Green bonds & climate change: Do green bonds help the environment?

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Motivation

- Decarbonization requires huge investments (USD 131 trillion by 2050, estimated)
- Green bonds are issued to finance projects with positive environmental impact.
- Green bond issuance was more than USD 500 billion in 2021 and is projected to surpass USD 1 trillion in 2023.
- The green bond market can certainly contribute a lot to financing decarbonization, but there is little evidence on how well it allocates capital.

⇨How effectively does the green bond market channel funds? How much impact do green bonds make?

⇨How the size of green bond issue volumes affects the carbon emissions?

⇨ How much impact do green bonds make in firms that are financially constrained or that have an above-average credit risk?

Research purpose

- We investigate cross-sectional differences in the association between the *size* of green bond issue volumes and ***carbon reductions***.

- Further, we examine a cross-sectional hypothesis consistent with impact:

  - Do firms with *financing difficulties* show a stronger association between the green bond issuance and carbon reductions?

Direct and Indirect effects of projects funded by green bonds proceeds to reduce carbon.

- **Better access to bond financing**

- **Signaling or internal commitment device**

Literature

- Average yield advantage (“greenium”) of green bonds is below 5 BP (Flammer, 2021; Zerbib 2019)
- After first green bond issuance, firms have lower CO_2 emissions (Flammer, 2021; Fatica and Panzica, 2021). Flammer favors a signalling effect over direct effect:

  “…results need not imply a causal effect of green bonds on environmental performance. In fact, the green bonds themselves are likely too small to bring about significant improvements at the firm level”

- Green bond issuers are more financially constrained than other firms (Glavas, 2022).
- Survey evidence indicates that green bond issue activity helps strengthen internal commitment to climate action (Sangiorgi and Schopohl, 2021).

=> Literature focuses on effects of issuance (yes/no). Whether issue volumes and firm financial conditions make a difference is not investigated.

Data sources

- ***Bond data***
  - Green bond universe compiled with lists from: Climate Bonds Initiative, Environmental Finance Bond Database, Refinitiv.
  - Additional bond specific data from Eikon and Datastream (Refinitiv).

- ***Issuer data***
  - We examine listed firms and exclude financial firms
  - Company data for bond issuers from Datastream
  - Matching of bond issuers to listed companies is performed manually
  - If a bond issuer does not have listed equity, we check whether the parent company that Eikon states for the bond issuer has public equity

- Control firms are firms with environmental data from Refinitiv (Asset4 database)

Variables

- We construct a yearly panel based on fiscal years
  - Example: a firm with fiscal year end September issued a green bond in October 2019. The green bond will be allocated to fiscal year 2020.
- ***Environmental performance*** is measured as estimated Scope 1 and Scope 2 greenhouse gas emissions, in metric tons of CO2 equivalents.
- CO2 emissions (in tons) are scaled by firm revenues (in million USD).
- All variables defined as a ratio are winsorized at the 2.5% and 97.5% levels by year.

Variables

- To capture green ***bond issuance activity*** dummy variables are used:
  - $GreenBond_{i,t}$ takes the value one if firm i has issued a green bond by year t, and zero otherwise.
  - $FirstGreenBond_{i,t}$ takes the value one if firm i issued its first green bond in year t.
- To capture effects related to green ***bond issuance's purpose***:
  - These dummies are also defined using only climate-related green bond issues (e.g., $ClimateGreenBond_{i,t}$)
- To capture the ***Magnitude of a firm's green bond financing***
  - $OutVolume_{i,t}$ is the volume of a firm's green bonds outstanding at the end of year t, scaled by the firm's revenue in year t.
  - $HighOutVolume_{i,t}$ is a dummy variable that takes the value one if $OutVolume_{i,t}$ is above the median $OutVolume$ of the issuers that in the respective year have a non-zero outstanding green bond volume.

Regression specification

$$CarbonIntensity_{i,t} = \alpha_i + \alpha_{c(i)} \times \alpha_t + \alpha_{s(i)} \times \alpha_t + \beta' x_{i,t-k} + \gamma' z_{i,t-l} + u_{it}$$

- $x_{i,t-k}$ is a vector of variables related to green bond issues of firm i, and $z_{i,t-l}$ is a vector of firm-specific control variables.
- The regression includes firm fixed effects α_i, country-year fixed effects $\alpha_{c(i)} \times \alpha_t$, and industry-year fixed effects $\alpha_{s(i)} \times \alpha_t$.
- We estimate standard errors that are robust to clustering on the two-digit SIC level.
- We use difference-in-difference specification.
- For each firm that has issued a green bond, apply a matched control firm approach

