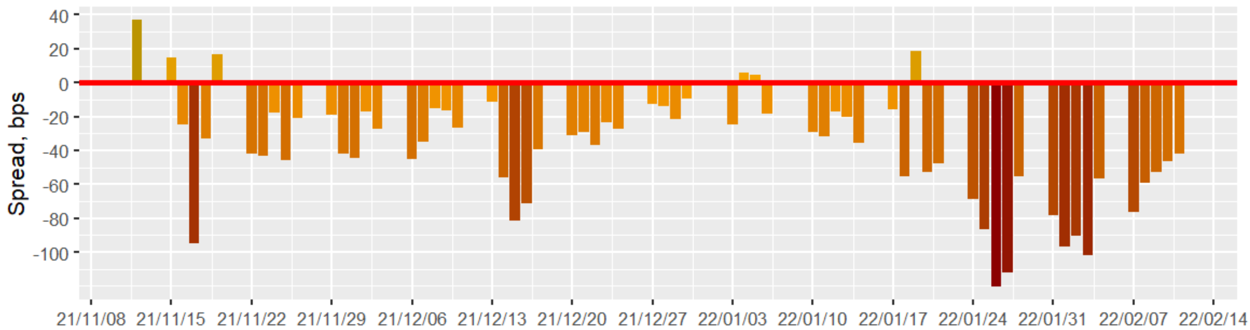

Figure 8. Yield spread between Sberbank green and non-green bonds

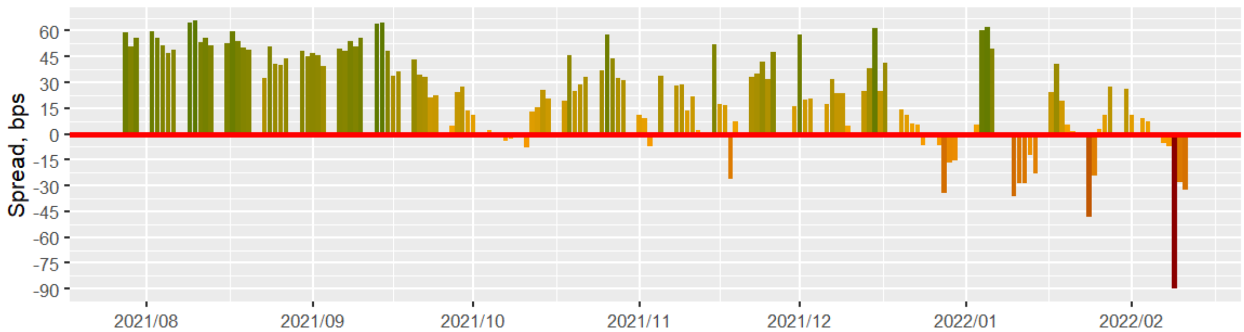

Figure 9. Yield spread between Sinara green and non-green bonds

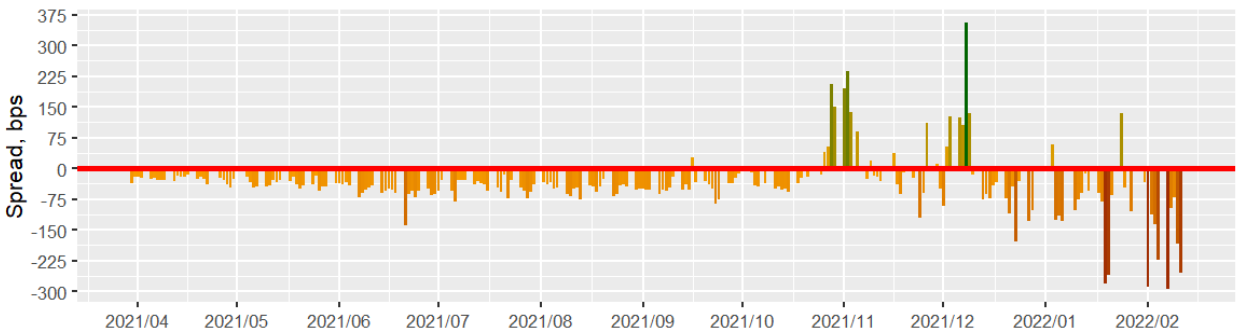

Figure 10. Yield spread between Garant-Invest (2-nd issue) green and non-green bonds

