Greenness ratings and green bond liquidity

Gregor Dorfleitner [a,b], Jens Eckberg [a], Sebastian Utz [c,d,e,f,*]

[a] *Department of Finance, University of Regensburg, Regensburg, 93053, Germany*
[b] *Hanken Centre for Accounting, Finance and Governance, Hanken School of Economics, Helsinki, 00100, Finland*
[c] *Department of Climate Finance, University of Augsburg, Augsburg, 86159, Germany*
[d] *Centre for Climate Resilience, University of Augsburg, Augsburg, 86159, Germany*
[e] *Swiss Institute of Banking and Finance, University of St. Gallen, St. Gallen, 9000, Switzerland*
[f] *Sustainable Finance Research Platform, Berlin, 10117, Germany*

1. Introduction

This study investigates the effect of greenness ratings for green bonds, assigned by second-party opinion (SPOs), on green bond liquidity. It is important to examine this relationship since liquidity, in addition to parameters such as credit rating, is a well-documented risk factor in the financial literature that has an impact on the value of bonds (e.g. Elton and Green, 1998; Elton, 2001; Amihud et al., 2006; Chen et al., 2007; Dick-Nielsen et al., 2012; Utz et al., 2015). Specifically, studies predominantly show that bonds with higher liquidity tend to have lower yields.

In the environment of green bond market, the analysis of bond liquidity and its determinants is not yet covered in the literature. However, there are numerous studies on the green bond premium, i.e., the difference between the yields of green bonds and similar conventional bonds (e.g. Hachenberg and Schiereck, 2018; Bachelet et al., 2019; Zerbib, 2019; Tang and Zhang, 2020; Dorfleitner et al., 2022; Koziol et al., 2022). These studies consider the liquidity of green bonds as an important control variable for a possible liquidity premium when examining the green bond premium. In this context, Wulandari et al. (2018) find that green bond liquidity has an effect on yield spreads. Therefore, and since the research question of which factors influence the liquidity of green bonds is still unanswered, we analyze the relationship between greenness ratings of green bonds and their liquidity.

Theory dictates that market liquidity is related to the level of information asymmetry and adverse selection costs in markets (e.g. Copeland and Galai, 1983; Glosten and Milgrom, 1985; Kyle, 1985). As of today, green bonds lack an official and universally accepted framework which assures the environmental impact of the financed projects and the correct use of proceeds. The alignment of a green bond according to the Green Bond Principles (GBPs) is not mandatory and the issuer can decide if they assign an independent external review such as an SPO to the green bond. Also, post-issuance reporting on the use of proceeds is not standardized. However, SPOs may contain additional and relevant information, leading to information asymmetry when SPOs are not used. In particular,

* Corresponding author at: Department of Climate Finance, University of Augsburg, Augsburg, 86159, Germany.
E-mail address: sebastian.utz@uni-a.de (S. Utz).

the use of a greenness rating by SPOs can reduce information asymmetry by providing a standardized and transparent assessment of the environmental impact of a green bond. This may result in higher liquidity and lower returns, as investors may be more willing to invest in bonds that have been independently verified as environmentally friendly. By reducing liquidity risk, green bond issuers could benefit from lower costs of capital and higher market valuations. Thus, liquidity effects have high capital-market implications, especially for green bonds.

We analyze a sample of 3,496 green bonds to examine the determinants of green bond liquidity. Firstly, we use three alternative liquidity measures over a period of 14 years: the bid–ask spread, the LOT liquidity estimate (Lesmond et al., 1999; Chen et al., 2007), and the measure of zero-trading days (Lesmond et al., 1999; Chen et al., 2007). Secondly, we analyze the effect of greenness ratings on green bond liquidity by estimating regressions in which we control for credit risk, bond-specific characteristics, macroeconomic variables, and year effects. We find clear evidence that green bonds with a good greenness rating awarded by an SPO show higher liquidity. When we split the greenness rating of green bonds into a dark green and medium green shade, we do not find a significant difference in liquidity between the green bonds of these two shades. Hence, while the color of green, awarded by a greenness rating in an SPO, versus no shade matters for the liquidity of a green bond, the particular shade of green does not have an effect on liquidity. In additional tests, we investigate whether the greenness–liquidity relation differs for specific issuer types. Green bonds issued by corporate entities and municipalities show a significant effect of greenness ratings on liquidity, while our findings do not provide significant evidence for green bonds issued by financial institutions and public issuers.