Matching approach

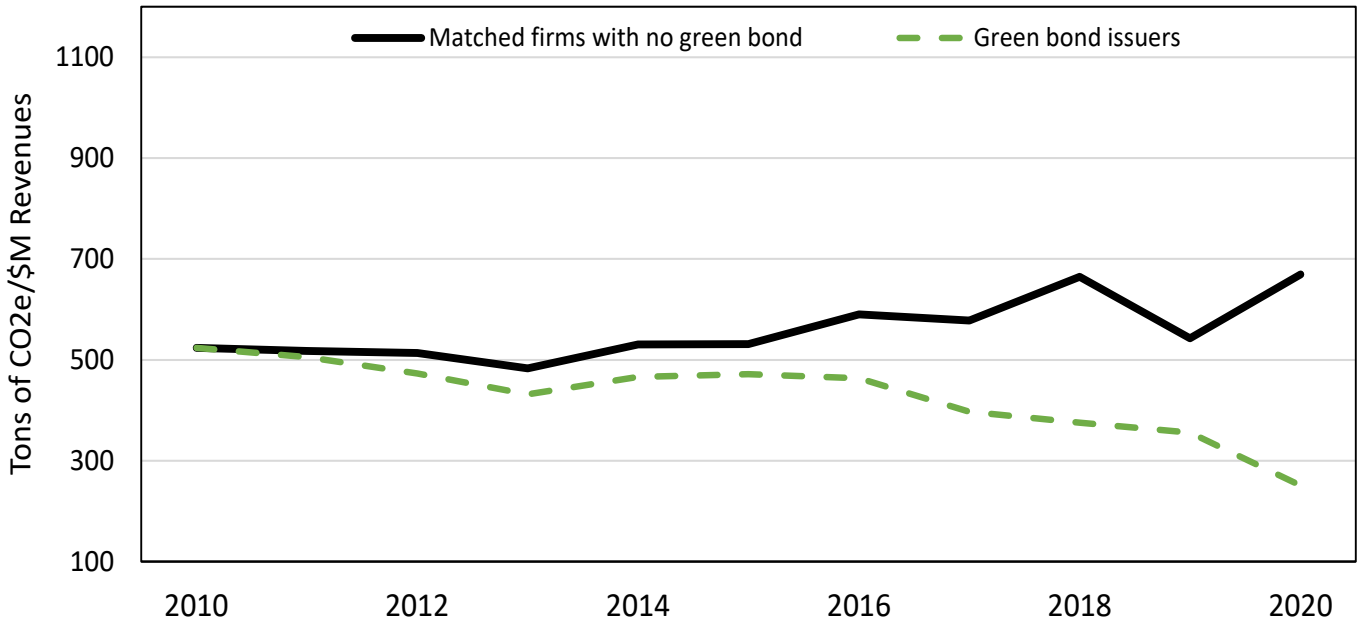
- Firm years from 2010–2020
- Green bond issuers are matched with control firms with no green bond issues
- Closest-neighbour matching is done with the following variables, taken from the year before the first green bond issuance:

  $Leverage$, ROA, $Size$, $TobinQ$, the three components of the Refinitiv ESG rating
- In a second round, to increase the number of matches, we determine neighbors for firms that remained without a neighbor after the first round, using only the four characteristics $Leverage$, $Size$, ROA, $TobinQ$ as well as their one-year changes.