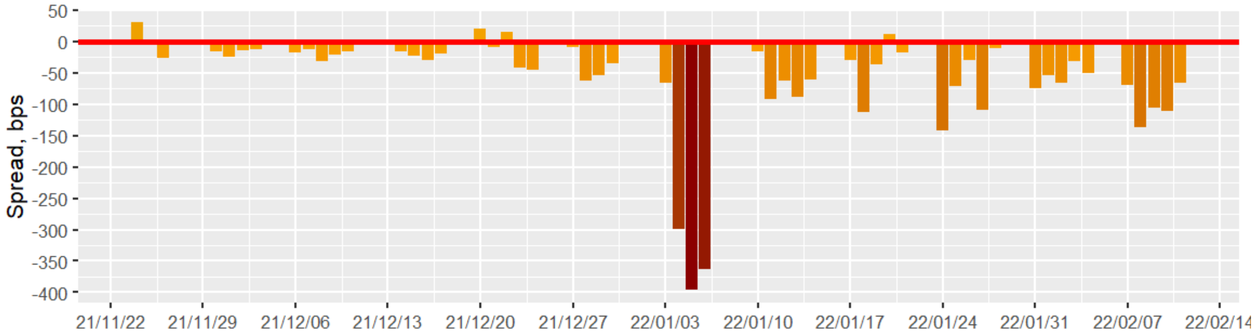

Figure 11. Yield spread between KAMAZ green and non-green bonds

Visual analysis of the graphs does not allow for an easy and simple interpretation of Greenium results. For some bond pairs, most notable for those in the middle of investment rating scale, the yield spread remains consistently negative until autumn 2021, providing support for our main hypothesis. At the same time, for municipal bonds of the City of Moscow and for one of the issues of Garant-Invest, the spread is not stable in time.

The t-test-based comparison of the spreads obtained according to equations (11) and (12) allows us to judge whether the mean values of both spreads (for green and non-green bonds) are equal.

Table 7. Mean values of spreads

Bond	**Mean of spread**		***t*-stat**	***p*-value**
	Green	**Non-green**		
Atomenergoprom / VTB	18.42584	12.54806	1.0146	0.3112
Garant-Invest (1-st issue)	502.1682	500.5818	0.16474	0.8692
Moscow	47.220701	-6.579735	10.696	0.000
Sinara	184.7852	160.8924	5.8505	0.000
Sberbank	-0.5362438	37.9972163	-6.4425	0.000
Garant-Invest (2-nd issue)	408.1489	446.1005	-5.1068	0.000
KAMAZ	16.36964	74.00647	-4.302	0.000

*** p<0.01, ** p<0.05, * p<0.1

As can be seen from table 7, 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. This suggests that proceeding with our baseline model (14) is reasonable.

Before the estimation of the equation (14), we have checked that all time-series are stationary (the ADF and the PP unit root tests were used). The RVI, KIR and RPUI variables are taken in the first difference as they demonstrate unit roots in levels. Hence, they characterize the absolute increase in the respective variables. All other variables are stationary in levels. The panel data for the dependent variable Spread and for the Liquidity variable were tested using the Fisher-type panel tests on the basis of ADF or PP tests with a preliminary subtracting of cross-sectional means. This type of tests allows us to check for unit roots in unbalanced panels (with different time intervals and with gaps).

