The Green Bond Premium

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Introduction and motivations

The environmental transition is also an investment issue

COP 21: "Making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development".

- Need for cumulative investment in energy supply and energy efficiency (1.5 degrees path) by 2030: USD 93 trillion
- Total assets held by the OECD institutional investors (2013): USD 92.6 trillion

⇒ Key role of private investors to amplify the environmental transition.

Today: Private investors = 1/3 total investments in sustainable energy.

Private and public initiatives

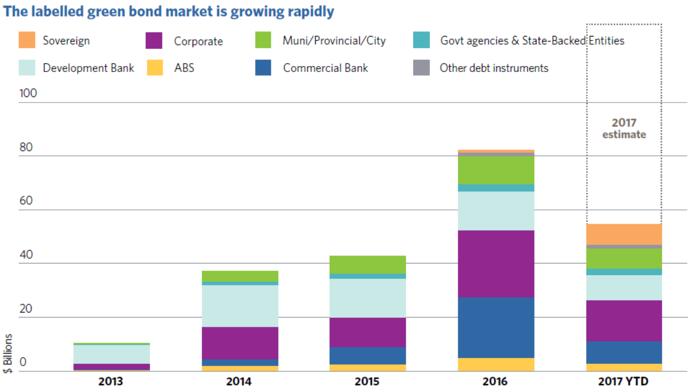
Many initiatives have therefore been launched to *decarbonize* portfolios and redirect assets towards green investments, e.g.:

- The Portfolio Decarbonization Coalition
- The Montreal Carbon Pledge

These trends have also been supported and strengthened by national regulations in both industrialized and emerging countries, e.g.:

- China
- France
- The Bank of England and the Securities and Exchange Board of India

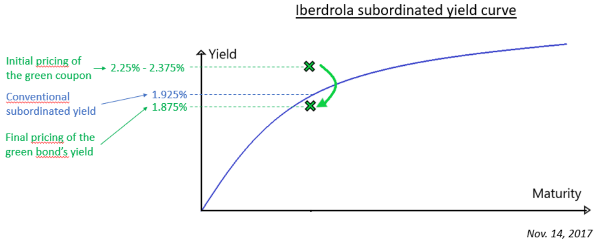
The Green bond market (Source: Climate Bond Initiative)



GB ≈ 1.2% (USD 266bn) of the global bond market and ≈ 2.2% (USD 150bn, exp. 2017) of the total issuances. ≈ 80% are investment grade bonds and the energy sector is the main sector involved (38%). The USD (36%) and the EUR (38%) are the main currencies involved.

Motivating example

On Nov. 14, 2017, Iberdrola issued a green hybrid bond (perpetual 5.5Y callable, step up coupon after 10 and 25Y) for EUR 1 bn.



With an initial order book at EUR 3.4bn, the yield at issuance plummeted to 1.875%, i.e. 43bps inside the initial pricing and 5bps below the conventional yield curve.

The funding cost: a crucial variable

- A low funding cost is valuable to achieving sustainable infrastructure development...
- ... However, a low green bond yield could indicate a strong buying pressure on the green bond market and a risk of green bubble (suggested by DNB (2017)).

$\Rightarrow$ Main question: Is there a negative premium specific to green bonds? In other words, is a green bond yield lower than that of a completely equivalent non-green bonds?

Literature review

Existing literature on the relative price of Green bonds:

- Banks/Market articles: Barclays (2015), Bloomberg (2017), HSBC (2017)
- Academic working paper: Karpf and Mandel (2017)

This work builds on three strands in the literature:

- Studies assessing the effects of firms' environmental performances on their bond yields (see notably Menz (2010), Stellner et al. (2015), Bauer and Hann (2010), Frooman et al. (2008), Oikomonou et al. (2014), Ge and Liu (2015), Goss and Roberts (2011))
- Studies based on the matching method, in which a model-free approach is used to determine the intrinsic value of specialized financial instruments (see notably Kreander et al. (2005), Renneboog et al. (2008), Bauer et al. (2005), Longstaff and Schwartz (1995), Amihud and Mendelson (1991), Kamara (1994), Strebulaev (2001), Helwedge et al. (2014))
- Studies on liquidity proxies (see notably Bao et al. (2011), Houweling et al. (2005), Beber et al. (2009), Dick-Nielsen et al. (2012), Van Loon et al. (2015), Chen et al. (2007))

Main contributions

Main contributions:

1. First academic study focusing on the specific cost of green bonds
2. Method for analyzing the costliness of bonds with specific proceeds
3. There is a negative premium on green bonds yield which we quantify and explain on the basis of the characteristics of the bond:
   $\Rightarrow$ Evidence a shortage of green bonds vs. non-green bonds + early warning signs of a green bubble risk
   $\Rightarrow$ Opportunity to keep on increasing the supply of green bonds + need for public support to feed the pipeline of green bond issuances

Data description

Green bonds candidates : a matching method

→ To compare a green bond (GB) with a synthetic equivalent conventional (CB) we take matched pairs of bonds consisting of a GB and a CB with identical charecteristics except for its liquidity (see Helwege et al. (2014)).
⇒ We examine the entire sample of 681 green bonds (GB) complying with the Green Bonds Principles on December 30, 2016 searching for the two conventional bonds (CB1 and CB2) from the same issuer with the closest maturity, having the same characteristics: same currency, rating, bond structure, seniority, collateral and coupon type.
Additional constraints:
- Restriction on the maturity: $|\Delta \text{ Maturity}| < 2 \text{ years}$
- Restriction on the liquidity:

- $\frac{1}{4} <$ GB issued amount / CB issued amount < 4
- $|\Delta \text{ Date of issuance}| < 6 \text{ years}$

⇒ 161 GB ⇒ 141 investment grade senior bullet fixed-coupon GB.

