KU LEUVEN

Are Green Bonds Different From Ordinary Bonds?
A Statistical and Quantitative Point of View

NBB International Conference 2020
on
Climate Change: Economic Impact and Challenges for Central Banks and the Financial System

Wim Schoutens

23/10/2020

Joint work with Cong Ma, Jan Beirlant, Jan De Spiegeleer, Stephan Höcht & Robert Van Kleeck

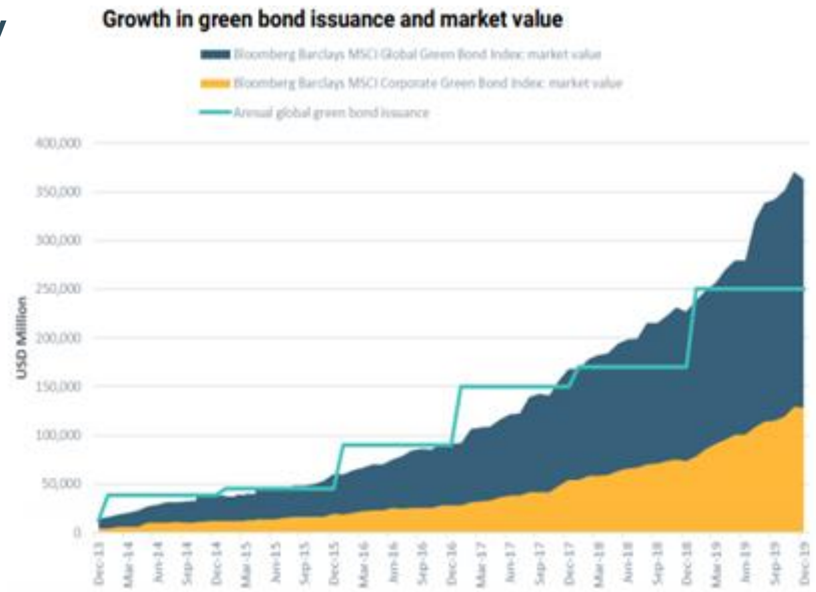
Outline

1. Introduction
2. Data Set
3. Stylized Features
4. Statistical Analysis
5. Greenium of Green Bond
6. Conclusion

1. Introduction

1. Introduction

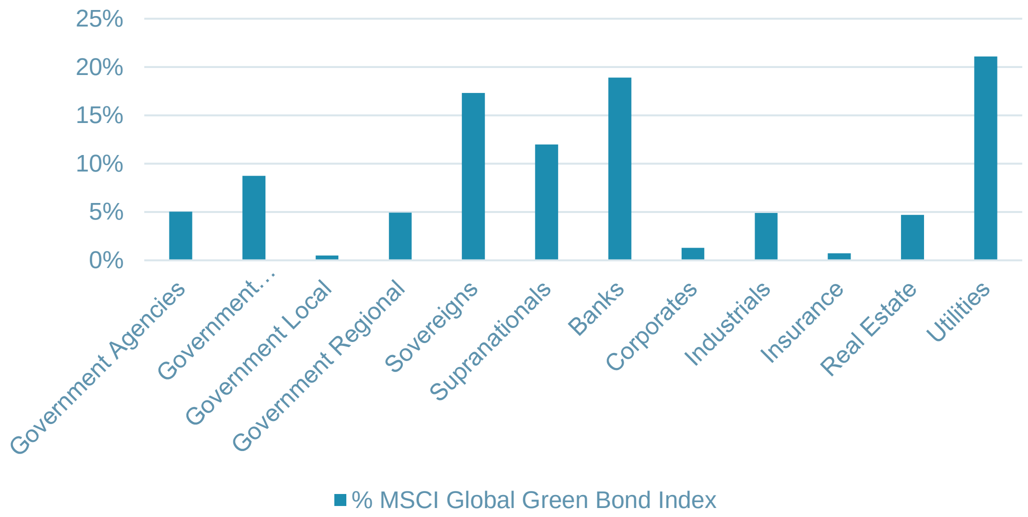
- Green bonds are fixed income securities which usually differ from conventional debt instruments only in that they finance environmental or climate-related activities.
- The green bond market kicked off in 2007 with the AAA-rated issuance from multilateral institutions like the European Investment Bank (EIB) and the World Bank.
- The market of green bonds is rapidly expanding since its inception in 2007, notwithstanding the absence of a commonly agreed definition of ‘greenness’.
- Green bonds annual issuance rose from about $3 bn in 2012 to $257 bn in 2019. Estimate issuance for 2020 is around $350 bn.

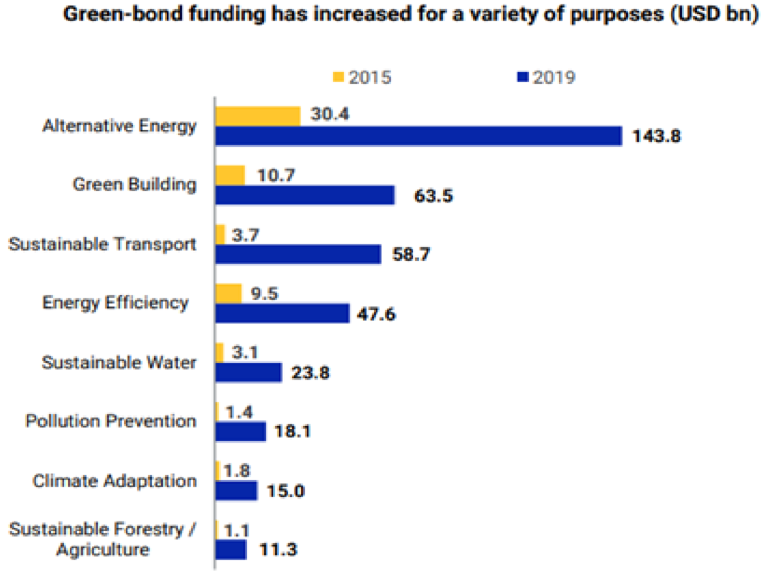


Source: MSCI ESG Research, Bloomberg Barclays MSCI Green Bond Index; market-wide issuance based on Climate Bonds Initiative estimates.