Table 8 presents results of four different models for 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 8. Models on the full sample

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

*t-stat or z-stat (for RE-model) in parentheses. *** p<0.01, ** p<0.05, * p<0.1*

The zero p-value of F-statistics ($F_{(10,2757)} = 1427$) in the pooled model (1) allows us to reject the null hypothesis that all coefficients are equal to zero. The *t*-statistic values suggest that all coefficients are also significant at the 1% level. However, the sign of the coefficient for the green bond label is positive, which is at odds with the research hypothesis and preliminary visual 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 8 does not allow for estimation of the coefficient of the variable $Green$ aimed at verifying our 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. In the fixed effects model, the F-statistics ($F_{(13,2749)} = 649.5$) and the null p-value of the Wald test reject the null hypothesis that the coefficients reflecting individual effects are equal to zero. Therefore, the fixed effects model (2) is preferable to the pooled model (1).

The random effects (RE) model is presented as model (3) in table 8. The high value of the Wald test statistics ($\chi^2 = 1696$) indicates the significance of the regression in general. The covariates do not correlate with unobservable random effects, so the model estimates may be consistent. The p-value of the Breusch-Pagan test statistics indicates that the random effects model (3) is preferable to the pooled model (1). The value of the Hausman test statistics ($\chi^2 = 11.53$) suggests that the alternative hypothesis should be accepted, i.e., the fixed effects model (2) is preferable. The estimates of the RE model (3) could be biased and inconsistent although the value of the t-statistics 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. This allows us to conclude that the between intergroup effects are irrelevant. The reason for this is our extremely limited sample (a narrow panel). Also, idiosyncratic risks may be significant for all seven bond pairs.

The controversial Greenium charts presented in Fig. 5-11 can be explained by the fact that the spread changed its sign for most of the bond pairs in the fall of 2021. We have examined the time series of the composite bond index of the Moscow Exchange (RUABITR) to check if there were significant structural changes in the bond market. For this purpose, the RUABITR time series for the period of May 27, 2021, to February 11, 2022, has been tested for multiple structural breaks using the Bait-Perron test. The F-statistic of the resulting structural shift dated September 16, 2021, is significant at the 5% level ($\mathrm{F} = 23{,}5,\ \mathrm{F}_{crit} = 11{,}83$).

The index's fall, starting on September 16th 2021 (see Fig. 12), could have been caused by the capital outflow from the emerging markets due to the potential COVID-19 threats, as well as rising inflation and tightening of central banks' monetary policies. As a result, more risky emerging market assets were discounted more than those of the developed markets. This could have led to lower asset demand from investors.

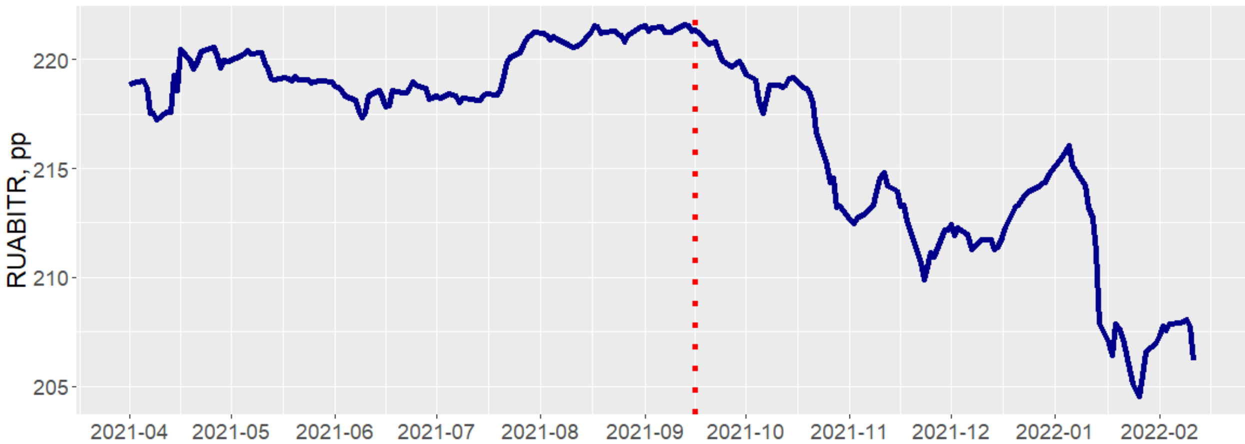

Fig.12. Structural breakpoint of the composite bond index of the Moscow Exchange

Thus, the first (earlier) part of the sample counts 1413 observations. The dependent variable remains $Spread_{it}$.