Construction of the difference in yield and filtering of the sample

We interpolate or extrapolate the two CB linearly to remove the maturity bias and we get the synthetic equivalent conventional bond's yield $\tilde{y}_{i,t}^{CB}$. We set $\Delta\tilde{y}_{i,t} = y_{i,t}^{GB} - \tilde{y}_{i,t}^{CB}$, which include a reduced liquidity premium + the GB premium.

We apply Bernoth et al. (2006) filter and we then winsorized the transactions below the 2.5% and above the 97.5% percentile based on the distribution of $\Delta\%\tilde{y}_{i,t} = \frac{y_{i,t}^{GB} - \tilde{y}_{i,t}^{CB}}{|\tilde{y}_{i,t}^{CB}|}$.
$\Rightarrow$ 135 remaining GB, 43,445-line unbalanced panel. The earliest information dates back to April 23, 2012 and the latest information is dated December 30, 2016.

Significant variations in the yield levels between the issue currencies (in %)

	Average green bond yield				
	AAA	AA	A	BBB	Average
AUD	2.73	2.99	3.06		2.90
BRL	10.88		11.72		11.18
CAD	1.23				1.23
CHF	0.14				0.14
CNY			3.39		3.39
EUR	0.18	0.79	0.44	0.97	0.39
GBP	0.78				0.78
IDR	8.29				8.29
INR	6.37		7.54		6.76
JPY			0.21		0.21
MXN	5.51		5.57		5.55
NOK	1.97				1.97
NZD			2.70		2.70
RUB	8.31				8.31
SEK	- 0.07		0.76		0.21
TRY	10.01				10.01
USD	1.38	1.94	1.97	3.88	1.86
ZAR	7.85				7.85
Average	4.73	2.06	4.05	2.72	4.30

General characteristics of the bonds in the database

	All bonds					
	Min.	**2nd quart.**	**Median**	**Mean**	**3rd quart.**	**Max.**
Number of days per bond	11	122	260	322	454	1 186
Ask yield of the GB y^{GB}	- 0.29	0.94	2.55	4.30	7.35	13.53
Ask yield of the CB1 y^{CB_1}	- 0.29	0.94	2.71	4.29	7.45	13.49
Ask yield of the CB2 y^{CB_2}	- 0.29	0.90	2.83	4.36	7.51	13.49
Ask yield of the interp. CB $\tilde{y}^{CB}$	- 0.35	0.94	2.74	4.36	7.40	13.49
Yield difference % $\Delta\tilde{y}_{i,t}$	-2.59%	-0.14%	-0.02%	-0.06%	0.02%	2.29%
Green bond maturity on Dec. 30, 2016 (in years)	0.08	1.91	2.89	3.33	4.28	14.41
Conventional bond 1 maturity	- 0.26	1.71	2.62	3.27	4.16	15.04
Conventional bond 2 maturity	0.03	1.44	2.73	3.11	4.04	13.41

The difference in yield is skewed to the left: 65% negative values. Average of -6 bps and median of -2 bps.

$\Rightarrow$ Is there a premium attributable to the greenness of a bond within $\Delta\tilde{y}_{i,t}$?

Empirical methodology

A liquidity bias

$\Delta \tilde{y}_{i,t}$, still shows a slight liquidity bias.

	Average issued amounts (in USD)		
	Green bond	Conventional bond 1	Conventional bond 2
AUD	169 436 053	258 406 800	249 282 673
BRL	22 779 244	18 080 183	16 277 192
CAD	372 050 000	1 041 740 000	892 920 000
CHF	343 525 000	269 912 500	588 900 000
CNY	215 820 000	143 880 000	71 940 000
EUR	914 170 000	1 782 227 000	1 817 297 150
GBP	1 419 100 000	4 858 875 000	1 635 050 000
IDR	14 188 686	13 500 429	10 101 497
INR	16 165 664	14 204 666	23 349 204
JPY	89 846 064	120 940 050	215 478 417
MXN	14 279 040	8 244 216	21 929 904
NOK	173 550 000	173 550 000	173 550 000
NZD	24 962 400	24 962 400	6 934 000
RUB	5 010 417	17 333 333	12 772 500
SEK	210 526 667	184 897 333	144 622 667
TRY	23 394 580	10 897 920	20 594 420
USD	577 375 862	1 135 917 241	1 225 641 379
ZAR	86 718 562	125 547 225	279 297 088
Average	260 716 569	566 839 794	411 441 005
Median	129 641 059	134 713 613	159 086 333

We therefore need to carry out a second liquidity control to exctract the premium.

