Finance Research Letters 27 (2018) 53–59

Contents lists available at ScienceDirect

Finance Research Letters

journal homepage: www.elsevier.com/locate/frl

The impact of liquidity risk on the yield spread of green bonds

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ARTICLE INFO

Keywords:
Green bond
Liquidity risk
Yield spread
Sustainable investment
Fixed income security
Financial innovation

JEL classification:
G12
G32

ABSTRACT

This study analyses how liquidity risk affects bonds' yield spreads after controlling for credit risk, bond-specific characteristics and macroeconomic variables. Using two liquidity estimates, LOT liquidity and the bid-ask spread, we find that, in particular, the LOT liquidity measure has explanatory power for the yield spread of green bonds. Overall, however, the impact of LOT decreases over time, implying that, nowadays liquidity risk is negligible for green bonds.

1. Introduction

This study investigates the effects of the liquidity premium on the green bond yield spreads. We control for credit risk, as well as bond-specific and macroeconomic factors. Liquidity concerns may be pertinent in green bonds market due to (1) its disproportional thinness, and (2) its unclear solvency profile.

The demand for green bonds is likely to surpass the supply due to investors' need to address the ESG (Environmental, Social, and Governance) and SRI (Social Responsible Investment) mandates. In addition, green bonds show low correlation with other fixed income securities and provide diversification benefits to investors (Inderst et al., 2012). Despite the rapid growth of green bonds' demand in the market, the supply of green bonds is insufficient due to: (1) a lack of fiscal incentive for green investment (Zerbib, 2017), and (2) a lack of an official and universal classification system for green bonds that is in accordance with market based frameworks, such as, the Green Bonds Principle (Cochu et al., 2016). The latter might cause opacity on the definition of "green" investment and bonds, and issuers will be subject to additional transaction costs, e.g., contracting with external reviewers pre and post green bonds' issuance. This leaves the issuance of green bonds less attractive than that of conventional bonds. Due to the shortage of green bonds' supply in the market, issuers are able to offer green bonds at lower interest rates, relative to the wider bonds market (Preclaw and Bakshi, 2015; Bloomberg, 2017; Zerbib, 2017). However, the shortage of supply and the excess of demand in green bonds market imply a thin market, and, liquidity becomes relevant. Consequently, a liquidity premium may emerge.

The second factor that may cause illiquidity in the green bonds market, such as, a lack of credit risk profile, is partly endogenous for the issuers. Cochu et al. (2016) put forward that the green bonds' credit risk profile is unclear, since: (1) transparency in the reporting of green projects is lacking, and (2) the ratings of green bonds rely heavily on the balance sheets of the issuers instead of green project investment. A green project usually involves experimental innovation activities that are considered less mature, and due

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https://doi.org/10.1016/j.frl.2018.02.025
Received 20 November 2017; Received in revised form 19 December 2017; Accepted 22 February 2018
Available online 26 February 2018
1544-6123/

to a scarcity of evidence on the performance of green projects, investors might deem the green bonds as more risky than investing in conventional bonds. The lack of reporting transparency signifies the existence of private information that results in an increase of adverse selection costs (Lin et al., 2012). Both Bagehot (1971) and Amihud and Mendelson (1980) argue that transaction costs and adverse selection costs may trigger illiquidity and cause a liquidity premium.

To this end, we use two alternative liquidity measures in order to analyze effects of liquidity shortage on bond yield spreads: the LOT liquidity measure proposed by Chen et al. (2007), and the bid-ask spread (Amihud and Mendelson, 1986; Brandt and Kavajecz, 2004). By modeling the return generating process, the LOT liquidity measure can capture additional information, such as, market impact costs, commission costs and opportunity costs (Utz et al., 2016). We use fixed effects panel regressions with robust clustered standard errors at bond level, and control for year effects. In addition, we provide estimates of the pooled OLS model for panel data.

Our study has important practical implications for green bond issuers. Specifically, if issuers know the impact of liquidity risk, they may prevent increased risk by reducing the source of adverse selection cost, e.g., by increasing transparency of green projects' financial performance. The success of sustainable and low-carbon projects, also relies on funding costs. By avoiding increased liquidity risk, ultimately the issuers will be able to enjoy affordable cost of debt when financing green projects.

The remainder of this article is organized as follows. Section 2 presents data and method. Section 3 provides results. Section 4 concludes.