Quality of matching approach

		Obs.	Mean	Median	St.dev.	p-value (diff. in means)	p-value (diff. in medians)
Panel A: Variables used for matching							
Size	Green bond issuers	163	16.787	16.786	1.319	0.000	0.000
	Matched control	163	16.201	16.058	1.433		
TobinQ	Green bond issuers	163	1.462	1.206	0.861	0.396	0.155
	Matched control	163	1.385	1.197	0.787		
ROA	Green bond issuers	163	5.851	4.710	5.595	0.182	0.262
	Matched control	163	5.053	4.190	5.158		
Leverage	Green bond issuers	163	0.337	0.332	0.149	0.671	0.733
	Matched control	163	0.329	0.319	0.160		
SoScore	Green bond issuers	157	65.251	68.940	21.185	0.001	0.000
	Matched control	157	57.412	60.440	22.163		
CGScore	Green bond issuers	157	60.425	63.430	20.495	0.010	0.002
	Matched control	157	54.302	54.080	21.389		
EnScore	Green bond issuers	157	65.307	70.210	22.972	0.005	0.001
	Matched control	157	57.377	58.420	26.351		
dSize	Green bond issuers	163	0.071	0.051	0.159	0.264	0.125
	Matched control	163	0.052	0.032	0.140		
dTobinQ	Green bond issuers	163	-0.004	-0.004	0.254	0.990	0.541
	Matched control	163	-0.005	0.002	0.243		
dROA	Green bond issuers	163	0.368	-0.020	4.453	0.059	0.183
	Matched control	163	-0.482	-0.080	3.597		
dLeverage	Green bond issuers	163	0.004	0.005	0.045	0.983	0.974
	Matched control	163	0.004	0.001	0.032		
dSoScore	Green bond issuers	149	1.995	0.340	7.511	0.975	0.545
	Matched control	149	1.970	0.310	6.141		
dCGScore	Green bond issuers	149	0.090	-0.430	9.580	0.224	0.114
	Matched control	149	1.461	1.270	9.824		
dEnScore	Green bond issuers	149	2.229	0.940	6.821	0.376	0.380
	Matched control	149	1.553	0.340	6.332		
Panel B: Carbon intensity at time of matching							
CarbonIntensity	Green bond issuers	147	780.54	80.56	1622.87	0.983	0.446
	Matched control	147	784.77	96.27	1717.58		

Carbon intensity of green bond issuers and of matched firms with no green bonds over time



Green bond issues of publicly listed non-financial corporates with carbon emission data—by year of issuance

	No. of green bond issues		No. of green bond issuers		Issue amount (billions of $)	
Year	All	of which climate-related	All	with climate-related issues	All	of which climate-related
2012	1	0	1	0	0.65	0.00
2013	2	2	2	2	1.91	1.91
2014	15	14	10	9	8.30	7.62
2015	14	13	9	9	7.24	6.67
2016	14	12	10	9	9.39	8.95
2017	48	33	28	23	21.13	15.23
2018	46	27	35	23	15.67	13.44
2019	108	66	68	48	47.31	33.84
2020	108	58	61	40	50.71	29.01
Total	356	225			162.30	116.67

Green bond issues of publicly listed non-financial corporates with carbon emission data—by country

Issuer domicile	No. of green bond issues: All	No. of green bond issues: climate-related	No. of green bond issuers: All	No. of green bond issuers: with climate-related issues	Issue amount (billions of $): All	Issue amount (billions of $): climate-related
Argentina	2	0	1	0	1.00	0.00
Australia	1	1	1	1	0.28	0.28
Austria	1	1	1	1	0.63	0.63
Brazil	11	7	6	6	4.29	2.53
Canada	2	2	2	2	0.40	0.40
Chile	3	1	2	1	0.45	0.45
China	12	9	6	4	2.69	2.36
Denmark	4	4	2	2	2.66	2.66
Finland	5	2	2	2	2.14	1.50
France	30	17	12	7	25.57	16.53
Germany	20	11	11	9	13.54	7.91
Greece	4	3	2	1	1.32	1.16
Hong Kong	28	12	9	9	6.48	3.60
India	5	5	2	2	2.02	2.02
Italy	21	18	8	8	13.99	12.07
Japan	26	12	20	10	3.49	1.14
Mexico	1	0	1	0	0.71	0.00
Netherlands	4	2	2	1	2.27	1.10
New Zealand	6	4	2	1	0.54	0.36
Norway	3	1	3	1	0.50	0.22
Philippines	1	0	1	0	0.50	0.00
Portugal	7	6	1	1	5.84	4.99
Singapore	6	2	1	1	0.84	0.26
South Korea	12	5	4	3	5.99	2.35
Spain	41	32	7	7	18.55	17.79
Sweden	20	8	10	6	2.82	1.52
Switzerland	3	2	3	2	2.93	0.74
Taiwan	6	5	4	3	0.89	0.82
UK	9	6	5	4	3.90	3.32
United States	62	47	28	22	35.07	27.94
Total	356	225	159	117	162.30	116.67

Descriptive statistics for the annual green bond issue volume per ton of issuer CO2 emissions

	N	Median	75% Quantile
Annual green bond issue volume per ton of CO2 emissions	280	399.6	4,668.0
Annual climate related green bond issue volume per ton of CO2 emissions	202	374.8	3,839.0

	Capital investment needed to save one ton of CO2 per year	CO2 Savings = issue volume / capital investment needed **(Median of Climate - related)**	CO2 savings = issue volume / capital investment needed **(75% quantile of Climate - related)**
Onshore wind energy	USD 484.8	374.8 / 484.8 = 77%	3,839/ 484.8 = 800%
Utility scale solar	USD 1035.2	374.8 / 1035.2= **36%**	3,839/ 1035.2 = 370%
Rooftop solar	USD 3955.6	374.8 / 3955.6 = 9%	3,839/ 3955.6= **97%**