Extracting the green bond premium

We design a proxy $\Delta\text{Liquidity}_{i,t}$ reflecting the difference in liquidity:

$$\Delta\text{Liquidity}_{i,t} = \text{Liquidity}_{i,t}^{GB} - \text{Liquidity}_{i,t}^{CB} \quad (1)$$

Since the synthetic conventional bonds are based here on the two closest conventional bonds (CB1 and CB2), let
$d_1 = |\text{Green Bond maturity - CB1 maturity}|$ and
$d_2 = |\text{Green Bond maturity - CB2 maturity}|$.
The synthetic conventional bond's liquidity proxy will therefore be:

$$\text{Liquidity}_{i,t}^{CB} = \frac{d_2}{d_1 + d_2}\text{Liquidity}_{i,t}^{CB1} + \frac{d_1}{d_1 + d_2}\text{Liquidity}_{i,t}^{CB2} \quad (2)$$

The green bond premium p_i is therefore defined as the unobserved effect in the fixed effect panel regression of $\Delta\tilde{y}_{i,t}$ on $\Delta\text{Liquidity}_{i,t}$:

$$\Delta\tilde{y}_{i,t} = p_i + \beta\Delta\text{Liquidity}_{i,t} + \epsilon_{i,t}, \text{ with } \epsilon_{i,t} \text{ being the error term} \quad (3)$$

A Fixed Effect panel regression

Why a fixed effect regression?

- To bring out the bond-specific time-invariant unobserved effect without imposing any distribution or using any information about the other bonds
- We do not require the difference in liquidity proxy to be uncorrelated with the unobserved specific effect => broader range of potential control parameters
- Strict exogeneity holds (see next section): the idiosyncratic error term is not correlated with either the previous or forthcoming differences in liquidity

We control for serial correlation and heteroscedasticity (Fixed Effect Generalized Least Squares (FEGLS) estimator, see Kiefer (1980), and Arellano estimator, see Arellano (1987)).

Homogenous dependence structure across currencies

The determinants of the green bond premium are assessed, based on both the structure of the curve (*Structural part*) and the specific features of each bond (*Variable part*).

We consider two specifications:

(i) Homogeneous dependence structure across currencies:

$$\widehat{p_i} = \overbrace{\alpha_0 + \alpha_1 \text{Yield}_i}^{\text{Structural part}} + \overbrace{\alpha_{2,1}\text{Issued Amount}_i + \alpha_{2,2}\text{Issued Amount}_i^2 + \alpha_{3,1}\text{Maturity}_i + \alpha_{3,2}\text{Maturity}_i^2}^{\text{Variable part}}$$
$$\underbrace{+\sum_{j=1}^{p}\alpha_{4,rating_j}1_{rating_j} + \sum_{j=1}^{q}\alpha_{5,currency_j}1_{currency_j} + \sum_{j=1}^{r}\alpha_{6,group_j}1_{group_j}}_{\text{Variable part}} + \eta_i \quad (4)$$

Heterogeneous dependence structure across currencies

(ii) Heterogeneous dependence structure across currencies:

$$\widehat{p}_i = \overbrace{\alpha_{CUR,0} + \alpha_{CUR,1}\text{Yield}_i}^{\text{Structural part}} + \overbrace{\alpha_{CUR,2,1}\text{Issued Amount}_i + \alpha_{CUR,2,2}\text{Issued Amount}_i^2}^{\text{Variable part}}$$
$$\underbrace{+\alpha_{CUR,3,1}\text{Maturity}_i + \alpha_{CUR,3,2}\text{Maturity}_i^2 + \sum_{j=1}^{p}\alpha_{CUR,4,rating_j}1_{rating_j} + \sum_{j=1}^{q}\alpha_{CUR,5,group_j}1_{group_j}}_{\text{Variable part}} + \eta_i \quad (5)$$

Regarding the independent variables:

- Rating: Qualitative variable, the four modalities of which are AAA, AA, A, BBB
- Maturity: number of years
- Issued amount: in USD billions with the reference date of December 30, 2016
- Group: Bloomberg BICS level 1 (Government, Utilities and Financials in our sample)

The liquidity-control variables

The liquidity proxies which can be used here are subject to three constraints:

- We cannot use intraday liquidity indicators (Amihud measure, Range measure or intraday Roll and Gamma measure) $\Rightarrow$ We focus on low frequency data
- We do not have any information about the daily trading volumes (contrary to TRACE) that might have been used as liquidity proxies
- To ensure the full rank condition of the Within regression, any variable that does not change over time with a given bond is not suitable (the issued amount or the issue date)

We therefore use:

- The yield bid-ask spread
- The Zero trading day measure

The liquidity-control variables

$\Delta\mathrm{Liquidity}_{i,t}$ is calculated with equations (1) and (2). The distribution of the average value of the three liquidity proxies applied to each pair of bonds is presented in the table below.