2. Data and method

2.1. Data description

Our sample consists of 64 labeled green bonds that are listed on the London Stock Exchange and on the Luxembourg Stock Exchange, and 56 conventional bonds traded on the Luxembourg Stock Exchange having similar characteristics to our green bonds. All of our bonds samples are plain vanilla or straight bonds. The total value of climate-aligned bonds is about 694 million USD, and labeled green bonds account for 17% of climate-aligned bonds (CBI, 2015). We use a sample of labeled green bonds in our study, since we would like to capture the true "greenest" of the bonds. In order to be labeled as "green", the climate bonds' proceeds have to be in accordance with the framework of Green Bond Principles (GBP) and/or Climate Bonds Initiative (CBI).[1] Climate-aligned bonds are susceptible to "greenwashing" issues, thus, by using the labeled green bonds in this study we minimize the chance of investigating bonds that lack environmental benefits.

We use ISINs of green and conventional bonds to match with firm-level issuer data collected from Bureau Van Dijk's Amadeus. Some green bonds are issued by multilateral organizations, and municipalities. In these cases firm-level data are hand collected. Table 1 presents a list of variables, descriptions and data sources.

2.2. The LOT model

According to Amihud and Mendelson (1986), the liquidity premium is defined by the difference between the "true" value of bonds and the observed value of bonds. The "true" returns of the bonds are computed by following the two-factor model of Chen et al. (2007). Following Jarrow (1978), the return generating process is given by

$$R^{\star}_{j,t} = \beta_{j,1} D_{j,t} \Delta R_{f,t} + \beta_{j,2} D_{j,t} \Delta Index_t + \epsilon_{j,t} \tag{1}$$

where

$$\begin{aligned} R_{j,t} &= R^{\star}_{j,t} - a_{1,j} \quad \text{if } R^{\star}_{j,t} < a_{1,j} \text{ and } a_{1,j} < 0 \\ R_{j,t} &= 0 \quad \text{if } a_{1,j} \le R^{\star}_{j,t} \le a_{2,j} \\ R_{j,t} &= R^{\star}_{j,t} - a_{2,j} \quad \text{if } R^{\star}_{j,t} > a_{2,j} \text{ and } a_{2,j} > 0. \end{aligned} \tag{2}$$

The estimation of the sell ($a_{1,\ j}$) and buy ($a_{2,\ j}$) transaction costs are performed by maximizing log-likelihood function of $L(a_{1,j}, a_{2,j}, \beta_{j,1}, \beta_{j,2}, \sigma_j | R_{j,t}, \Delta Index)$ (see Chen et al., 2007),

$$\begin{aligned} \ln L = & \sum_1 \ln \frac{1}{(2\pi\sigma_j^2)^{\frac{1}{2}}} - \sum_1 \frac{1}{2\sigma_j^2}(R_{j,t} + a_{1,j} - \beta_{j,1} D_{j,t} {}^{*} \Delta R_{f,t} - \beta_{j,2} D_{j,t} {}^{*} \Delta Index_t)^2 \\ & + \sum_2 \ln \frac{1}{(2\pi\sigma_j^2)^{\frac{1}{2}}} - \sum_2 \frac{1}{2\sigma_j^2}(R_{j,t} + a_{2,j} - \beta_{j,1} D_{j,t} {}^{*} \Delta R_{f,t} - \beta_{j,2} D_{j,t} {}^{*} \Delta Index_t)^2 \\ & + \sum_3 \ln(\Phi_{2,j} - \Phi_{1,j}), \end{aligned} \tag{3}$$

where $\Phi_{i,\ j}$ denotes the cumulative distribution function for each bond-year evaluated at $L(a_{i,j} - \beta_{j,1} D_{j,t} {}^{*} \Delta R_{f,t} - \beta_{j,2} D_{j,t} {}^{*} \Delta Index_t)/\sigma_j$.

[1] The Green Bond Principles is a key framework that provides guidelines for launching credible green bonds. The GBP consists of four components: use of proceeds, project evaluation process, management of proceeds and reporting. The GBP and CBI require third party reviews to assure the eligibility of green projects.

Table 1
This table describes the data used in this study.