1. Introduction

- For green bonds, non-corporate issuance is dominated by sovereigns and supranationals, while corporate issuance is dominated by utilities and banks.
- Additional transparency on how the proceeds have been/will be used is provided.
- Alternative energy projects is the most common use of funds, followed by green building.
- Risk wise: green bonds are pari-pasu with their non-green counterparts.





This chart reflects estimated proceeds (in billion USD) raised by bonds eligible for inclusion in the Bloomberg Barclays MSCI Global Green Bond Index, as of Dec. 31 of the corresponding year. Included are energy-efficiency investments not otherwise classified under sustainable transport or green building — e.g., energy efficiency for noncertified buildings, public infrastructure, industrial processes, electrical grids and district heating.

Sources: MSCI ESG Research LLC, Bloomberg Barclays MSCI Global Green Bond Index

1. Introduction

A green bond may be issued with lower/higher yield compared to existing debt. This is termed it **greenium**.

Bloomberg Professional Services

Functions for the Market November 26, 2018

There is no consistent premium in green bonds from European financial companies that is identifiable using Bloomberg Barclays indexes. The "greenium" often perceived by the market may be more elusive or even fail to materialize.

But it's important to note that, regardless of whether there's a true "greenium," green bonds are popular with companies seeking to raise capital. Issuance of green bonds reached a high of $170 billion last year and eclipsed $100 billion for 2018 as of early September.

- **7 days after pricing,** 56% of green bonds had tightened more than comparable bonds, 71% of green bonds had tightened more than their comparable index
- **28 days after pricing,** 44% of green bonds had tightened more than comparable bonds, 67% of green bonds had tightened more than their comparable index

Source: the Climate Bonds Initiative and the International Finance Corporation

Where's the Greenium?

STANFORD BUSINESS GRADUATE SCHOOL OF

By David F. Larcker, Edward M. Watts

February 22, 2019 | Working Paper No. 3766

Accounting, Corporate Governance

This study investigates whether investors are willing to trade-off wealth for societal benefits. We take advantage of unique institutional features of the municipal securities market to provide insight into this question. Since 2013, over $23 billion Green Bonds have been issued to fund eco-friendly projects. Comparing Green securities to nearly identical securities issued for non-Green purposes by the same issuers on the same day, we observe economically identical pricing for Green and non-Green issues. In contrast to a number of recent theoretical and experimental studies, we find that in real market settings investors appear entirely unwilling to forgo wealth to invest in environmentally sustainable projects. When risk and payoffs are held constant, municipal investors view Green and non-Green securities by the same issuer as almost exact substitutes. Thus, the "greenium" is essentially zero.

2. Data Set

2. Preliminary Data Set

- Daily ASW of 521 bonds from 58 companies, including 107 green bonds and 414 non-green bonds
- EUR denominated bonds currency
- Comparable maturities
- In total 717 bond pairs

→ For each green bonds:
a synthetic non-green bond with maturity matching the green bond maturity via interpolation of the ASW curve of the non-green bonds

3. Stylized Features

- Descriptive Statistics
- Fat-tail Distribution of ASW Changes
- Two-sample QQ-plots of Green Bond against Non-Green Bond returns
- Extreme Value Index Estimation: Hill estimator

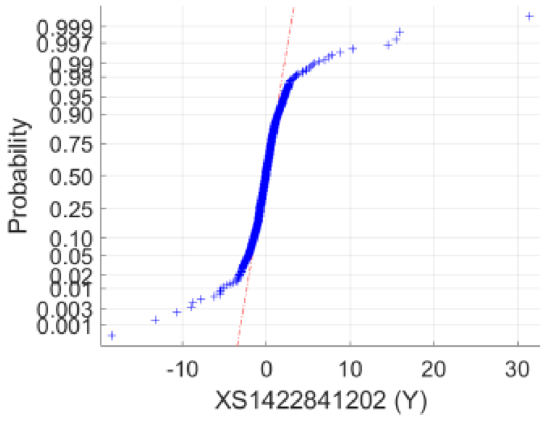
3. Stylized Features

- Descriptive Statistics

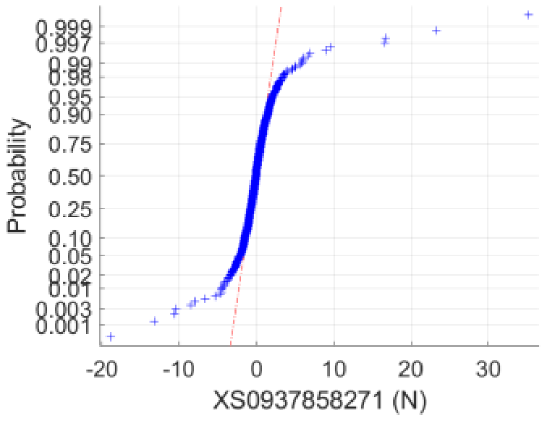
Company	Bond Code	Mean	Standard deviation	Skewness	Kurtosis
	XS1422841202 (Y)	-0.0186	2.0864	3.4372	64.7071
	XS1808739459 (Y)	0.0303	2.7282	4.6110	60.8360
	XS1982037696 (Y)	0.0103	3.4452	4.3736	47.2720
	XS1935139995 (N)	-0.0785	3.1197	4.5757	55.7239
	XS1856791873 (N)	0.0042	2.7854	3.7760	52.6930
	XS0765299572 (N)	-0.0287	2.1116	4.1888	72.3798
ABNANV	XS1218821756 (N)	-0.0213	2.1405	5.3403	95.1212
	XS1917577931 (N)	-0.0045	2.5562	2.9219	28.9388
	XS1917574755 (N)	-0.0242	2.4913	4.3970	36.2698
	XS0937858271 (N)	-0.0274	2.1600	4.7456	84.5115
	NL0009980945 (N)	-0.0539	2.3816	2.4811	57.1245
	XS1935134095 (N)	-0.0198	2.3041	2.3708	23.6842
	XS0997342562 (N)	-0.0392	1.6234	2.1217	20.9651