Table 9. 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*** (2.93)	0.15*** (2.95)	-0.73 (-2.89)	-0.04 (-0.52)	0.15*** (3.00)	0.02 [1.43]	0.02 [1.39]
lrRUABITR	0.36*** (2.78)	0.38*** (2.78)	11.77 (1.34)	-0.02 (-0.05)	0.36*** (2.78)	0.07** (2.41)	0.06** [2.18]
ΔRVI	8.88*** (19.81)	9.10*** (19.63)	73.79 (4.73)	2.89 (1.43)	8.88*** (19.79)	2.51*** [9.50]	2.31*** [8.66]
ΔKIR	-36.11*** (-9.35)	-35.42*** (-8.93)	11.19 (0.24)	-18.26*** (-2.97)	-36.09*** (-9.34)	-15.61*** [-8.62]	-14.99*** [-8.24]
ΔRPUI	0.15***	0.16***	-1.89	-0.05	0.15***	0.02	0.02*

Variables	(5) Fixed effects	(6) Random effects	(7) Between effects	(8) Population averaged	(9) Hybrid	(10) Hybrid HAC	(11) Hybrid HAC
	(4.89)	(5.16)	(-2.18)	(-0.89)	(4.89)	[1.28]	[1.68]
1.Green	—	**50.10*** (4.07)**	**-60.24 (-2.57)**	**-0.58 (-0.03)**	**-32.18*** (-3.64)**	**-35.45*** [-4.77]**	**-34.48*** [-4.57]**
1.Bank	—	63.53*** (2.98)	-134.63 (-3.06)	13.12 (0.39)	-84.21*** (-3.79)	-87.12*** [-5.76]	-73.74*** [-4.76]
(A).rating	—	-255.18*** (-14.73)	-181.78 (-3.55)	-228.70*** (-8.77)	-183.9*** (-6.01)	-166.48*** [-8.12]	-139.37*** [-6.61]
(A+).rating	—	-281.23*** (-11.61)	-337.77* (-6.65)	-283.96*** (-7.75)	-325.6*** (-11.58)	-326.27*** [-16.06]	-313.44*** [-15.31]
(AAA).rating	—	-400.55*** (-27.64)	-238.91 (-4.04)	-350.39*** (-16.22)	-269.2*** (-9.67)	-269.44*** [-12.46]	-249.93*** [-11.16]
Constant	322.37*** (12.91)	374.90*** (14.14)	-874.95 (-3.25)	463.50*** (11.19)	458.49 (0.97)	772.02*** [2.65]	1,261.2*** [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

*t-stat or z-stat (for RE and HM-models) in parentheses. *** p<0.01, ** p<0.05, * p<0.1*

The re-estimated fixed effects model (5) with omitted main variable and on the restricted sample is presented in table 9. This model is estimated for the purpose of comparison with the random effects model (6). However, the Hausman test statistics ($\chi^2 = 98{,}2$) gives the preference to the fixed effects model (5) despite the 99% confidence interval of the $Green$ coefficient estimate. The results of between effects (BE) model (7) repeat the previous conclusion on the whole sample: the estimated coefficients of interest are not significant.

The results of yet another approach are shown in the output of model (8). These are the estimates of the population-averaged model with the unstructured correlation matrix based on the generalized estimating equations (GEE), which is a type of generalized linear models. According to Koziol (2015), “the GEE method accounts for variation of the random effects by specifying a more complex variance structure for [the depended variable]”[51]. One of the important advantages of this approach is that its estimators are robust to misspecification. This model shows a high value of the Wald test statistics ($\chi^2 = 417{,}1$) but no significance of the $Green$ coefficient and all other control variables except of rating and key rate.