Summary statistics for regression variables

	N	Mean	Median	Std.
Panel A: Both green bond issuers and matched control firms				
$CarbonIntensity_{i,t}$	3,055	719.200	78.10	1,5
$GreenBond_{i,t}$	3,055	0.041	0.00	
$OutVolume_{i,t-2}$	3,055	2.340	0.00	
$ClimateOutVolume_{i,t-2}$	3,055	1.414	0.00	
$HighOutVolume_{i,t-2}$	3,055	0.021	0.00	
$HighClimateOutVolume_{i,t-2}$	3,055	0.017	0.00	
Panel B: Green bond issuers only				
$CarbonIntensity_{i,t}$	1,333	792.000	97.17	1,6
$GreenBond_{i,t}$	1,333	0.093	0.00	
$OutVolume_{i,t-2}$	1,333	5.362	0.00	
$ClimateOutVolume_{i,t-2}$	1,333	3.241	0.00	
$HighOutVolume_{i,t-2}$	1,333	0.048	0.00	
$HighClimateOutVolume_{i,t-2}$	1,333	0.038	0.00	
Panel C: Matched control firms only				
$CarbonIntensity_{i,t}$	1,722	662.900	71.34	1,5
$GreenBond_{i,t}$	1,722	0.000	0.00	
$OutVolume_{i,t-2}$	1,722	0.000	0.00	
$ClimateOutVolume_{i,t-2}$	1,722	0.000	0.00	
$HighOutVolume_{i,t-2}$	1,722	0.000	0.00	
$HighClimateOutVolume_{i,t-2}$	1,722	0.000	0.00	

Green bond issuance and carbon intensity

	Dependent Variable: $CarbonIntensity_{it}$				
	(1)	(2)	(3)	(4)	(5)
$GreenBond_{i,t}$	-100.62**				
	(41.32)				
$FirstGreenBond_{i,t}$		-2.78			
		(79.82)			
$FirstGreenBond_{i,t-1}$		-153.27	-152.47		
		(122.29)	(137.27)		
$GreenBond_{i,t-2}$		-263.85***	-262.98**	-220.16***	
		(94.96)	(111.48)	(79.33)	
$ClimateGreenBond_{i,t-2}$					-238.11**
					(97.64)
Firm Controls	YES	YES	YES	YES	YES
Company FE	YES	YES	YES	YES	YES
CountryYear FE	YES	YES	YES	YES	YES
IndustryYear FE	YES	YES	YES	YES	YES
Observations	3,055	3,055	3,055	3,055	3,055
R-squared	0.95	0.95	0.95	0.95	0.95

Green bond issue volumes and future carbon intensity

	Dependent variable: $CarbonIntensity_{it}$				
	(1)	(2)	(3)	(4)	(5)
$GreenBond_{i,t-2}$	-97.60	-143.11**	-104.70	-130.85*	
	(60.34)	(69.56)	(64.28)	(73.71)	
$ClimateGreenBond_{i,t-2}$					-92.98
					(90.16)
$OutVolume_{i,t-2}$	-2.38***				
	(0.35)				
$ClimateOutVolume_{i,t-2}$			-3.61***		-3.67***
			(0.59)		(0.68)
$HighOutVolume_{i,t-2}$		-169.00***			
		(52.38)			
$HighClimateOutVolume_{i,t-2}$				-233.96***	
				(48.19)	
Firm Controls	YES	YES	YES	YES	YES
Company FE	YES	YES	YES	YES	YES
CountryYear FE	YES	YES	YES	YES	YES
IndustryYear FE	YES	YES	YES	YES	YES
Observations	3,055	3,055	3,055	3,055	3,055
R-squared	0.95	0.95	0.95	0.95	0.95

Cross-sectional hypotheses related to financing difficulties

- We define indicators taking the value 1 if
  - the **credit risk** (measured by Altman's Z-score) of a green bond issuer is above the cross-sectional median of green bond issuers, or
  - the Kaplan Zingales (KZ) index of **financial constraints** is above is above the cross-sectional median of green bond issuers
  - The SA index of Hadlock and Pierce (2010) for **financial constraints.**
  - Refinitiv corporate governance score to sort firms according to the quality of **corporate governance.**
- then we interact the green bond variables with these indicators

Cross-sectional differences in the relationship between green bond issue volumes and future carbon intensity