3. Stylized Features

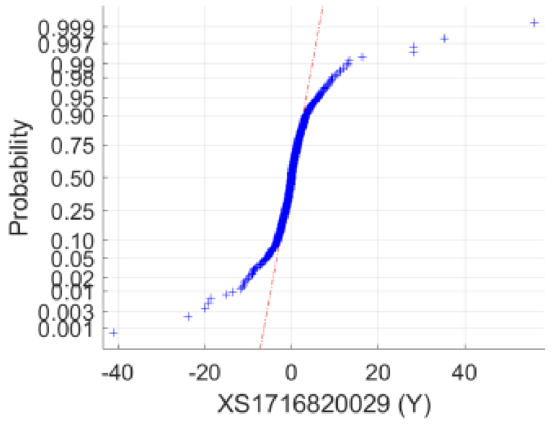
- Fat-tail Distribution of ASW Change



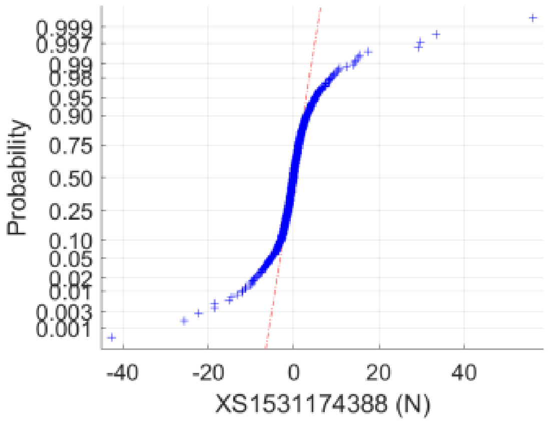
(a) ABNANV (Green)



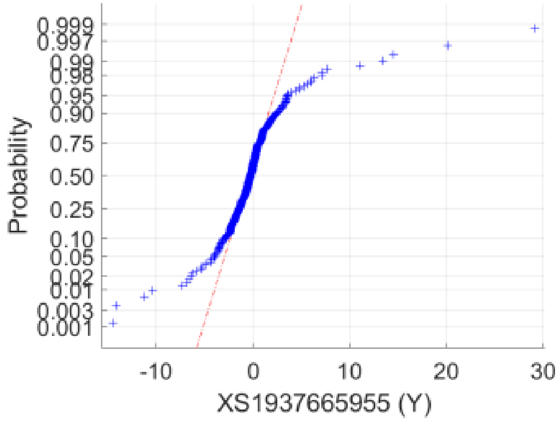
(b) ABNANV (Non)



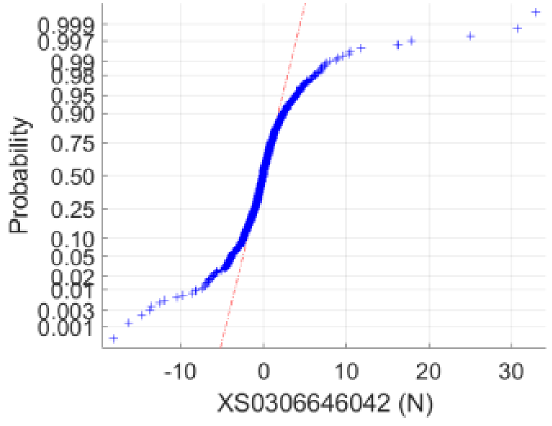
(c) BACR (Green)



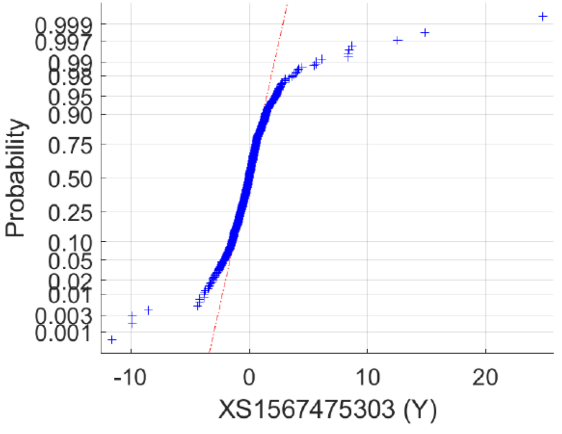
(d) BACR (Non)



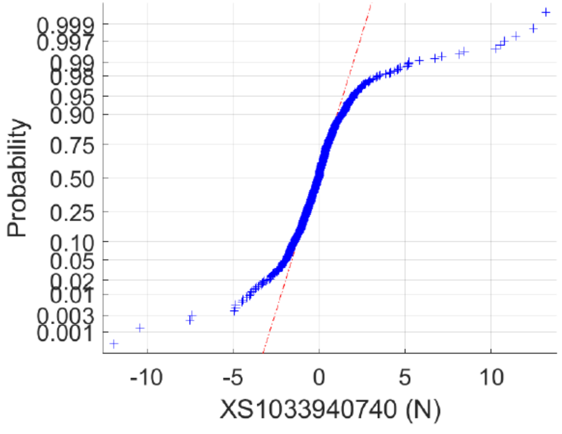
(e) ENELIM (Green)



(f) ENELIM (Non)



(g) SEB (Green)

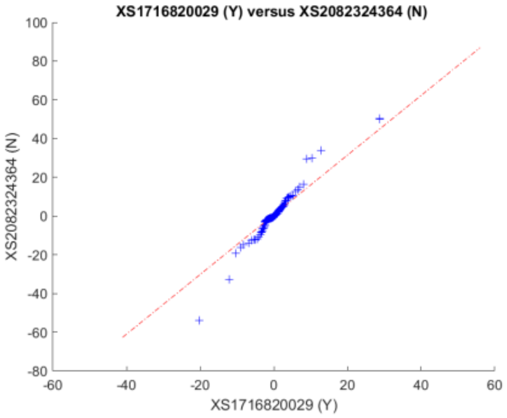


(h) SEB (Non)