Results of estimating of the hybrid model, or the within-between random effects model (REWB), are presented in column (9). The model combines two types of effects: RE and FE. According to Schunck et al. (2013), “a decomposition into between and within effects can be used with generalized estimating equations, which enables us to specify less restrictive within-cluster error structures”[52]. Another advantage of this approach is that it represents an alternative to the Hausman test.

All the coefficients of the hybrid model are significant and have expected signs. The green label for a bond reduces the spread to the government yield curve by 32 bps, with everything else being equal. It should be also noted that all variables in model (9) that change over time have very similar coefficient values as in model (5). In other words, the hybrid model provides the same estimates as the FE model but with the estimates of time invariant variables.

[51] Koziol N. A comparison of population-averaged and cluster-specific approaches in the context of unequal probabilities of selection. Dissertation. Lincoln, Nebraska. 2015. P.40-41.

[52] Schunck R. Within and between estimates in random-effects models: Advantages and drawbacks of correlated random effects and hybrid models // The Stata Journal. 2013. Vol.13 (1). P.67

The hybrid model (9), which showed significant results, was tested by the LR test and the Wooldridge test. The tests have detected both heteroscedasticity and serial correlation in residuals. The hybrid model (10) of table 9 presents the results of the re-evaluation of the REWB model. The heteroscedastic structure of errors and the first-order within-group correlation (HAC), individual for each bond, have been taken into account. Despite the significance missing for Liquidity and RPUI variables, the Green variable is still significant and negative.

Robustness tests for the bond market

To check for robustness of our results, we have substituted part of our sample. As we have 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 bonds counterparts consisting of six criteria, the results of table 9 have changed in two cases.

For the green bond of Atomenergoprom, we have chosen 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, and the issuer has the highest national rating, although from a different rating agency. Besides, we have chosen another security of the same issuer for the green bond of Sberbank. The new non-green bond has a lower coupon and a period of six months longer, but these facts are not a limitation for applying the methodology, as has already been noted above. For the remaining five green bonds mentioned in table 5, it was impossible to find other non-green counterparts.

We have 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 have obtained a similar number of observations as in models (5) – (10) from table 9. As a result of the revision of the two non-green counterparts, the total number of observations changed in 291 cases out of 1413, which constitutes about 20% of the original sample.

We have used the REWB model, which showed its consistency, to check the updated sample. The estimates take into account heteroscedasticity and within-group autocorrelation (HAC). The sample change has not caused significant differences in the results according to model (11) from table 9. All estimates of the control variables have showed 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 bps 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 are counterintuitive. Therefore, in Table B of the Appendix we present the estimates with the rating variable substituted for the logarithmic probability of default. We also provide in Table B regression results without Bond Index variable to ensure that there is no endogeneity problem. The results are robust to these changes.

Conclusion

In this paper we have considered whether there is a return spread between assets depending on their environmental characteristics on the Russian financial market on the example of the stock and bond markets. Our main hypothesis, based on the literature review, was that should such return spread exist, it should be in favour of the brown assets, implying that a portfolio hedging environmental risks should have a negative risk premium.

In the stock market we have tested our hypothesis for the realized returns. The results of the green factor estimation by the three-factor Fama-French model did not demonstrate a stable statistically significant negative value for the whole sample. However, the cumulative return of the green factor estimated using the PST methodology, i.e. the realized return of the climate-risk hedge portfolio, constructed according to the company's environmental performance, has showed a negative value over a nearly ten-year observation period. The environmental risk premium ranged from 6% to 9% over a period of 9.5 years. Consequently, green company stocks may generate lower realized returns than brown stocks (i.e. the negative yield spread), which is consistent with the research hypothesis. We have also demonstrated how to calculate the degree of climate risk exposure for individual companies.