The contribution of this study is as follows. First, we extend the literature on green bonds and bond liquidity by providing evidence of the relationship between greenness ratings and green bond liquidity. Albeit most studies on green bonds (mostly with a focus on the green bond premium) suffer from small sample sizes due to the application of matching approaches, we provide evidence from a large sample of green bonds as no bond pairs are formed to analyze green bond liquidity. Second, the study contributes to the literature on environmental and climate finance by examining how the use of greenness ratings can increase transparency and standardization in the green bond market. Finally, the results are particularly important (1) for investors to know what liquidity they can expect when investing in a green bond and (2) for issuers to know how they can improve the liquidity of their green bonds to benefit from reduced capital costs.

2. Sample and data set

2.1. Data set

Our data set comprises a unique combination of information from different sources. The main data is extracted from the Environmental Finance (EF) bond database and contains green bonds issued from April 2008 until April 2020. It includes self-labeled green bonds with information on bond issuance and related documents, such as external review reports. The data set is supplemented by bonds which are labeled as green on Thomson Reuters Eikon. Further basic bond features are added from Eikon, such as credit rating[1] and seniority. As information on external reviews included in the EF database is comprehensive but not complete, the data set is augmented by external review reports from the International Capital Market Association (ICMA) and the Climate Bond Initiative (CBI). Still missing data is hand-collected from the issuers' official websites while existing data is validated through manual checks. Data on the shade of green ratings is also hand-collected via downloaded SPOs. We adapt the methodology of Dorfleitner et al. (2022) and classify the awarded shade of green by the different SPO providers into three unified categories: dark green, medium green, and no shade. Finally, daily time-series data on clean prices, bid and ask yields, and macroeconomic data from April 2008 to April 2021 are extracted from Bloomberg and Eikon. Following Bao et al. (2011), only bonds that have been active for at least one year are included in the data set, and quotes with bid–ask spreads that are negative or zero are eliminated. Additionally, as greenness ratings only appear in our sample from 2013 onwards, only observations from 2013 onwards are included in the analysis. After these corrections, the final data set consists of 3,496 green bonds.

2.2. Description of liquidity measures

We consider the three liquidity measures (1) bid–ask spread, (2) LOT liquidity estimate, and (3) zero-trading days. The bid–ask spread is defined as the amount by which the ask price exceeds the bid price of a security and can be interpreted as the round-trip transaction cost for an immediate transaction (e.g. Longstaff et al., 2005; Chen et al., 2007; Bao et al., 2011). The LOT liquidity estimate captures transaction cost of equity and is defined as the difference between the buy-side and sell-side transaction cost with respect to a marginal investor (Lesmond et al., 1999; Chen et al., 2007). The measure of zero-trading days is calculated as a percentage of zero-trading days relative to total trading days per bond per year and follows the rationale that zero-trading days are more likely for less liquid securities (Lesmond et al., 1999; Chen et al., 2007). We calculate liquidity measures on bond-year level and winsorize all liquidity measures at the 1% and 99% levels. Moreover, to reduce noise in the liquidity measures stemming from bond-year observations with only a few daily price observations to estimate liquidity measures, we remove 95 bond-year observations of green bonds from the original sample since their maturity is less than six months. Subsequently, we have a total of 17,679 bond-year observations in our panel dataset, whereas only 13,002 observations are available for the LOT liquidity estimate due to data limitations. The correlation between the bid–ask spread and the LOT liquidity estimate is 6.73%, while the correlation

[1] Note that different credit rating regimes are converted into the same scale as that of S&P on Eikon.

Table 1
Descriptive statistics for metric variables.

Variable	Obs.	Mean	Std.	Min	Median	Max
A. Time-variant						
Bid–Ask (bp)	17,679	9.30	13.38	1.60	4.99	101.20
LOT (bp)	13,002	22.57	11.46	2.30	20.64	66.55
%ZTD (%)	17,679	16.47	29.28	1.15	4.65	100.00
maturity (years)	17,679	10.00	17.94	0.25	8.37	1,000.61
B. Time-invariant						
issued_amount (m USD)	3,496	121.36	328.19	0.01	5.43	6,693.70
coupon (%)	2,518	3.56	1.72	0.00	4.00	10.18

Notes: This table summarizes the descriptive statistics on metric time-variant and time-invariant variables. The sample consists of a total of 3,496 green bonds with 17,679 annual observations.

between the bid–ask spread and the zero-trading days measure is 16.43%. The correlation between the LOT liquidity estimate and the zero-trading days measure is not significantly different from zero. Comparable correlation levels between liquidity measures can be found, for example, in Dick-Nielsen et al. (2012). The liquidity measures are interpreted in the sense that the lower their value, the more liquid the security. A higher value of the measures means less liquidity or a higher level of illiquidity. We follow the majority of bond liquidity papers such as Longstaff et al. (2005), Goyenko et al. (2009) and Schestag et al. (2016) and use the term liquidity measures.