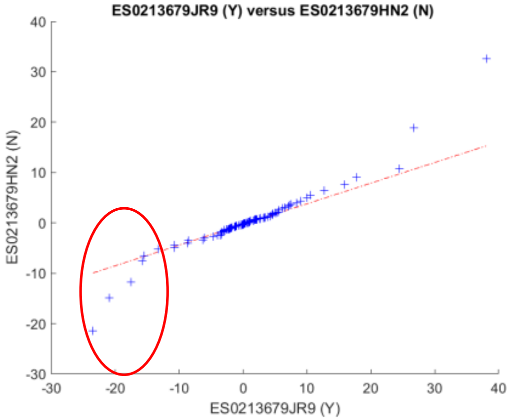
KU LEUVEN

3. Stylized Features

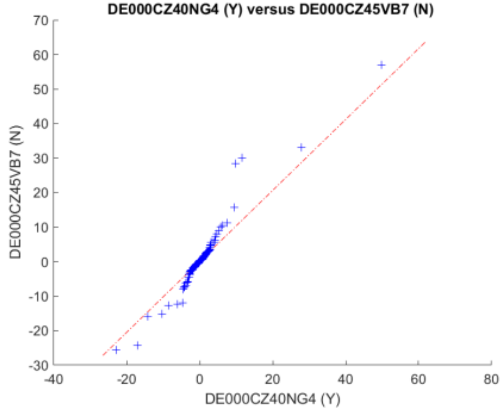
- Two-sample QQ-plots of Green Bond against Non-Green Bond



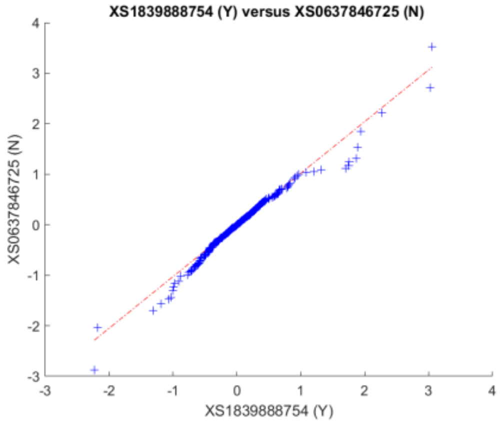
(a) BACR



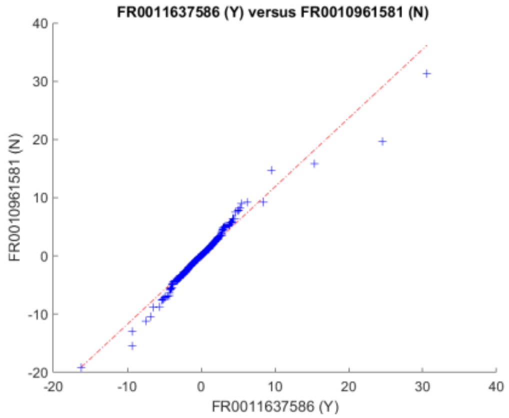
(b) BKTSM



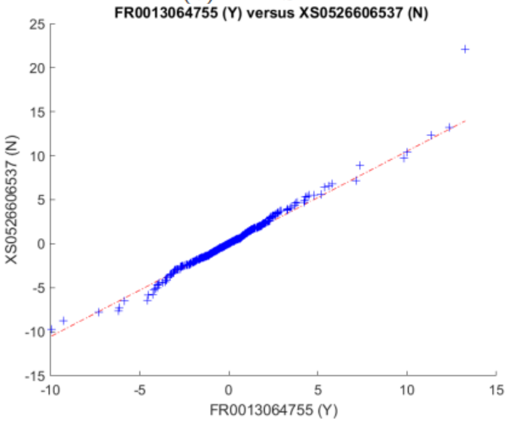
(c) CMZB



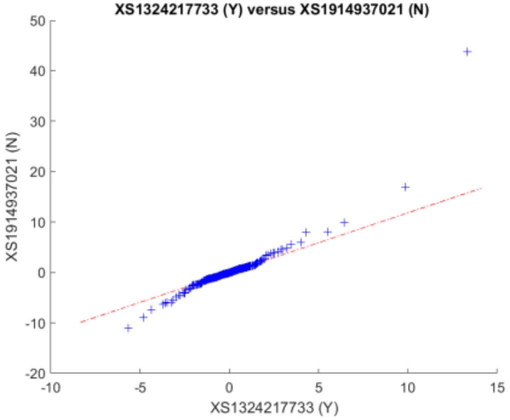
(d) DNBNO



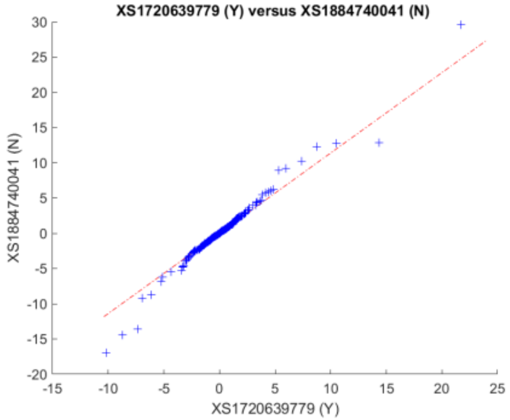
(e) EDF



(f) HSBC



(g) INTNED



(h) TOYOTA

3. Stylized Features

- Two-sample QQ-plots of Green Bond against Non-Green Bond

  - QQ-plots exhibit quite a straight line in the main central parts of the returns in almost all sub-figures, suggesting that the green bond and non-green bond from one company follow the same underlying distribution of ASW returns in the center.
  - In several cases, some deviations can be observed at the extreme negative returns. For instance, in cases (a), (b), (e), (g) and (h) the size of **the most extreme negative green bond returns are less extreme than the corresponding non-green bond returns**.