The presence of a yield spread between green and non-green issues, or the Greenium, is examined for a sample of Russian green bonds. The methodology used for estimating the Greenium includes finding a twin bond that is non-green and then constructing synthetic government bonds with cash flows similar to existing bonds to find excess return. The Greenium was calculated for all existing issues of green bonds quoted on the Moscow Exchange with a sufficient level of liquidity. Our results indicate that the mean excess return differs for bonds with or without the green label for the majority of the analyzed issues.

Six econometric models were built to quantify the Greenium. The pooled, fixed effects, random effects and between effects models proved to be inapplicable for the evaluation of how the bonds' *greenness* affects the expected return both for the whole sample and for a shorter version. The pooled model proved to be inconsistent in comparison with the fixed effects and random effects models. The random effects model, despite confirming the negative yield spread hypothesis, provided inconsistent estimates according to the Hausman test. The fixed effects model turned out to be inapplicable to test the research hypothesis due to the time invariance of the environmental characteristic of the bond.

The population-averaged model and the hybrid model gave significant estimates and allowed us to conclude that an environmentally friendly asset shows a lower expected return for the relatively stable period in the fixed income market. Our conclusion means that a green bond issuer in the Russian market can reduce the cost of debt and partly offset additional costs for non-financial reporting.

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Appendix

