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# Climate Change Risk and Green Bond Pricing

# Is climate change correctly priced in financial markets?



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## Research questions:

- Do financial markets react to the occurrence of extreme climate-related events?
- Do behavioral mechanisms lead investors to misestimate climate risk after such events?
- Major issue: Measuring asset exposure to climate risk

- What financial market?
  - **Bond market:** ideal setting where to test the effects of environmental concerns on asset prices due to the presence of **green bonds**, i.e. securities financing climate-related projects.
  - **Hypothesis:** Green bonds are better hedges against climate change risk (Pástor et al., 2021). Adverse climate shocks should increase investor preference for green bonds
  - **Implication:** diverging price reactions of green and brown bonds to unexpected climate-related event
- What proxy for climate-related events?
  - **Natural disasters**
  - Exogenous to bond characteristics and prices

Investigate the price reactions of green and brown bonds to climate-related events

As green bonds are less exposed to climate risks, investors' preference for green assets increases after disasters

- This increases investors' willingness to pay (and decreases bond's yield) for green bonds
- **Main Hypothesis:**
  - Green bond yields **decrease** relative to brown bond yields post-disaster
  - The effect is stronger with increasing disaster **severity**, i.e. the actual intensity of a disaster's impact

- **Green and brown bonds: Refinitiv**
  - population of bonds issued worldwide from 2015 to 2021 along with bond and issuer characteristics
  - Use green and brown bonds from the same country and, when possible, same issuer
  - Focus on secondary market data to avoid selection bias in primary market data
  - Secondary market price and liquidity data (monthly) from bond issuance till 2022 year end
- **Bond variables**
  - **Yield:** annualized yield to maturity

- **Natural disasters: Emergency Events Database (EM-DAT)**
  - Maintained by the Centre for Research on the Epidemiology of Disasters (CRED) at Université Catholique de Louvain (Belgium)
  - Information on disaster type, date of occurrence, number of affected people
  - We consider disasters occurring globally and belonging to one of the following categories
    - Meteorological (e.g., tropical cyclone)
    - Hydrological (e.g., flood)
    - Climatological (e.g., drought)
  
- **Disaster-related variables**
  - **Affected population** (continuous): percentage of population hit by a disaster in a given month in the bond's country of issue
  - **Large-scale disaster** (dummy): equals 1 in months when a large-scale disaster occurs
    - Large-scale = top 1% of the disaster distribution in terms of number of affected people (Cavallo et al., 2013)

# Sample distribution: bonds



	Brown bonds		Green bonds		Total	
	No.	%	No.	%	No.	%
2015	165,537	8.5	481	1.8	166,018	8.4
2016	191,741	9.8	974	3.7	192,715	9.8
2017	208,497	10.7	1,456	5.5	209,953	10.6
2018	243,727	12.5	2,093	7.9	245,820	12.5
2019	260,566	13.4	2,978	11.3	263,544	13.4
2020	277,050	14.2	4,276	16.2	281,326	14.3
2021	299,233	15.4	6,138	23.3	305,371	15.5
2022	300,266	15.4	7,961	30.2	308,227	15.6
Total	1,946,617	98.7	26,357	1.3	1,972,974	100.0

# Sample distribution: disasters



Panel A. Year	Disasters (no.)	Affected people (% pop., average)	Large-scale disasters (no.)
2015	27	0.004	0
2016	22	1.217	1
2017	29	0.025	0
2018	26	0.071	1
2019	34	0.017	0
2020	27	0.019	0
2021	67	0.020	1
2022	46	0.036	0
Panel B. Disaster type			
Climatological	48	0.025	0
Wildfire	48	0.025	0
Hydrological	96	0.041	2
Flood	90	0.044	2
Landslide	6	0.004	0
Meteorological	134	0.212	1
Extreme temperature	5	0.020	0
Storm	129	0.219	1
Total	278	0.207	3