2.3. Descriptive analysis

Table 1 reports the descriptive statistics for the metric green bond characteristics. The average bid–ask spread of a green bond is 9.30 basis points (bp), the average LOT estimate is 22.57 bp, and an average green bond in our sample has 16.47% zero-trading days. The average time to maturity is 10 years yet with a notable standard deviation of 17.94 years. The sample includes green bonds with both low and high issued amounts, with a focus on low to medium issued amounts. The average coupon rate is 3.56%, with a standard deviation of 1.72%.

Table 2 shows descriptive statistics for categorical explanatory variables. The sample includes the following types of external reviews for third-party validation of the green credentials of a green bond: SPOs, CBI certifications, verifications, and green ratings.[2] One-third of green bonds in the sample is assigned to an SPO, while CBI certifications, verifications and green ratings are used less frequently. Over 85% of green bonds have no shade of green. Of those green bonds that have a shade of green, about two-thirds have a dark green shade (349) and one-third have a medium green shade (158). Nearly three-quarters of green bonds are denominated in USD, while the currencies EUR (9.75%) and SEK (5.64%) have a lower share and the remaining currencies account for less than 5% each. Regarding the issuer types, the largest share of green bonds comes from municipal issuers (63.44%) and corporates (19.05%). The remaining green bonds are issued by financial issuers such as banks or originate from the public issuers agency, sovereign, and supranational. In addition, over one-third of green bonds have an AAA credit rating, while those with a credit rating of less than A- have a share of 8.20%. Only a small number of green bonds (68) are non-investment grade.

3. Empirical results

3.1. Main results

We analyze the relation between the greenness of SPOs and the liquidity of green bonds in a regression model with double-clustered (issuer and bond) standard errors and year fixed effects. The main advantage of this model is that it allows us to estimate coefficients of time-invariant variables (such as the greenness rating of the green bonds) and at the same time make use of the panel structure of the data with year fixed effects and double-clustered standard errors. To this extent, we specify our regression model respectively with the bid–ask spread, the LOT liquidity estimate, and the percentage of zero-trading days as the dependent variable. The macroeconomic variables *government_bond* and *term_slope* are assigned to green bonds according to their denominated currency and are integrated into the regression model as control variables for general economic growth. The bond-specific variable *issued_amount* (in USD) is logarithmized. *no_SPO* is set as the reference category for the shade of green variables. *municipal* is set as the reference category for the issuer types.

The two specific regression models are set up as follows: In the first specification, the main variables of interest are the dummy variables *dark_green*, *medium_green*, and *no_shade*, indicating whether a specific shade of green rating is available. We integrate these dummy variables besides control variables (see Models (1), (3), and (5) in Table 3). In the second specification, we integrate the dummy variables *green* and *no_shade* besides control variables (see Models (2), (4), and (6) in Table 3). *green* indicates that a green bond has a dark green or a medium green shade but does not differentiate between these shades.

[2] CBI provides a detailed description of existing external review types: www.climatebonds.net/market/second-opinion

Table 2
Descriptive statistics for categorical variables.