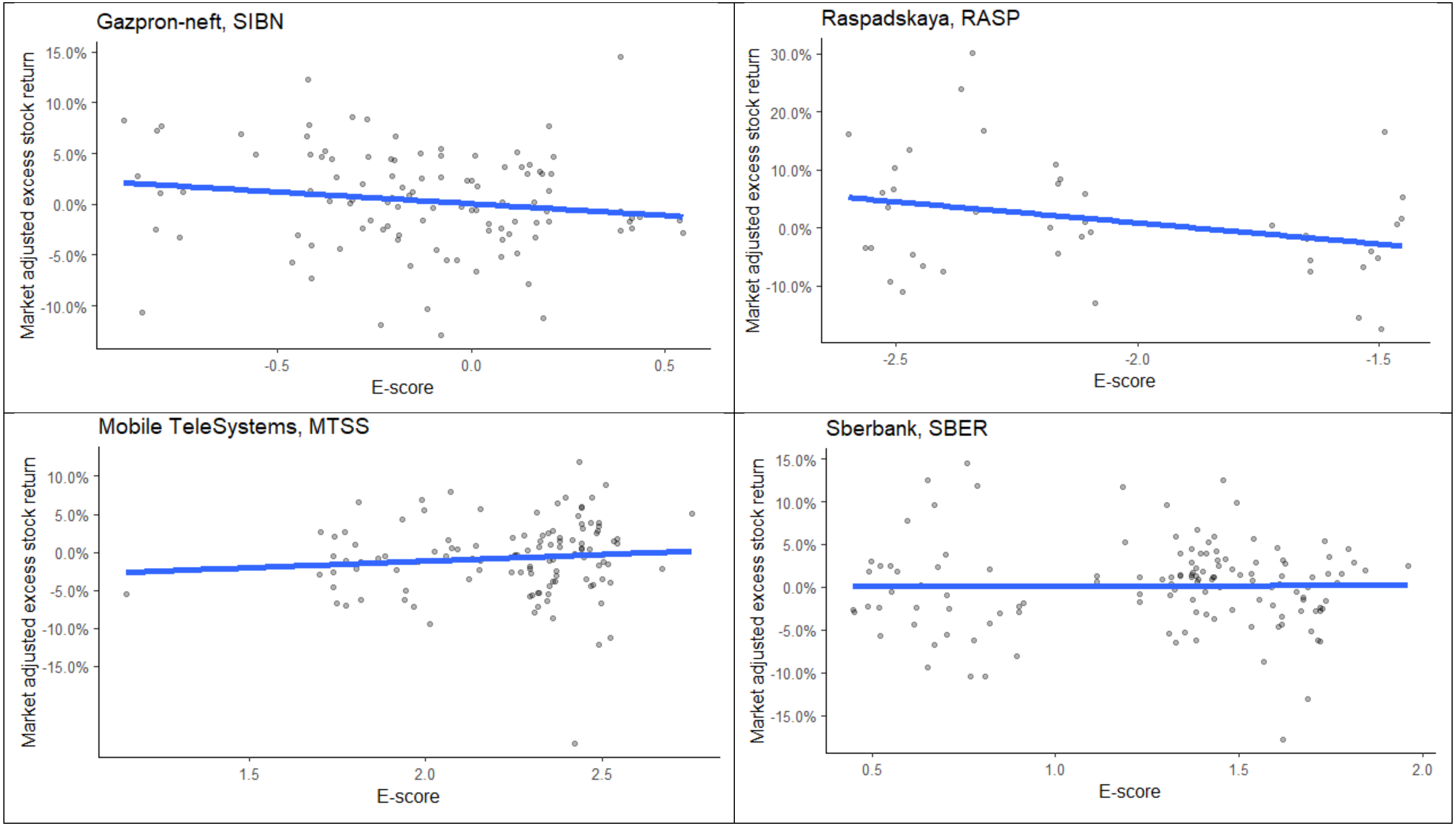

Fig. A. Slope of the regression or the green factor $\hat{f}_g$ estimation for individual companies

Table B. 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	(14) Hybrid HAC	(15) Hybrid HAC
1.Green	**-35.45*** (-4.77)**	**-26.42*** (-3.31)**	**-37.35*** (-4.77)**	**-7.31 (-0.86)**
Liquidity (between)	-0.66*** (-6.05)	-0.48*** (-4.10)	-0.52*** (-4.98)	-0.24** (-1.96)
Liquidity (within)	0.02 (1.43)	0.02 (1.43)	0.02 (1.23)	0.02 (1.08)
lrRUABITR (between)	41.49*** (5.79)	22.91*** (3.05)	—	—
lrRUABITR (within)	0.07** (2.41)	0.07** (2.49)	—	—
ΔRVI (between)	117.32*** (9.05)	94.30*** (6.01)	79.47*** (6.43)	85.62*** (5.13)
ΔRVI (within)	2.51*** (9.50)	2.15*** (7.98)	2.17*** (8.03)	1.77*** (6.30)
ΔRPUI (between)	-5.28*** (-6.02)	-3.88*** (-3.75)	-2.81*** (-2.70)	-3.59*** (-3.14)
ΔRPUI (within)	0.02 (1.28)	0.02* (1.68)	0.01 (1.10)	0.01 (1.00)
ΔKIR (between)	-311.26*** (-6.48)	-342.80*** (-6.40)	-223.37*** (-3.64)	-358.17*** (-5.78)
ΔKIR (within)	-15.61*** (-8.62)	-14.00*** (-7.30)	-13.06*** (-7.08)	-10.39*** (-5.42)
(A).rating	-166.48*** (-8.12)	—	-195.46*** (-6.67)	—
(A+).rating	-326.27*** (-16.06)	—	-313.04*** (-12.31)	—
(AAA).rating	-269.44*** (-12.46)	—	-283.35*** (-10.40)	—
ln(PD)	—	45.19*** (8.47)	—	43.64*** (6.95)
1.Bank	-87.12*** (-5.76)	-46.03*** (-2.63)	-91.17*** (-5.24)	-40.21** (-2.01)
Constant	772.02*** (2.65)	1,364.26*** (4.93)	427.88 (1.04)	1,532.30*** (5.38)
Observations	1,413	1,413	1,413	1,413
Number of id	12	12	12	12
Wald chi2	8562.45	6427.74	5887.74	4864.26

*z-statistics in parentheses. *** p<0.01, ** p<0.05, * p<0.1*
(10) The model is re-estimated as model (10), Table 9.
(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) Both assumptions of models (12)-(13) have been made.