Difference in	Min.	1st Quart	Median	Mean	3rd Quart.	Max.	Std. Dev
ΔBA (in %)	-0.77	-0.03	0.00	-0.02	0.01	0.78	0.14
ΔZTD	-21.6%	-0.4%	0.0%	-0.2%	0.1%	17.6%	2.7%

The statistics show that the variables are concentrated around zero and a low standard deviation is observed, especially in the case of ΔZTD.
⇒ The first liquidity control on the amounts issued and the date of issuance in the data construction procedure yields satisfactory results.

The green bond premium

Step 1 regression tests, focusing on ΔBA

		Panel : $\Delta\bar{y}$ controled by ΔBA		
		Statistic	**P Value**	**Conclusion**
Fixed vs. Random effect	Hausman's test	14.906 (df=1)	0.0001	Fixed effect
Individual effect	F test	121.09 (df1=134, df2=43309)	$<2.2.10^{-16}$	Individual effect
	Wooldridge's test	2.43	0.015	Individual effect
	Breusch-Pagan's test	135100000 (df=1)	$<2.2.10^{-16}$	Individual effect
	Honda's test	11623	$<2.2.10^{-16}$	Individual effect
Serial correlation	Breusch-Godfrey Wooldridge's test	38044 (df=11)	$<2.2.10^{-16}$	Serial correlation
	Durbin Watson's test	0.1315	$<2.2.10^{-16}$	Serial correlation
	Wooldridge's test for AR(1)	12326	$<2.2.10^{-16}$	AR(1) serial correlation
Heteroscedasticity	Breusch-Pagan's test	881750 (df=135)	$<2.2.10^{-16}$	Heteroscedastitiy

The strict exogeneity is confirmed by the Su et al (2016)'s test.
To improve the efficiency of the estimation, we therefore use :

- Within / Fixed Effect regression (FE)
- Fixed Effect Generalized Least Square regression (FEGLS): heteroscedasticty and intra-group serial correlation
- Arellano estimator of the variance: heteroscedasticity and serial correlation

Step 1 regression results

	Dependent variable:			
	$\Delta\tilde{y}_{i,t}$			
	FE	FEGLS	FE	FEGLS
	(i)	(ii)	(iii)	(iv)
Bid-Ask spread	−0.882***	−0.882***		
	(0.034)	(0.071)		
Zero trading day			0.017	0.017
			(0.044)	(0.071)
Observations	43,445	43,445	43,445	43,445
Adjusted R^2 / Multiple R^2	0.27	0.27	0.26	0.26

The FE-Arellano estimation provides the same result as the FEGLS one. The sign of $\widehat{\beta}$ differs between the two regressions for two reasons:

- These two proxies do not capture the same kind of illiquidity
- In the regression of $\Delta\tilde{y}_{i,t}$ on ΔBA, $\widehat{\beta}$ can be negative in various cases

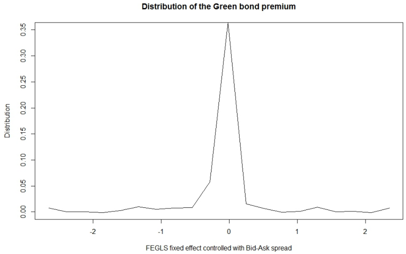
The green bond premia

We extract the 135 $\widehat{p_i}$ constituting each of the green bonds' premia. They are similar for the three types of regressions and for the two liquidity controls.

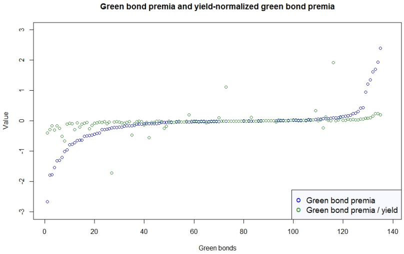
	Min.	1st quart.	Median	Mean	3rd quart.	Max.
$\Delta\tilde{y}_i$: Average $\Delta\tilde{y}_{i,t}$ over t	-2.59%	-0.14%	-0.02%	-0.06%	0.02%	2.29%
Fixed effect $\widehat{p_i}^{FE}(\Delta BA)$	-2.66%	-0.16%	-0.02%	-0.08%	0.02%	2.39%
Fixed effect $\widehat{p_i}^{FEGLS}(\Delta BA)$	-2.66%	-0.16%	-0.02%	-0.08%	0.02%	2.39%
Fixed effect $\widehat{p_i}^{FE}(\Delta ZTD)$	-2.59%	-0.14%	-0.02%	-0.06%	0.02%	2.29%
Fixed effect $\widehat{p_i}^{FEGLS}(\Delta ZTD)$	-2.59%	-0.14%	-0.02%	-0.06%	0.02%	2.29%

64% of the premia are negative and the amplitudes are greater on the downside than on the upside.

The green bond premia distribution



(a) Distribution of the green bond premia across all bonds.



(b) Green bond premia and yield-normalized green bond premia sorted across all bonds.