Variables	Descriptions	Source
Yield Spread	The difference between bond yield and government bond yield	(a)
LOT	LOT liquidity generated by modelling the returns generating process	(a)
$R_{j,\ t}{}^{(1)}$	Daily return of a bond j in year t based on clean prices	(a)
$D_{j,\ t}{}^{(1)}$	Modified duration of a bond j in year t	(a)
$\Delta R_{f,\ t}{}^{(1)}$	Daily change of 10-year Eurozone rate or 10-year US treasury notes or 10 year Riskbank treasury bills	(a)
$\Delta Index(1)$	Daily return of Eurostoxx 50 or FTSE 100 index	(a)
Bid-Ask	The ask price minus the bid price divided by the average (spread) of both prices	(a)
Maturity	Time to maturity (remaining life of bonds)	(a)
Government Bond	1-year government bonds rates respective to bonds' currencies	(a)
Term Slope	Difference between 10-year and 2-year government bonds' rates	(a)
Rating Scale	Numeric values of bonds' ratings ranging between 1(AAA) and 7 (Baa3). Credit ratings come from Moody's ratings	(a)
Income/Sales	Operating income divided by sales	(b)
Debt/Assets	Long term debts divided by total assets	(b)
Debt/Capital	Total liabilities divided by capital	(b)
Interest Coverage	EBIT to interest expense	(b)

Note: [(1)] Used as input variables for generating the LOT liquidity measure by means of returns generating process. (a) Thomson Reuter's Datastream, (b) Bureau VanDijk's Amadeus Database.

The LOT liquidity measure for bond j is simply the difference between the percent buying cost and the percent selling cost[2]

$$LOT_j = \alpha_{2,j} - \alpha_{1,j} \tag{4}$$

The average of sell trades, buy trades and LOT liquidity estimate for conventional and green bonds are reported in Tables 7 and 8.

2.3. The yield spread determinants

We estimate pooled OLS and fixed-effects panel regressions with robust clustered standard errors at bond level to assess how the liquidity risk affects yield spreads. We control for year effects in every model. More specifically, we employ first a pooled OLS regression for green and conventional bonds separately (Model 1 and 2),

$$YieldSpread_{it} = f\,(Year_t,\ LOT_{it},\ BidAsk_{it},\ Controls_{it}). \tag{5}$$

The Controls$_{it}$ in Eq. (5) are $Maturity_{it}$, $GovernmentBond_{it}$, $TermsSlope_{it}$, $RatingScale_{it}$, $Income/Sales_{i,t-1}$, $Debt/Assets_{i,t-1}$, $Debt/Capital_{i,t-1}$, $InterestCoverage_{i,t-1}$. Next, we apply

$$\begin{aligned} YieldSpread_{it} = \ & f\,(Year_t,\ Bond_i,\ BidAsk_{it} \times Green_i,\ LOT_{it} \times Green_i,\ BidAsk_{it} \times Conventional_i, \\ & LOT_{it} \times Conventional_i,\ Controls_{it}), \end{aligned} \tag{6}$$

with the bond-specific fixed effect $Bond_i$ to conduct a fixed-effects panel regression (Model 3). The interaction effect of bond type and liquidity indicators allows us to identify the effect of the specific liquidity risk of green bonds or conventional bonds on the yield spread. Finally, we include an interaction variable between year and LOT liquidity and conduct the estimation for green bonds only (Model 4),

$$YieldSpread_{it} = \ f\,(Year_t,\ Bond_i,\ LOT_{it} \times Year_t,\ Controls_{it}). \tag{7}$$

This fixed effects regression model allows us to assess the impact of LOT liquidity on yield spread for each year.

3. Empirical results

3.1. Summary statistics

Based on the summary statistics and t-tests presented in Table 2, yield spreads between conventional and green bonds are not significantly different between the years 2013–2015. However, in 2016, the difference between conventional and green bond yield spreads is significant, showing that the yield spread of conventional bonds is higher by 69.2 bp compared to green bonds. Our result is consistent with a study by Zerbib (2017) who investigates a combined sample of both labeled and unlabeled green bonds. This study finds that, on average, green bonds' yield spread is lower than that of conventional bonds by 5 bp to 30 bp.

Interestingly, our t -tests show that both liquidity measures, the bid-ask spread and the LOT liquidity measure, suggest that conventional bonds are less liquid than green bonds, and the differences are significant for all three years under investigation, 2014, 2015 and 2016.

[2] A potential drawback of applying the LOT measure occurs when there are no or too many (more than 85%) zero returns.