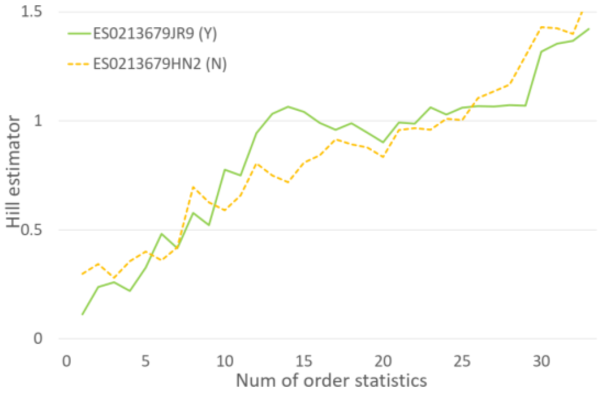
3. Stylized Features

- Extreme Value Index Estimation: Hill estimator

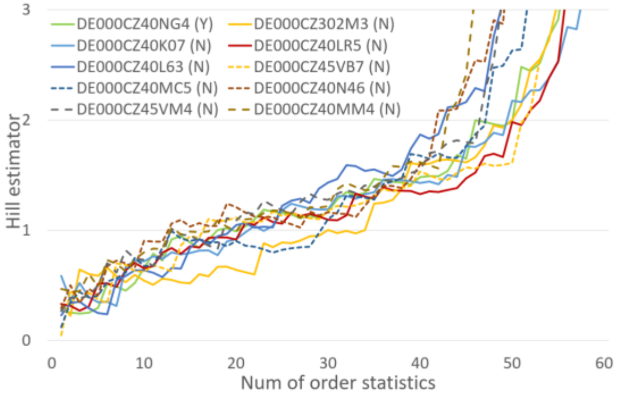
$$\hat{\gamma}_k = \frac{1}{k}\sum_{i=0}^{k-1}\left(\log X_{n-i,n} - \log X_{n-k,n}\right),$$

where k is the number of upper order statistics and $X_{1,n} \leq \cdots \leq X_{n,n}$ denote the ordered absolute values of the negative returns.

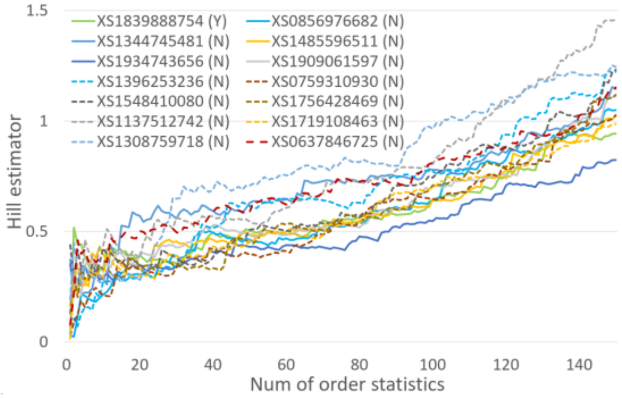
(a) BACR



(b) BKTSM



(c) CMZB

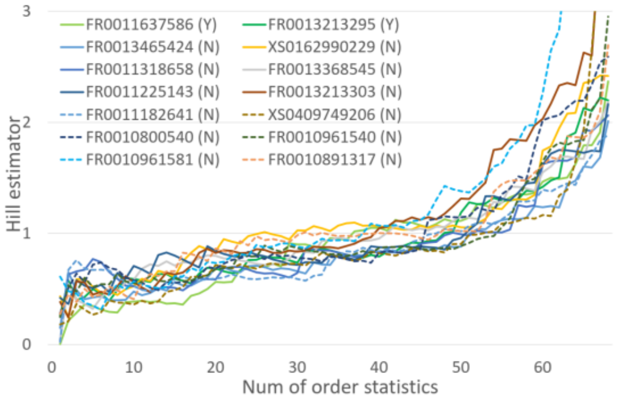


(d) DNBNO

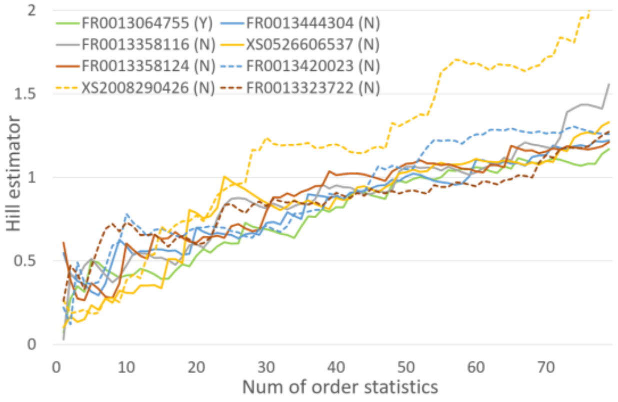
KU LEUVEN

3. Stylized Features

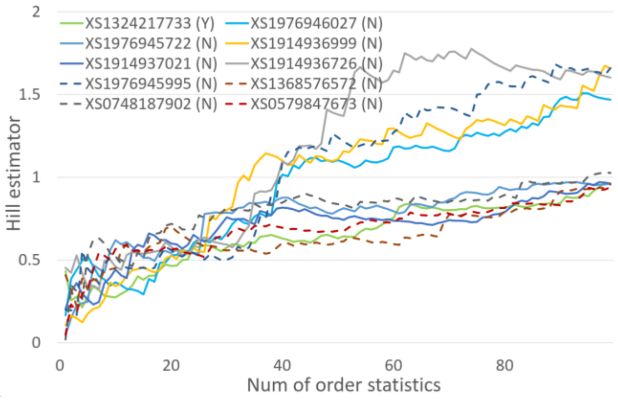
- Extreme Value Index Estimation: Hill estimator