Variable	Obs.	Relative	Variable	Obs.	Relative
SPO			*CBI_certification*		
Yes	1,165	33.32	Yes	565	16.16
No	2,331	66.68	No	2,931	83.84
shade			*verification*		
dark green	349	9.98	Yes	113	3.23
medium green	158	4.52	No	3,383	96.77
no shade	658	18.82			
no SPO	2.331	66.68	*green_rating*		
			Yes	84	2.40
SPO_provider			No	3,412	97.60
CICERO	444	12.70			
DNV GL	47	1.34	*issuer_type*		
ISS ESG	82	2.35	agency	170	4.86
Sustainalytics	416	11.90	corporate	666	19.05
Vigeo Eiris	108	3.09	financial	252	7.21
Other	68	1.95	municipal	2,218	63.44
No SPO	2,331	66.68	sovereign	19	0.54
			supranational	171	4.89
credit_rating					
AAA	1,192	34.10	*currency*		
AA+	369	10.55	AUD	40	1.14
AA	596	17.05	BRL	11	0.31
AA−	199	5.69	CAD	35	1.00
A+	157	4.49	CHF	19	0.54
A	188	5.38	CNY	100	2.86
A−	131	3.75	COP	1	0.03
BBB+	106	3.03	DKK	2	0.06
BBB−	37	1.06	EUR	341	9.75
BBB	76	2.17	GBP	21	0.60
BB+	21	0.60	HUF	2	0.06
BB	19	0.54	IDR	6	0.17
BB−	8	0.23	INR	31	0.89
B+	5	0.14	JPY	66	1.89
B	5	0.14	MXN	8	0.23
B−	8	0.23	MYR	40	1.14
D	2	0.06	NGN	1	0.03
NR[a]	377	10.78	NOK	23	0.66
			NZD	8	0.23
seniority[b]			PLN	2	0.06
MTG	14	0.40	RUB	3	0.09
SEC	6	0.17	SEK	197	5.64
SR	966	27.63	SGD	3	0.09
SRBN	12	0.34	TRY	2	0.06
SRP	18	0.51	USD	2,527	72.28
SRSEC	68	1.95	ZAR	7	0.20
UN	190	5.43			
OTHER	31	0.89	*straight*		
NULL	2,191	62.67	Yes	1,708	48.86
			No	1,788	51.14

Notes: This table reports descriptive statistics of categorical variables for the sample which consists of 3,496 green bonds.
[a]NR means that a credit rating is not available on Eikon.
[b]*seniority* indicates the combined information on bond seniority and collateral status on Eikon. MTG: senior secured and mortgage backed; SEC: secured; SR: senior secured; SRBN: senior non-preferred; SRP: senior preferred; SRSEC: senior secured; UN: unsecured; OTHER: other seniority and collateral status; NULL: no information available.

Table 3 presents the results. The coefficients of *dark_green* and *medium_green* are both significantly negative in each model when *no_SPO* is set as the reference category, except for *medium_green* in Model (3) in which the LOT liquidity measure is the dependent variable. Moreover, the coefficient of *no_shade* is either not significant (Models (1) and (5)) or the coefficient of *dark_green* has a higher negative value than *no_shade* (Model (3)), indicating a higher liquidity effect for green bonds with a specific shade of green compared to green bonds without a shade of green. To this extent, also Models (2), (4), and (6) show consistent and significant negative coefficients for the variable *green*. Since a lower value of the liquidity measures indicates higher liquidity, green bonds with a shade of green rating are associated with better liquidity than green bonds without such a rating. Specifically, green bonds with a shade of green rating, on average, have a lower bid–ask spread of 3.90 bp and 4.47% fewer zero-trading days, which is significant at the 1% and 5% levels, respectively. At the same time, the negative coefficient of 0.94 bp for the LOT estimate at the 10% level also indicates higher liquidity. Hence, a greenness rating on green bonds is actually related to higher liquidity. However,

Table 3
Liquidity of green bonds according to the shade of green rating.