Table 2
Summary statistics and *t*-test of conventional and green bonds over the sample period 2014–2016.

Year		2013	2014	2015	2016
Yield spread (bp)					
Conventional	*Mean*	158.2	89.2	53.3	139.6
	#bonds	18	25	31	42
Green	*Mean*	59.4	41.4	52.1	70.4
	#bonds	3	15	38	64
	Difference[a]	98.9	47.8	1.2	69.2*
	t-stat	1.3	1.2	0.03	1.6
LOT (bp)					
Conventional	*Mean*	25.2	22.0	26.4	33.5
	#bonds	18	25	31	42
Green	*Mean*	18.1	15.1	18.0	19.5
	#bonds	3	15	38	64
	Difference[a]	7.1	6.9*	8.4**	14.1***
	t-stat	0.74	1.54	1.75	2.38
BidAsk (bp)					
Conventional	*Mean*	73.2	53.4	42.1	71.1
	#bonds	18	25	31	42
Green	*Mean*	72.1	30.1	28.3	30.5
	#bonds	3	15	38	64
	Difference[a]	1.1	23.4***	13.8***	40.6***
	t-stat	0.06	2.71	2.99	3.25

Notes: Difference[a] shows the difference of mean between conventional and green and bonds. *, ** and *** denote significance at 10%, 5% and 1% level, respectively.

Table 3
Descriptive statistics of conventional and green bonds time-invariant characteristics in the year of bond issuance.

Variables	Obs	Mean	Median	SD	Min	Max	Skewness	Kurtosis
Conventional								
Maturity	56	8.48	8	2.11	3	12	−0.22	2.46
Rating Scale	56	2.38	2	2.65	0	7	0.49	1.57
Volume	56	711	708	213	778	1000	−0.82	4.1
Green bonds								
Maturity	64	6.98	6	3.85	2.5	30	3.37	20.84
Rating Scale	64	1.33	1	1.56	0	7	2.45	8.43
Volume USD	21	464	400	381	5	1500	1.1	3.81
Volume SEK	22	1222	1000	930	230	3750	1.5	4.83
Volume EUR	21	710	500	549	30	1900	0.9	2.78

Note: All volume variables (Volume USD, Volume SEK, Volume EUR, and Volume) are reported in millions. The volume variable of conventional bonds is denoted in EUR.

Table 3 reports the descriptive statistics of green and conventional bonds' characteristics. The results show that our sample of green and conventional bonds possess similar characteristics. The average time to maturity of green bonds is 8.5 years, with a standard deviation of 3.85 years. Conventional bonds' average time to maturity is 7 years, with a standard deviation of 2.11 years. Those features indicate that both green and conventional bonds' maturity belong to the class of medium maturity bonds but are considerably heterogeneous. The average issue volume of green and conventional bonds shows that both bond types are characterized by high volume issuances. The green bonds' average issue volume is 710 million, 1222 million, and 464 million denominated in EUR, SEK and USD respectively. The conventional bonds' average issue volume is 711 million EUR. Green bonds have an average rating scale of 1.33, while the conventional bonds have a higher average scale of 1. Both green and conventional bonds are investment grade bonds that have a maximum numeric rating scale of 7, equivalent to Baa3 (Moody's rating).

3.2. The bid-ask spread regression

We perform a correlation analysis between the bid-ask spread and the LOT liquidity measure. We find 62% correlation between the two measures that signifies a relatively strong dependency between the two measures. Due to our data limitation we cannot use alternative liquidity proxies, such as, Range measure (Han and Zhou, 2008) and Amihud measure (Amihud, 2002). Green bonds are not listed in TRACE, thus, we are not able to acquire intraday trading volumes required for those proxies.

In order to check the consistency of our two estimates, we perform a within effects panel regression and we regress the bid-ask spread on the LOT liquidity measure. Table 5 shows the results for the regression.

Table 4
This table shows the correlation between the bid-ask and the LOT measure.

	LOT	BidAsk
LOT	1	
BidAsk	0.6205*	1

* Signifies significance level of 5%.

Table 5
The bid-ask spread regression.