Summary table of the average green bond premia and significance levels

	Average $\widehat{p}_i^{FEGLS}(\Delta BA)$ (in %)	Significantly $\neq 0$	Sample size
All bonds	-0,08	Yes at 90%	135
All bonds > USD 100m	-0,02	No	71
All bonds: AAA	-0,14	Yes at 94%	80
All bonds > USD 100m: AAA	0,02	No	38
All bonds: AA + A + BBB	0,00	No	55
All bonds > USD 100m: AA + A + BBB	-0,06	Yes at 99%	33
USD bonds	-0,11	Yes at 95%	29
USD bonds > USD 100m	**-0,05**	**Yes at 95%**	**26**
USD bonds: AAA	-0,02	No	15
USD bonds > USD 100m: AAA	-0,02	No	14
USD bonds: AA + A + BBB	-0,20	Yes at 95%	14
USD bonds > USD 100m: AA + A + BBB	**-0,09**	**Yes at 90%**	**12**
EUR bonds	-0,01	No	26
EUR bonds > USD 100m	**-0,02**	**Yes at 90%**	**25**
EUR bonds: AAA	0,01	No	12
EUR bonds > USD 100m: AAA	0,01	No	11
EUR bonds: AA + A + BBB	-0,04	Yes at 99%	14
EUR bonds > USD 100m: AA + A + BBB	**-0,04**	**Yes at 99%**	**14**
BRL bonds	0,28	No	17
AUD bonds	-0,23	Yes at 95%	12
INR bonds	-0,20	No	18
IDR bonds	-0,79	Yes at 99%	7

Step 2 regression with a heterogeneous dependence structure across currencies

In this presentation, we focus on the regression (4) with the heterogeneous dependence structure across currencies.
We apply it to USD and EUR bonds. We exclude bonds with an issued amount lower than USD 100 million (i.e. 1 EUR bond among 26 and 3 USD bonds among 29).

For the 18 specifications (9 EUR and 9 USD) considered:

- No heteroscedasticity
- No multicolinearity
- 3 cases of an AR(1) serial correlation ((g), (h) and (t))

⇒ We apply an OLS or a GLS with an AR(1)-structure of the variance-covariance matrix of the error term to estimate the determinants of the green bond premium.

Step 2 regression for EUR bonds

	Dependent variable:										
	$\hat{p}_i^{FEGLS}$(BA)										
	OLS	*GLS*	*OLS*	*GLS*	*OLS*	*OLS*	*OLS*	*OLS*	*OLS*	*OLS*	*OLS*
	(g)	(g)	(h)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)
Constant	−0.008	−0.010	−0.015	−0.005	−0.079***	0.009	0.002	0.009	−0.045	−0.039	−0.030
	(0.014)	(0.017)	(0.022)	(0.022)	(0.025)	(0.012)	(0.011)	(0.012)	(0.031)	(0.032)	(0.037)
Yield (%)	−0.021	−0.016									
	(0.026)	(0.021)									
Maturity (years)			−0.0001	−0.002							
			(0.003)	(0.002)							
Issued amount (bn USD)					0.095**				0.071	0.054	0.051
					(0.042)				(0.043)	(0.048)	(0.052)
Issued amount^2					−0.021				−0.016	−0.012	−0.011
					(0.013)				(0.013)	(0.014)	(0.015)
Rating AA						−0.061**		−0.042	−0.044		−0.031
						(0.027)		(0.031)	(0.028)		(0.033)
Rating A						−0.047**		−0.002	−0.032		0.011
						(0.019)		(0.052)	(0.020)		(0.054)
Rating BBB						−0.010		−0.004	−0.001		0.024
						(0.032)		(0.066)	(0.031)		(0.071)
Group Financials							−0.057***	−0.056		−0.039*	−0.052
							(0.018)	(0.049)		(0.021)	(0.050)
Group Utilities							−0.003	−0.006		−0.005	−0.027
							(0.023)	(0.058)		(0.023)	(0.062)
Observations	25	25	25	25	25	25	25	25	25	25	25
R^2	0.027		0.0001		0.293	0.301	0.332	0.419	0.416	0.399	0.461
Adjusted R^2	-0.015		-0.043		0.228	0.202	0.271	0.266	0.263	0.278	0.240
Log Likelihood		45.322		45.267							
Akaike Inf. Crit.		-82.644		-82.534							
Bayesian Inf. Crit.		-77.769		-77.659							
Residual Std. Error	0.047		0.047		0.041	0.041	0.040	0.040	0.040	0.039	0.040
F Statistic	0.638		0.001		4.551**	3.021*	5.470**	2.738*	2.709*	3.315**	2.081
	(df = 1; 23)		(df = 1; 23)		(df = 2; 22)	(df = 3; 21)	(df = 2; 22)	(df = 5; 19)	(df = 5; 19)	(df = 4; 20)	(df = 7; 17)

Note: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

- Positive and concave effect of increasing the issued amount
- Negative effect of a AA rating < AAA < A < BBB
- Negative effect of Corporate bonds, mainly Financials, versus Gov-related bonds