	Bid–Ask		LOT		%ZTD	
	(1)	(2)	(3)	(4)	(5)	(6)
dark_green	−3.666***		−1.148*		−3.372*	
	(1.157)		(0.588)		(1.989)	
medium_green	−4.409***		−0.322		−6.863***	
	(1.089)		(0.801)		(2.053)	
green		−3.900***		−0.941*		−4.471**
		(1.054)		(0.512)		(1.924)
no_shade	0.180	0.185	−0.648**	−0.655**	0.008	0.034
	(0.708)	(0.709)	(0.259)	(0.258)	(1.964)	(1.967)
CBI_certification	−0.238	−0.246	−0.569**	−0.566**	1.573	1.535
	(0.553)	(0.554)	(0.278)	(0.278)	(1.616)	(1.619)
verification	−2.762**	−2.734**	0.248	0.224	−5.175**	−5.041**
	(1.240)	(1.235)	(0.699)	(0.697)	(2.564)	(2.559)
green_rating	−1.051	−1.134	0.492	0.700	0.657	0.269
	(1.287)	(1.292)	(1.432)	(1.484)	(2.213)	(2.174)
issued_amount	0.333*	0.330*	0.160**	0.162**	4.906***	4.892***
	(0.194)	(0.194)	(0.073)	(0.073)	(0.509)	(0.510)
maturity	−0.024*	−0.024*	−0.001	−0.001	−0.050	−0.050
	(0.014)	(0.014)	(0.003)	(0.003)	(0.034)	(0.034)
straight	−0.778*	−0.790*	0.231**	0.237**	4.426***	4.371***
	(0.441)	(0.439)	(0.104)	(0.103)	(1.466)	(1.466)
government_bond	0.678	0.677	5.048***	5.049***	0.129	0.126
	(0.498)	(0.498)	(1.884)	(1.884)	(1.058)	(1.058)
term_slope	−0.153	−0.156	−3.183	−3.172	−1.784	−1.795
	(0.861)	(0.860)	(4.496)	(4.496)	(1.533)	(1.529)
agency	1.091	1.032	1.553**	1.588**	−1.856	−2.132
	(1.091)	(1.077)	(0.691)	(0.685)	(2.111)	(2.099)
corporate	4.222***	4.211***	0.596	0.587	4.542*	4.494*
	(1.631)	(1.624)	(0.916)	(0.912)	(2.416)	(2.413)
financial	1.842	1.784	−0.445	−0.405	−0.082	−0.353
	(1.585)	(1.570)	(0.912)	(0.921)	(2.993)	(2.990)
sovereign	3.111	3.045	−6.013**	−6.112**	−5.928	−6.241*
	(2.257)	(2.188)	(2.568)	(2.565)	(3.716)	(3.657)
supranational	2.722*	2.633*	−0.868	−0.793	−2.559	−2.977
	(1.412)	(1.397)	(0.805)	(0.805)	(2.558)	(2.606)
year	Yes	Yes	Yes	Yes	Yes	Yes
credit_rating	Yes	Yes	Yes	Yes	Yes	Yes
seniority	Yes	Yes	Yes	Yes	Yes	Yes
currency	Yes	Yes	Yes	Yes	Yes	Yes
_cons	25.756**	25.874**	87.224***	86.939***	19.827	20.385
	(10.260)	(10.301)	(12.488)	(12.487)	(18.875)	(19.252)
N	17,679	17,679	13,002	13,002	17,679	17,679
R^2	0.327	0.327	0.840	0.840	0.116	0.116
Adjusted R^2	0.324	0.324	0.839	0.839	0.112	0.112

Notes: This table reports the results of the regression models with *Bid–Ask*, *LOT* or *%ZTD* as the dependent variable. The reference category for the shade of green variables is *no_SPO*. The reference category for the issuer type variables is *municipal*. Standard errors are double-clustered at the issuer and bond levels. The full sample includes 17,679 annual observations from 3,496 green bonds. The subsample in Models (3) and (4) only includes 13,002 annual observations from 2,486 green bonds.
***$p < 0.01$.
**$p < 0.05$.
*$p < 0.10$.

comparing the coefficients of the two shade of green variables *dark_green* and *medium_green* in Models (1), (3), and (5), we cannot find a consistent difference in the impact on liquidity. As such, a better shade of green in the greenness rating of green bonds shows no relation to liquidity.

3.2. Differences between issuer types

To examine the differences in the impact of greenness ratings on green bond liquidity by issuer type, we set up four additional regression models. We combine the public issuer types agency, sovereign, and supranational into the category ‘other’. Then, we use

Table 4
Differences in the liquidity effect of shade of green ratings by issuer type.

	Corporate	Financial	Municipal	Other
	(1)	(2)	(3)	(4)
green	−6.807***	0.418	−1.745***	−2.328
	(2.577)	(2.808)	(0.421)	(1.698)
no_shade	−3.615	3.768	−0.395	1.146
	(2.858)	(3.150)	(0.429)	(1.625)
CBI_certification	−1.897	2.608	−0.071	8.492***
	(2.481)	(2.595)	(0.455)	(3.119)
verification	−5.872**	−0.309	0.789	−0.765
	(2.834)	(2.474)	(1.982)	(1.749)
green_rating	−1.492	−3.997*	59.931***	1.791
	(1.842)	(2.228)	(2.163)	(1.778)
issued_amount	0.143	1.462*	0.907***	−0.320
	(0.628)	(0.750)	(0.088)	(0.505)
maturity	−0.020**	−1.351***	−0.023	−0.339***
	(0.010)	(0.353)	(0.049)	(0.063)
straight	−4.738**	−1.457	0.081	−3.394**
	(1.857)	(1.826)	(0.554)	(1.609)
government_bond	4.291***	1.220	−3.228***	2.307**
	(1.197)	(1.635)	(1.107)	(0.878)
term_slope	4.844***	2.870	−3.084**	5.241**
	(1.764)	(2.668)	(1.471)	(2.486)
year	Yes	Yes	Yes	Yes
credit_rating	Yes	Yes	Yes	Yes
seniority	Yes	Yes	Yes	Yes
currency	Yes	Yes	Yes	Yes
_cons	21.963*	−20.662**	23.614***	−5.352
	(11.501)	(10.267)	(5.493)	(6.407)
N	2,776	973	12,243	1,687
R^2	0.403	0.462	0.102	0.641
Adjusted R^2	0.390	0.432	0.099	0.629