	Split according to			
	KZ index	SA index	Z score	*CGScore*
	(1)	(2)	(3)	(4)
$GreenBond_{i,t-2}$	-72.60**	-71.54	-34.62	-95.25
	(26.27)	(55.50)	(24.47)	(61.27)
$OutVolume_{i,t-2} \times (HighKZ\_Index_{i,t-2} = 1)$	-2.41***			
	(0.55)			
$OutVolume_{i,t-2} \times (HighKZ\_Index_{i,t-2} = 0)$	2.55***			
	(0.46)			
$OutVolume_{i,t-2} \times (HighSA\_Index_{i,t-2} = 1)$		-5.32**		
		(2.01)		
$OutVolume_{i,t-2} \times (HighSA\_Index_{i,t-2} = 0)$		-0.75		
		(0.49)		
$OutVolume_{i,t-2} \times (HighZ\_Score_{i,t-2} = 1)$			1.05**	
			(0.39)	
$OutVolume_{i,t-2} \times (HighZ\_Score_{i,t-2} = 0)$			-3.10***	
			(0.81)	
$OutVolume_{i,t-2} \times (HighCGScore_{i,t-2} = 1)$				-2.87***
				(0.47)
$OutVolume_{i,t-2} \times (HighCGScore_{i,t-2} = 0)$				-1.80***
				(0.53)
$HighKZ\_Index_{i,t-2}$	45.45			
	(48.64)			
		47.84**		
		(18.40)		
$HighZ\_Score_{i,t-2}$			-39.58	
			(43.13)	
$HighCGScore_{i,t-2}$				26.84
				(26.49)
Firm Controls	YES	YES	YES	YES
Company FE	YES	YES	YES	YES
CountryYear FE	YES	YES	YES	YES
IndustryYear FE	YES	YES	YES	YES
p(H_0: coefficients for *OutVolume* variables are identical)	<0.001	0.038	0.001	0.138
Observations	2,271	3,051	2,235	3,054
R-squared	0.96	0.95	0.96	0.95

Variations of regressions examining the relationship green bond issuance and future environmental performance

	Winsorize at		Use Jackknife for stand. errors	Use first lag of *OutVolume*	Include all firms	No firm controls	Use only reported CO2	Use total assets for scaling	Use ENSCORE as dep. var
	1% and 99%	5% and 95%							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$GreenBond_{i,t-2}$	-153.01*	-79.01**	-111.3***	-86.42*	-10.94	-103.46**	-72.57	-62.06	-4.62
	(78.57)	(35.12)	(40.75)	(47.97)	(31.98)	(49.05)	(64.78)	(42.72)	(2.88)
$OutVolume_{i,t-2}$	-4.53**	-1.86**	-2.01***		-1.75***	-2.33***	-1.32**	-2.27***	0.04***
	(1.65)	(0.70)	(0.41)		(0.65)	(0.64)	(0.49)	(0.70)	(0.01)
$OutVolume_{i,t-1}$				-2.49***					
				(0.83)					
Firm Controls	YES	YES	YES	YES	YES	NO	YES	YES	YES
Company FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
CountryYear FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
IndustryYear FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
Observations	3,055	3,055	-	3,055	36,891	3,309	2,404	3,055	3,055
R-squared	0.94	0.96	-	0.95	0.90	0.94	0.96	0.94	0.92

Variations of regressions examining the relationship green bond issuance and future environmental performance

- Green bonds certification effect

$$CarbonIntensity_{i,t} = \underset{(61.15)}{-57.88\ CertGreenBond_{i,t-2}} \underset{(1.27)}{-3.35\ CertOutVolume_{i,t-2}} + \text{fixed effects and controls}$$

- Bond liquidity effect

We define two variables to proxy for issuance of highly liquid bonds and capture issue size, and add them to base regressions. The coefficients of outvolume remains significantly negative, while the coefficients of the two variables are positive and insignificant.

This mitigates potential concerns that results obtained related to green bons volume go back to liquidity effect.

Summary and conclusion

- As in prior literature, we document larger CO2 reductions after green bond issuance
- Issue volumes are also related to future carbon reductions,
  - ➢ Higher green bond issue volumes predict future carbon reductions of non-financial corporates.
- Association between green bond issue volume and carbon reductions is limited to firms with a higher credit risk or higher financial constraints.

  => Evidence consistent with green bonds enabling firms to reduce CO2 emissions

⇒ Evidence consistent with additional dollars making a difference for CO2 emissions
⇒ But: no significant evidence for firms without financing difficulties

Thank you!

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