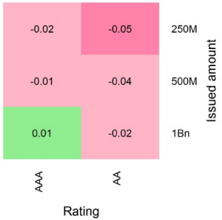
Step 2 regression for USD bonds

	Dependent variable: $\hat{p}_i^{FEGLS}$(BA)									
	OLS	*OLS*	*OLS*	*OLS*	*OLS*	*GLS*	*OLS*	*OLS*	*OLS*	*OLS*
	(p)	(q)	(r)	(s)	(t)	(t)	(u)	(v)	(w)	(x)
Constant	0.072	−0.002	−0.068	−0.019	−0.007	−0.006	0.060	0.135*	−0.019	0.076
	(0.051)	(0.054)	(0.056)	(0.033)	(0.027)	(0.027)	(0.050)	(0.068)	(0.030)	(0.078)
Yield (%)	−0.065**						−0.043	−0.110**		−0.067
	(0.024)						(0.027)	(0.043)		(0.051)
Maturity (years)		−0.017								
		(0.016)								
Issued amount (bn USD)			0.026							
			(0.078)							
Rating AA				0.045				0.103	0.045	0.081
				(0.094)				(0.088)	(0.084)	(0.087)
Rating A				−0.083				−0.024	0.274*	0.191
				(0.058)				(0.057)	(0.145)	(0.156)
Rating BBB				−0.111				0.160	0.127	0.214
				(0.079)				(0.129)	(0.115)	(0.130)
Group Financials					−0.128**	−0.130***	−0.087		−0.357**	−0.237
					(0.047)	(0.047)	(0.052)		(0.136)	(0.161)
Observations	26	26	26	26	26	26	26	26	26	26
R^2	0.231	0.041	0.005	0.155	0.238		0.313	0.352	0.364	0.416
Adjusted R^2	0.198	0.001	-0.037	0.040	0.207		0.253	0.229	0.243	0.269
Log Likelihood						20.775				
Akaike Inf. Crit.						-33.551				
Bayesian Inf. Crit.						-28.518				
Residual Std. Error	0.114	0.127	0.130	0.125	0.113		0.110	0.112	0.111	0.109
F Statistic	7.189**	1.017	0.111	1.343	7.512**		5.234**	2.855**	3.009**	2.844**
	(df = 1; 24)	(df = 1; 24)	(df = 1; 24)	(df = 3; 22)	(df = 1; 24)		(df = 2; 23)	(df = 4; 21)	(df = 4; 21)	(df = 5; 20)

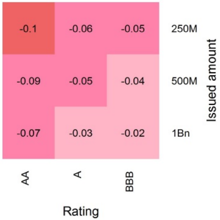
Note: *p<0.1; **p<0.05; ***p<0.01

- Negative effect of the yield
- Positive effect of lowering the rating, compensated by a...
- ... strong negative effect of Financials vs. Gov-related