Variables	(1) *BidAsk*
LOT	0.645**
	(0.285)
Constant	30.11***
	(6.576)
Observations	236
Number of idgroup	120
R-squared	0.099

Robust standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

3.3. Determinants of the yield spread

The results for the pooled OLS and the fixed-effects models are reported in Table 6. Based on the overall regression results, the LOT liquidity and the bid-ask spreads are significant and positively related to yield spread. In Model 1, where we only include conventional bonds, the bid-ask spread is significant and positive at the 1% level, while the LOT liquidity is insignificant. In Model 2, where we include only green bonds, both the LOT liquidity and the bid-ask spread are positive and significant at the 1% and 5% level, respectively. Both maturity variables in Model 1 and 2 are significant. However, the *Maturity* coefficient is negative for green bonds and the coefficient is positive for conventional bonds. A positive relationship between maturity and yield spreads is usually expected for investment grade bonds (Campbell and Taksler, 2003). Although our sample of green bonds belong to investment grade bonds, the *Maturity* variable of green bonds is negatively associated with yield spreads. The negative relationship between maturity and yield spreads is more expected for speculative grade bonds (Helwege and Turner, 1999).

In Model 3, which combines the subsamples of green and conventional bonds, the interaction term *LOT×Green* is positive and significant at the 5% level. This means when the LOT measure increases by 1 bp, the yield spread goes up by 0.72 bp. *BidAsk* × *Green* is insignificant, however, implying that the bid-ask spread does not influence yield spreads for green bonds. The opposite applies for conventional bonds where the interaction term *LOT* × *Conventional* is insignificant, which suggests the LOT measure does not explain the yield spread of conventional bonds. The coefficient of *BidAsk* × *Conventional* is positive and significant at the 5% level implying that the yield spread increases by 0.7 bp when the bid-ask spread goes up by 1 bp. The size of our LOT liquidity premium on yield spreads for green bonds is about two times stronger than LOT liquidity measure for US investment grade corporate bonds studied by Chen et al. (2007). Furthermore, the coefficient of *Debt/Capital* is positive and significant at the 10% level. This result is expected since the higher leverage ratio is associated with an increase in yield spreads.

In Model 4, only green bonds are included in the fixed-effects panel regression, the interaction variables *LOT* × *yr2013, LOT* × *yr2014*, and *LOT* × *yr2015* are positive and significant at the 1%, 1% and 10% level, respectively. The coefficient of *LOT* × *yr2013* is particularly high, indicating the liquidity risk was the highest in 2013 for green bonds. In 2013, a 1 bp increase in LOT measure lead to 12.40 bp increase in yield spread. Over the sample period, however, the effect of liquidity risk on green bonds' yield spread decreases. Furthermore, in 2016 the effect of liquidity risk on yield spread becomes insignificant. The LOT liquidity's explanatory power in combination with control variables is 37% (within R^2).

4. Conclusions

The green bond market has been growing in recent years. This paper investigates the relationship between liquidity risk and yield spread for both green and conventional bonds. We employ two measures of liquidity: the LOT measure and the bid-ask spread. Contrary to the initial expectation, the descriptive evidence indicates that green bonds are, on average, more liquid when compared to conventional bonds, over the years 2014–2016. The regression results reveal that both the LOT liquidity and the bid-ask measure are positively related to the yield spread. However, for the fixed-effects model, only the LOT measure turns out to be relevant for green bonds. We also find that the effect of LOT vanishes over time, pointing out that, for green bonds, the impact of liquidity risk on yield spread has become negligible in most recent years. This latter observation may hint at a growing maturity of green bonds markets.

Table 6
The determinants of bonds' yield spread.