Notes: This table reports the results of the regression models with *Bid–Ask* as the dependent variable and the subsamples of green bonds issued by the types corporate, financial, municipal, and other. The reference category for the shade of green variables is *no_SPO*. Standard errors are double-clustered at the issuer and bond levels.
***$p < 0.01$.
**$p < 0.05$.
*$p < 0.10$.

the bid–ask spread as the dependent variable for each model and add *green* as an explanatory dummy variable for the subsamples of the four different issuer groups (corporate, financial, municipal, and other). The results are presented in Table 4. The coefficients of *green* show that corporate entities have the highest negative value (−6.81 bp) which is significant at the 1% level. A green shade also has a significant impact on the bid–ask spread for municipal issuers (−1.75 bp). For financial institutions and the category 'other', we find no effect of a greenness rating on the bid–ask spread. Accordingly, corporate issuers appear to have significant excess liquidity when they assign greenness ratings to their green bonds. This effect can also be found for municipal green bonds, but not for green bonds from financial institutions and other public entities besides municipalities. A possible explanation for this pattern is that financial institutions only act as intermediaries for green bonds and do not implement their own green projects. However, it should also be noted that the categories 'financial' and 'other' have the smallest sample sizes of the issuer types.

For a robustness check, we examine the differences in the effects found by inserting the variables no_shade or $medium\_green$ instead of no_SPO as the reference category for the shade of green variables in the regression models from Tables 3 and 4. For these variations of the model specifications, we can confirm the main results and likewise find no significant difference between the variables $dark\_green$ and $medium\_green$. Additionally, a split in the observation period in two subperiods spanning from 2013–2016 and from 2017–2021 confirms the findings regarding the relationship between the greenness of the green bonds and their liquidity for both subperiods.

4. Conclusion

In this paper, we investigate the relationship between greenness ratings and the liquidity of green bonds in a large and comprehensive world-wide sample. The results of the study indicate that green bonds with a greenness rating by an SPO have higher liquidity. We find this effect for corporate and municipal issuers, but not for financial and other public issuers besides municipalities.

These findings have important implications for investors, issuers, and policymakers. Investors who value high liquidity, low transaction cost, and a verified green impact of the projects financed by the green bond should integrate the presence of greenness ratings in green bonds into their investment decision. Issuers may benefit from increased liquidity by obtaining a greenness rating pre-issuance, which can make the green bond more attractive to investors and lower the cost of capital to finance environmentally-friendly projects. For policymakers, these findings suggest that promoting greenness ratings for green bonds may help improve the liquidity of these bonds, which can help to raise trust in the green bond market, increase market efficiency, and support the development of a low-carbon and climate-resilient economy.

The study is subject to some limitations: although we have one of the largest samples of green bonds that has ever been studied, the market is young and still developing. In particular, the comparability of the LOT liquidity estimate with the other liquidity measures is slightly limited due to a lower number of observations. Moreover, we did not investigate intra-day liquidity using high-frequency liquidity measures. We encourage further research on green bond liquidity, including investigating the persistence of the found effect over future time periods, examining the impact of events on green bond liquidity, and exploring other factors that may affect green bond liquidity.

CRediT authorship contribution statement

Gregor Dorfleitner: Conceptualization, Methodology, Writing – original draft, Writing – review & editing, Supervision. **Jens Eckberg:** Conceptualization, Methodology, Data curation, Software, Formal analysis, Writing – original draft, Writing - Review & Editing. **Sebastian Utz:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing, Supervision.

Data availability

The authors do not have permission to share data.

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