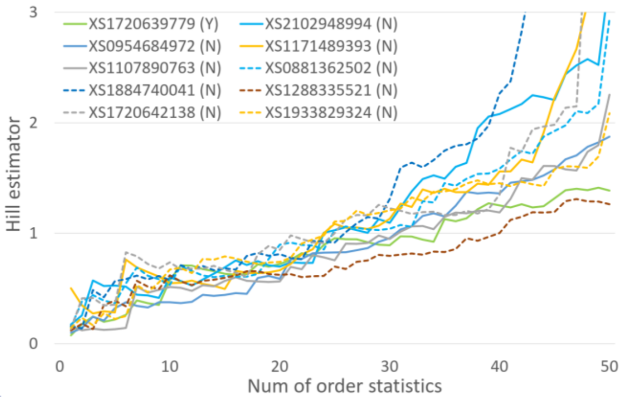
(e) EDF



(f) HSBC



(g) INTNED



(h) TOYOTA

- From these results, we observe these curves of $\hat{\gamma}_k$ as a function of k for the green bonds and non-green bonds are very close. That is, the bond pairs have a similar type of tail heaviness, while in the cases (a), (b), (e), (g) and (h) discussed in last part, **the tail index is somewhat lower for the green bonds**.

4. Statistical Analysis

- Hypothetical Tests: mean, median, variance and distribution

4. Statistical Analysis

- Hypothetical Tests – Distribution (daily)

In **Kruskal-Wallis tests**, $p > 0.05$ means that all bonds from one company have the same distribution;

- In this table, only one p-value is smaller than 0.05.
- Hence, <u>at first sight there is no evidence of significant difference between the ASW returns of green bond and non-green bond</u>.

Kruskal-Wallis (KW) test for each company

Companies	p values	Companies	p values	Companies	p values
ABNANV	0.9975	ACACB	1.0000	ACAFP1	0.9698
ACAFP2	0.8059	AEMSPA	0.5204	ALDFP	0.6673
BACR	0.9910	BBVASM	0.8892	BKTSM	0.7983
BNP1	1.0000	BNP2	1.0000	BPCEGP	1.0000
C	1.0000	CMZB	0.9845	DANBNK	0.9904
DEVOBA	0.6137	DLR	0.6845	DNBNO	0.9970
EDF	0.9993	EDPPL	0.9990	ENBW	0.9447
ENELIM	0.9867	ENGIFP	1.0000	EOANGR	1.0000
ESBIRE	0.9935	FERROV	0.8091	FRLBP	0.8943
FRPTT	0.9354	HERIM	0.7897	HSBC1	0.9943
HSBC2	0.5969	IBESM	0.9618	IGYGY	0.9945
INTNED1	0.9072	INTNED2	1.0000	ISPIM	0.7940
KBCBB	0.9999	LBBW	0.9914	LPTY	0.6990
MIZUHO	0.6922	MUFG	0.8143	NDASS	0.9996
NTGYSM	0.9952	OPBANK	0.9978	ORSTED	0.0731
PLD	0.9963	RABOBK1	0.9833	RABOBK2	0.9998
REESM	0.9937	RY	0.5439	SANTAN	0.9736
SEB	0.4842	SHBASS	0.9995	SOCGEN	0.9636
SOCSFH	0.9923	SSELN	0.8506	SUMIBK	0.9906
SWEDA	0.0374	TENN	0.9900	TOYOTA	0.9939
UBIIM	0.9371	VATFAL	0.8400		

4. Statistical Analysis

- Hypothetical Tests – Distribution (daily)

The null hypothesis of **Kolmogorov-Smirnov test** is green bond and non-green bond have the same continuous distribution.

Hypothesis tests		The proportion of $p < 0.05$
Kolmogorov-Smirnov test	h_7	12.55%

- ☐ About 12.55% of all bond pairs can't pass the Kolmogorov-Smirnov test.
- ☐ There is some evidence of significant differences between the distributions of green bonds and non-green bonds in about 1/8 of the cases.

4. Statistical Analysis

- Hypothetical Tests – mean and median (daily)

Hypothesis tests		The proportion of $p < 0.05$
T-tests	h_1	0
	h_2	0
	h_3	0
Wilcoxon rank-sum test	h_6	0.56%

- h_1 (h_2, h_3) (T-test) hypothesis : the mean of former is equal (greater/smaller) than the latter;
- h_6 (Wilcoxon rank–sum test) null hypothesis : the two samples are from continuous distributions with equal medians.
- CONCLUSION: there is no evidence of significant differences in the mean and median of the daily ASW return distribution between the green and non-green bonds from one company.

4. Statistical Analysis

- Hypothetical Tests – mean and median (weekly)

Hypothesis tests		The proportion of $p < 0.05$
T-tests	h_1	0
	h_2	0
	h_3	0
Wilcoxon rank-sum test	h_6	0

- ☐ The results of weekly ASW values are similar to the daily results.
- ☐ CONCLUSION: **there is no evidence of significant differences in the mean and median of the weekly ASW return distribution between the green bonds and non-green bonds from one company**.

4. Statistical Analysis

- Hypothetical Tests – Variance (daily)

Two-sample F-tests for variance

Hypothesis tests		The proportion of $p < 0.05$
	h_4	43.65%
F-tests	h_5	27.89%

- h_4 (h_5) F-test hypothesis : the variance of the former is equal (greater) than the latter;
- **There is some evidence of differences in variance/volatility.**
- From the table, only about a quarter of bond pairs indicate the variance of the green bond is greater than that of the non-green bond.