Variables	Model 1	Model 2	Model 3	Model 4
yr = 2014	−27.22	−21.85	−13.79	208.2***
	(38.20)	(31.39)	(27.32)	(45.43)
yr = 2015	−12.64	−7.412	83.32	239.8***
	(50.23)	(30.86)	(68.54)	(58.79)
yr = 2016	24.09	−0.0883	111.9	252.6***
	(40.08)	(29.93)	(76.91)	(62.94)
LOT	−3.051	1.613***	–	–
	(2.227)	(0.472)		
BidAsk	2.703***	0.513**	–	–
	(0.906)	(0.210)		
LOT × Conventional	–	–	−1.182	–
			(1.736)	
LOT × Green bond	–	–	0.720**	–
			(0.336)	
BidAsk × Conventional	–	–	0.702**	–
			(0.304)	
BidAsk × Green bond	–	–	−0.206	–
			(0.264)	
LOT × yr2013	–	–	–	12.40***
				(2.446)
LOT × yr2014	–	–	–	0.849***
				(0.270)
LOT × yr2015	–	–	–	0.369*
				(0.205)
LOT × yr2016	–	–	–	0.252
				(0.231)
Income/Sales	−1.474	−8.534	−2.122	11.50
	(1.316)	(6.922)	(1.436)	(9.903)
Debt/Assets	−8.088	−28.41	−110.9	−71.95
	(143.6)	(21.61)	(86.10)	(56.45)
Debt/Capital	−56.56	−5.963**	67.16*	5.769
	(83.33)	(2.953)	(37.15)	(8.357)
Interest Coverage	0.0141	1.449**	0.633	−0.128
	(0.183)	(0.574)	(0.508)	(0.405)
Maturity	11.00*	−4.764***	–	–
	(6.258)	(1.296)		
Government Bond	–	0.536	78.43*	20.84
		(6.108)	(44.35)	(18.37)
Term Slope	–	6.191	149.4**	39.25
		(14.50)	(65.61)	(30.16)
Rating Scale = 1	–	−54.05***	–	–
		(11.97)		
Rating Scale = 2	−19.58	−15.13	–	–
	(42.83)	(15.50)		
Rating Scale = 3	−78.41	–	–	–
	(57.80)			
Rating Scale = 4	−509.8***	–	–	–
	(128.1)			
Rating Scale = 5	−47.33	−16.87	–	–
	(43.27)	(21.16)		
Rating Scale = 6	24.79	−20.16	–	–
	(41.77)	(25.72)		
Rating Scale = 7	15.50	199.2***	–	–
	(52.33)	(24.91)		
Constant	68.06	103.7***	−125.6	−194.4***
	(72.27)	(39.11)	(136.7)	(71.56)
Observations	116	120	236	120
R-squared	0.511	0.763	0.282	0.371

Note: Robust standard errors in parentheses. *, **, *** denotes significance at 10, 5, and 1 percent respectively. Model 1 represents a pooled OLS regression for the subsample of conventional bonds. Model 2 represents a pooled OLS regression for the subsample green bonds. Model 3 represents a fixed effects regression with robust clustered standard errors at bond level for both bonds. Model 4 represents a fixed effects regression for the subsample of green bonds.

Appendix A

Table 7
Conventional bonds' average cost of sell trades ($\alpha_{1,\ j}$), buy trades ($\alpha_{2,\ j}$), and LOT liquidity estimate ($\alpha_{2,\ j}$–$\alpha_{1,\ j}$) in %.

Year	No. Bonds	α_1	α_2	LOT
2013	18	−0.1249	0.1269	0.2517
2014	25	−0.1167	0.1028	0.2195
2015	31	−0.1320	0.1316	0.2635
2016	42	−0.1693	0.1659	0.3352

Table 8
Green bonds' average cost of sell trades ($\alpha_{1,\ j}$), buy trades ($\alpha_{2,\ j}$), and LOT liquidity estimate ($\alpha_{2,\ j}$–$\alpha_{1,\ j}$) in %.

Year	No. Bonds	α_1	α_2	LOT
2013	3	−0.0970	0.0836	0.1810
2014	15	−0.0985	0.0488	0.1509
2015	38	−0.1121	0.0679	0.1800
2016	64	−0.1339	0.0609	0.1947

Table 9
Descriptive statistics of green and conventional bonds and firm-level data over all years.

Variables	Obs	Mean	Median	SD	Min	Max	Skewness	Kurtosis
Conventional								
Income/Sales	116	16.82	6.74	22.61	−46.95	89.38	0.96	3.88
Debt/Assets	116	0.39	0.37	0.29	0	2.11	1.88	12.57
Debt/Capital	116	0.71	0.74	0.28	0	1.4	−0.4	3.53
Interest Coverage	116	9.97	2.8	38.12	−15.75	395.9	9.11	92.23
Green								
Income/Sales	120	0.23	0.48	1.27	−3.19	2.01	−1.75	5.41
Debt/Assets	120	0.56	0.49	0.23	0.01	0.93	−0.27	2.64
Debt/Capital	120	0.87	0.88	0.73	0.09	7.76	7.52	69.71
Interest Coverage	120	−3	1.09	18.73	−82.68	59.92	−2.17	11.42

Supplementary material

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.frl.2018.02.025.

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