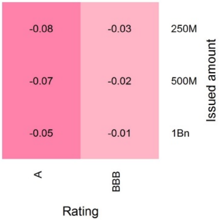
Heatmaps of green bond premia



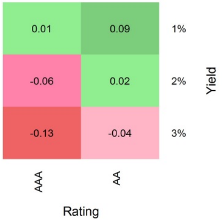
(a) EUR Government-related



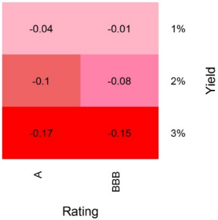
(b) EUR Financials



(c) EUR Utilities

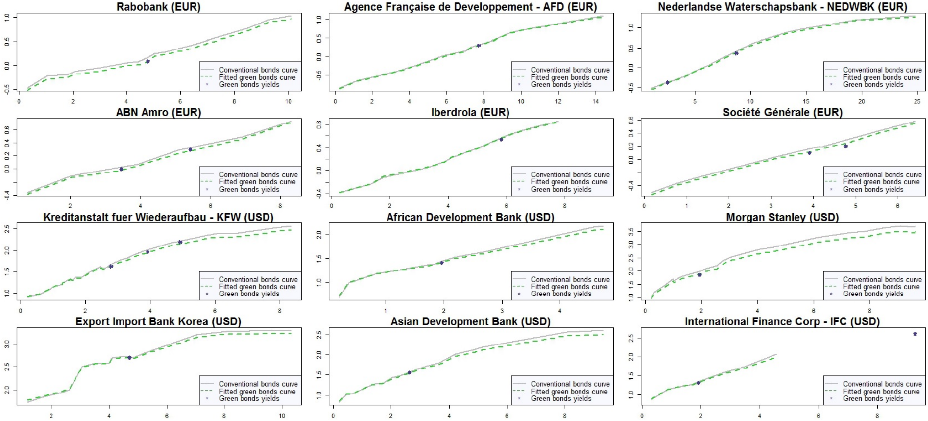


(d) USD Government-related

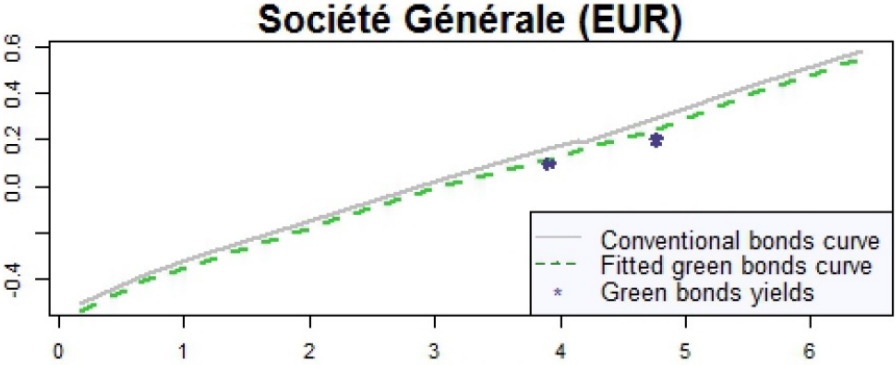


(e) USD Financials

Building green bond curves



Zoom on a green bond curve



Robustness checks

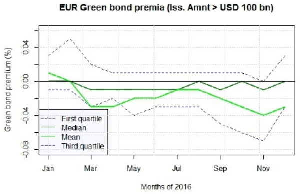
1. Does the green premium reflects a lower level of risk?

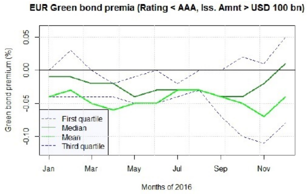
We calculate the annualized volatility of each GB and the closest CB and we take the difference between the members of each pair.
⇒ The average difference in the case of the 135 pairs is found to amount to almost zero: 0.2%.

We then add this difference in volatility as an independent variable to regressions (o) and (x).
⇒ No significance (P-Value= 88% and 66%, respectively).

⇒ The green bond premium does not reflect a lower level of risk.

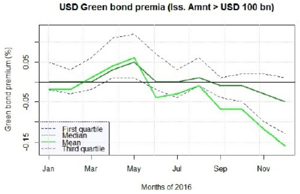
2. Is the green premium constant over time?

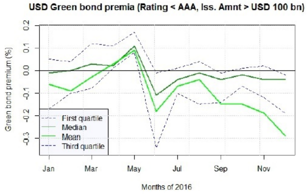




(a) EUR Green bond premia (Iss. Amnt > USD 100 bn)

(b) EUR Green bond premia (Rating < AAA and Iss. Amnt > USD 100 bn)





(c) USD Green bond premia (Iss. Amnt > USD 100 bn)

(d) USD Green bond premia (Rating < AAA and Iss. Amnt > USD 100 bn)

3. Is the green premium related to the market risk premium?

We run a Within-two-ways regression and extract the daily time effects.

1. The correlation between the daily return of the Eurostoxx 50, S&P 500 and the MSCI World on the one hand and the daily time effect returns is in each case close to zero.
2. The regression of the daily time effects return on the market returns does not show any significant effect (P Value of 71%, 25% and 88%, respectively).

⇒ The green bond premium is not a market risk premium.

4. Is the CB yield approximation a fair one?

If the maturities of CB1 and CB2 differ greatly from that of the green bond, the synthetic conventional bond yield is liable to be over- or under-estimated.
⇒ Any green bonds showing a difference in maturity of more than one year with the closest conventional bond, CB1, are therefore excluded (6 bonds).
⇒ The green bond premia are very similar to those estimated previously (Step 2 regression also yields similar results).

Maturity of CB1 < 1 year:	Average $\widehat{p}_i^{FEGLS}(\Delta BA)$ (in %)	Significantly different from zero
EUR bonds > USD 100m	-0.02	Yes at 90%
EUR bonds > USD 100m: AA + A + BBB	-0.04	Yes at 99%
USD bonds > USD 100m	-0.04	Yes at 90%
USD bonds > USD 100m: AA + A + BBB	-0.07	Yes at 83%

⇒ The CB yield approximation is a fair one.

Practical use: Natixis Research Report using the methodology of this paper

NATIXIS

REPORT

24 April 2017

GREEN & SUSTAINABLE BONDS

Is the EIB paving the way for a "Green Premium"?

- With almost €8bn in outstanding euro-denominated Climate Awareness bonds, the EIB is, in our view, a highly relevant benchmark against which the behaviour of green issuances in both the primary and secondary bond markets can be measured. As one of the largest euro green bond issuers, EIB is viewed by investors as the gold standard on the euro green bond market offering i) a relatively liquid curve compared with other green bond issuers; ii) choices in terms of tenors.

- Based on an analysis of the secondary performance of euro denominated CAB and Ecoop bonds on the z-spread levels on a mid-market (interpolated on a linear basis on the maturity date of the outstanding euro CAB bonds), the secondary pricing advantage of the euro CAB bonds, corresponding to a tighter z-spread than those of the Ecoop bonds, is appealing on three out of four, outstanding green references. In this note, we will refer to the pricing advantage of green bonds as a "green premium". The green premium observed on the EIB's secondary spreads is not a recent phenomenon and it seems that there is an immediate secondary outperformance of the CAB. The green bond offered up to c.8bp of green premium over the last six months but the premium is now in the region of 2bp. Results that Olivier David Zerbib, academic researcher at Institut de Science Financière et d'Assurances (ISFA), Université Lyon 1, has also observed (though to a lesser extent) through a liquidity

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Discussion and conclusion

A high Demand to Offer ratio for Green Bonds

We have presented a methodology for analyzing the costliness of bonds with specific proceeds.