4. Statistical Analysis

- Hypothetical Tests – Variance (weekly)

Two-sample F-tests for variance

Hypothesis tests		The proportion of $p < 0.05$
	h_4	20.22%
F-tests	h_5	16.04%

- ☐ The weekly results are similar to the daily results.
- ☐ <u>There is some evidence that the return of a green bond is less volatile than a non-green bond.</u>

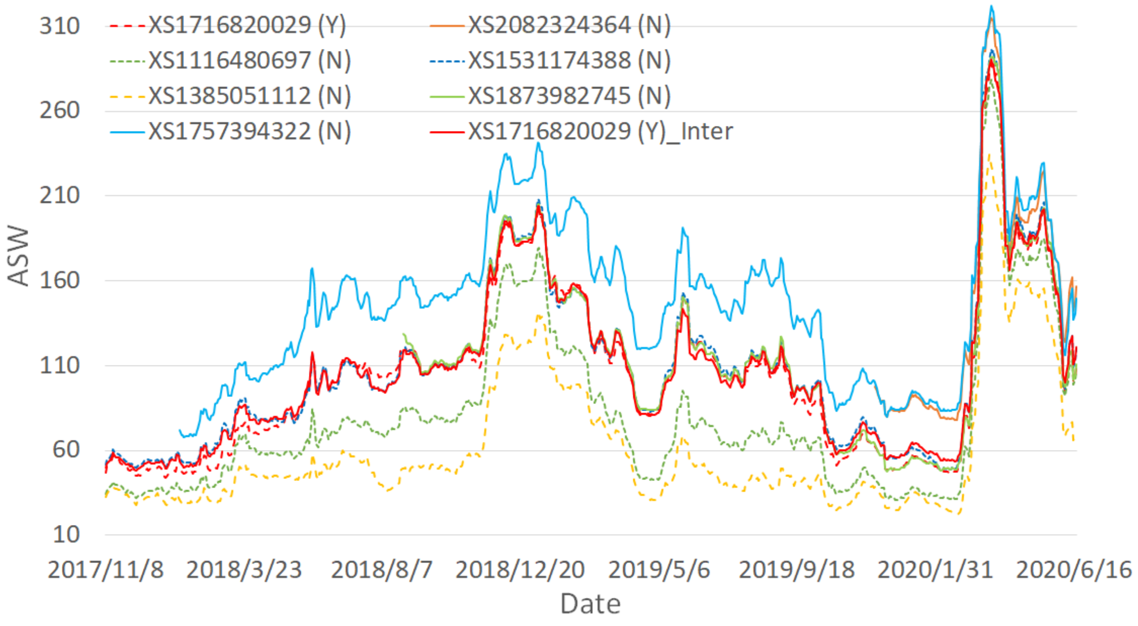
5. Greenium of Green Bond

- The ASW values of the synthetic bonds
- Hypothesis tests for green bonds and synthetic bonds
- Greenium
- Extreme Value Index Estimation
- Greenium during COVID-19 period
- Explanations about the greenium

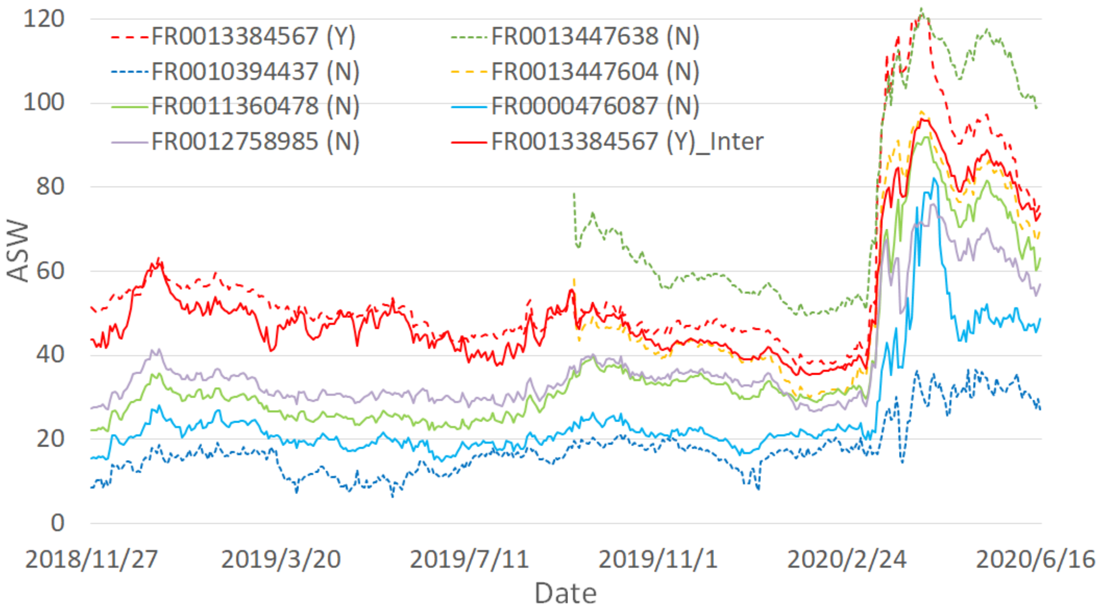
5. Greenium of Green Bond

- Synthetic Bonds

The synthetic bonds are created by interpolating the ASW term structure of non-green bonds at the green bonds maturity, and the synthetic bonds have the same maturity as the green bonds.