$\Rightarrow$ The results point to $\frac{D}{S}|_{GB} > \frac{D}{S}|_{CB}$ in various market segments.

$\Rightarrow$ Can be due to an excess of GB demand or a lack of GB issuances (not exclusive):

- Excess of GB demand: support the findings of the stakeholder theory via the increase of the size of the bondholder base (Heinkel et al. (2011) and Ge and Liu (2015))
- Lack of GB issuances: support the barriers evidenced at the issuer's level in I4CE (2017):
  - Barriers to green projects investment pipeline
  - Barriers to green bonds labelling

Effects and possible responses

	Implications	
	+ **Positive** +	− **Negative** −
GB issuers	◇ Possibility to issue more GB ◇ Possibility to issue at a yield lower than the CB benchmark	◇ Reveals a lack of green projects
GB investors		◇ Indicates a risk of green bubble ◇ Tends to concentrate GB among green investors: - Increases the systemic risk - Reduces the base of retail investors accessing to green investments

May call for a regulatory and fiscal support to the developement of the GB market:

- Draw up a precisely defined framework for GB requirements on an international scale (to avoid greenwashing) and streamline the approval process (25% of the climate-aligned bonds universe)
- Fostering risk pooling to enable minor players to enter the GB market
- Credit enhancement by public institutions
- Beneficial tax regime for GB issuers or green projects?


"That's all Folks!"

Appendix: Heteroscedastic and serially correlated panels

Here, denote $x_{i,t} \equiv \Delta \text{Liquidity}_{i,t}$, $y_{i,t} \equiv \Delta \tilde{y_{i,t}}$, $X_i = (x_{i,1}, ..., x_{i,T})'$ and $\bar{X}_i = (I_T - j_T(j_T' j_T)^{-1} j_T')X_i$ the regressor and the time-demeaned regressor, respectively. Recall that the following assumptions:

- (FE1) Strict exogeneity: $\mathbb{E}(\epsilon_{i,t}|x_i, p_i) = 0, t = 1, 2, ... T$. [Consistent estimator]
- (FE2) No multicolinearity: $\text{rank}[\mathbb{E}(\bar{X}_i' \bar{X}_i)] = 1$ is satisfied since $\Delta \text{Liquidity}_{i,t}$ varies over time
- (FE3) Homoscedasticity and no serial correlation of idiosynchratic errors: $\mathbb{E}(\epsilon_i \epsilon_i' | x_i, p_i) = \sigma_\epsilon^2 \mathbb{I}_T$ [Efficient estimator]

Under (FE1) and (FE2), $\hat{\beta}_{FE} = (\sum_{i=1}^n \bar{X}_i' \bar{X}_i)^{-1} (\sum_{i=1}^n \bar{X}_i' \bar{Y}_i)$ and, under (FE3), $\hat{\text{Avar}} = \hat{\sigma}_\epsilon^2 (\sum_{i=1}^n \bar{X}_i' \bar{X}_i)^{-1}$, with $\hat{\sigma}_\epsilon^2 = \sum_{i=1}^N \sum_{i=1}^T \hat{\epsilon}_{i,t}^2 / [N(T-1) - K]$.

If (FE3) does not hold, the previous variance matrix estimator is improper. Thus:

- Robust asymptotic variance matrix estimator of β_{FE} (Arellano (1987)): $\hat{\text{Avar}} = (\bar{X}_i' \bar{X}_i)^{-1} (\sum_{i=1}^n \bar{X}_i' \hat{\epsilon}_i \hat{\epsilon}_i' \bar{X}_i)(\bar{X}_i' \bar{X}_i)^{-1}$
- Fied Effects GLS (FEGLS) consistent estimator (with $\text{rank}[\mathbb{E}(\bar{X}_i' \Omega^{-1} \bar{X}_i)] = 1$): assume that $\mathbb{E}(\epsilon_i \epsilon_i' | x_i, p_i) = \Lambda$ (TxT), denote $\Omega \equiv \mathbb{E}(\bar{\epsilon}_i \bar{\epsilon}_i')$, $\hat{\epsilon}_i = \bar{y}_i - \bar{X}_i \hat{\beta}_{FE}$. We have $\hat{\Omega} = N^{-1} \sum_{i=1}^N \hat{\epsilon}_i \hat{\epsilon}_i'$ and therefore: $\beta_{FEGLS} = (\sum_{i=1}^n \bar{X}_i' \hat{\Omega}^{-1} \bar{X}_i)^{-1} (\sum_{i=1}^n \bar{X}_i' \hat{\Omega}^{-1} \bar{Y}_i)$ and $\hat{\text{Avar}} = (\sum_{i=1}^n \bar{X}_i' \hat{\Omega}^{-1} \bar{X}_i)^{-1}$.