BACR

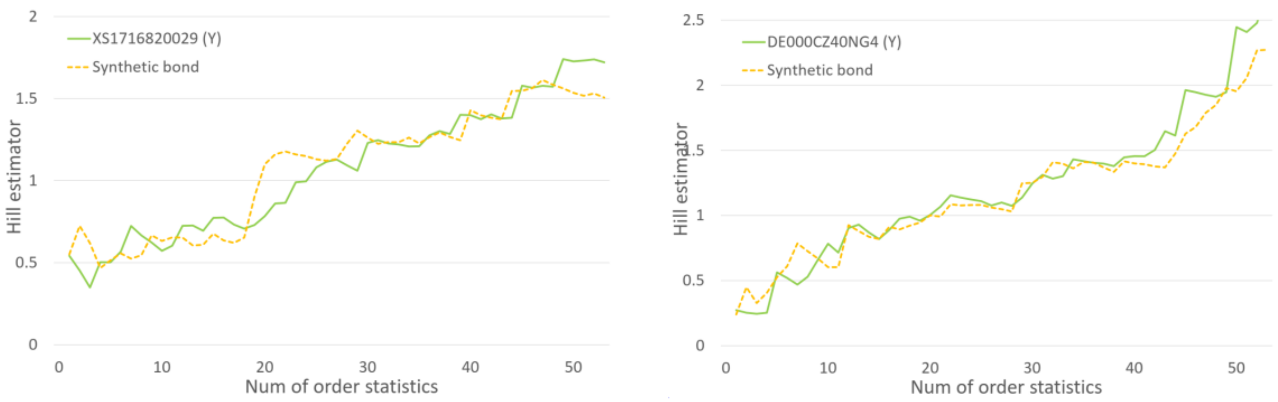


FRPTT

5. Greenium of Green Bond

- Extreme Value Index Estimation

Company	Green Bond Code	Green bond	Synthetic bond
ABNANV	XS1422841202	0.6812	0.4880
	XS1808739459	0.5258	0.5978
	XS1982037696	0.5597	0.6649
ACACB	FR0013465010	0.33511	0.52762
ACAFP	XS2067135421	0.5760	0.6244
	FR0013385515	0.3662	0.1585
BACR	XS1716820029	0.72402	0.52499
BBVASM	XS1820037270	0.2768	0.3719
	XS2013745703	0.3596	0.3161
BNP	XS1808338542	0.5196	0.4511
	FR0013405537	0.5418	0.4620
	FR0013465358	0.6008	0.5095
	XS1527753187	0.5133	0.4845



(a) BACR (b) CMZB

- From the case (a)/(b), the tail index for the green bonds is lower/higher than that of their corresponding synthetic bonds.
- There are a total of 98 green bonds, of which 45 pairs of bonds have the γ value of green bond greater than that of synthetic bond.
- Therefore, **there is no obvious difference in tail index between green bonds and synthetic bonds**.

KU LEUVEN

5. Greenium of Green Bond

- Hypothesis Tests for Green Bonds and Synthetic Bonds

Hypothesis tests		The proportion of $p < 0.05$
T-tests	h_1	0
	h_2	0
	h_3	0
F-tests	h_4	50.00%
	h_5	26.63%
Wilcoxon rank-sum test	h_6	0
Kolmogorov-Smirnov test	h_7	20.41%

- ☐ Some evidence that the synthetic bonds could have a different distributions with the corresponding green bonds.
- ☐ No evidence there is significant difference in the mean and median of green bonds and synthetic bonds.
- ☐ There is some evidence of differences in variance (volatility).

5. Greenium of Green Bond

- Average Dataset Greenium

$$Greenium = the\ ASW\ of\ green\ bond - the\ ASW\ of\ synthetic\ bond$$

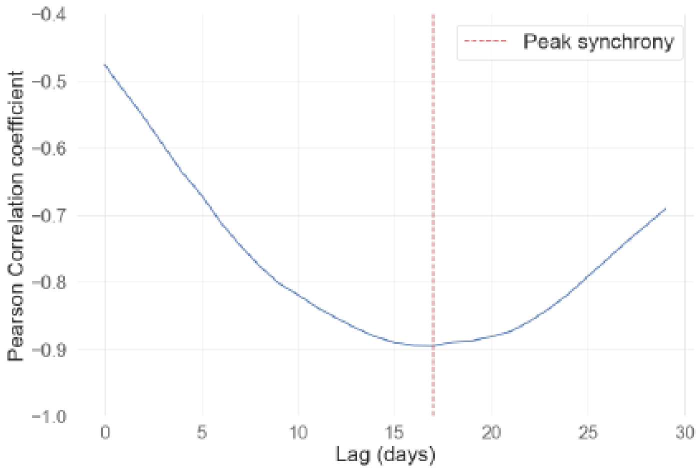
- ☐ The mean of greenium is around -7.07 bps
- ☐ The greenium value changes over time and fluctuates around zero.
- ☐ The greenium changes from positive to negative in recent years.
- ☐ Sharp decline in greenium in March 2020.

5. Greenium of Green Bond

- Greenium during COVID-19 period

The relationship between greenium and VIX during 2020

(a) The relationship between Greenium and VIX.



(b) The pearson correlation between Greenium and VIX.

Figure 6.4: Greenium and VIX during 2020. In the right figure, the horizontal axis is the lag (trading days) of greenium with VIX.

- Sharp drop of the greenium in March 2020 almost at the moment the VIX spikes.
- Greenium has a lag of about 17 trading days compared with the VIX index.

5. Greenium of Green Bond

- Explanations about the Greenium
  - A potential explanation is that green bonds are proportionally more held in portfolios of investors focusing on non-pecuniary (environmental) aspects of the bonds and are part of more buy-and-hold long-term strategies and therefore hence less affected by market volatility.
  - Another potential explanation is that although global financial markets saw large net outflows during the crisis, ESG focused strategies continued to see net inflows. This may have led to proportionally more flows into green bonds compared to non-green bonds, and hence increased demand on a relative basis. Rising spreads of the ordinary bonds in distressed markets, due to selling pressure and a flight to cash, could cause the greenium to become more negative.
  - Sustainable investments like green bonds seem to be hence more robust in systemic crises.

6. Conclusion

6. Conclusion

- From the results of hypothesis tests we can conclude:
  - there is at first sight no evidence that green bonds have significantly different distributions than their conventional counterparts;
  - there is no evidence of significant difference in the mean and median, but
  - **there is some evidence that some green bonds are less volatile then their conventional counterparts.**
- Comparing the green bonds with the synthetic bonds constructed by interpolation of non-green bonds, we have no evidence of a significant systematic long term greenium. The greenium fluctuating near zero over time.
- However, **currently the greenium is negative and around its overall average of -7 bps**.
- **We do observe evidence that the greenium becomes more negative in times of financial market stress**.
- These findings could have important consequences for construction of fixed income corporate bond portfolios.

Thank you!