# Descriptive statistics



	Brown bonds			Green bonds			Difference	
	Mean	Median	N	Mean	Median	N	brown - green	
Yield (%)	3.21	2.55	1,946,617	2.37	1.97	26,357	0.84***	0.59***
Issue amount (\$m)	1,591.5	477.0	47,715	646.8	500.0	761	1,002.3***	-23.0
Maturity (years)	9.07	7.01	47,715	9.46	7.50	761	-0.39	-0.49*
Putable (% bonds)	0.11	-	47,715	0.00	-	761	0.11	-
Callable (% bonds)	46.17	-	47,715	38.37	-	761	7.80***	-
Guaranteed (% bonds)	22.16	-	47,715	19.45	-	761	2.71*	-
Secured (% bonds)	13.38	-	47,715	14.98	-	761	-1.60	-
Senior (% bonds)	77.59	-	47,715	94.35	-	761	-16.76***	-



## Testing Main HP

Price reactions of green and brown bonds in the aftermath of a disaster

- Model specification 1:

$$\begin{aligned} &Yield_{i,t+1} \\ = &\alpha + \beta_1 \mathbf{Green}_i \times \mathbf{Disaster}_{i,t} + \beta_2 \mathbf{Disaster}_{i,t} + \beta' \mathbf{Controls}_i + \mathbf{Month}_t + \mathbf{Issuer}_i \\ &+ \mathbf{Issue\_year}_i + \mathbf{Currency}_i + \varepsilon_{i,t} \end{aligned}$$

- Model specification 2:

$$Yield_{i,t+1} = \alpha + \beta_1 \mathbf{Green}_i \times \mathbf{Disaster}_{i,t} + \mathbf{Month}_t + \mathbf{Bond}_i + \varepsilon_{i,t}$$

$$\beta_1 \mathbf{Green}_i \times \mathbf{Disaster}_{i,t}$$

captures the differences in the post-disaster behavior of green bond yields relative to brown bonds

# Natural disasters and bond yields (1)



	Affected people		Large-scale disaster	
	(1)	(2)	(3)	(4)
Green x Disaster	-0.0256*** [0.0063]	-0.0267*** [0.0056]	-0.6038*** [0.1539]	-0.6280*** [0.1358]
Disaster	0.0245*** [0.0038]	0.0270*** [0.0031]	0.4085*** [0.0920]	0.4617*** [0.0822]
Green	-0.0685*** [0.0224]		-0.0684*** [0.0224]	
Ln(Issue amount)	-0.0387* [0.0198]		-0.0389** [0.0198]	
Ln(Maturity)	1.0421*** [0.0261]		1.0421*** [0.0261]	
Puttable	-1.8117*** [0.5841]		-1.8117*** [0.5841]	
Callable	0.1655*** [0.0269]		0.1650*** [0.0270]	
Guaranteed	-0.0325 [0.0625]		-0.0325 [0.0625]	
Secured	-0.7078*** [0.0944]		-0.7080*** [0.0944]	
Senior	-0.1694*** [0.0442]		-0.1685*** [0.0442]	
Bond FE	No	Yes	No	Yes
Year-Month FE	Yes	Yes	Yes	Yes
Issuer FE	Yes	No	Yes	No
Bond issue year FE	Yes	No	Yes	No
Bond currency FE	Yes	No	Yes	No
Adjusted R-squared	0.7896	0.8305	0.7896	0.8305
Observations	1,972,974	1,972,974	1,972,974	1,972,974

- Green bond yields exhibit a **decrease** relative to those of brown bonds after a natural disaster
  - The magnitude of this effect **increases with disaster severity**
    - decrease in green bond yields relative to brown bond yields
      - 2.6-2.7 basis points for a one percentage point increase in affected population
      - 60-63 basis points after the occurrence of a large-scale disaster
- ➔ Main HP is empirically supported

# Does the demand for green bonds increase after a natural disaster?



Dependent variable:  
Bid-ask spread

	Affected people		Large-scale disaster	
	(1)	(2)	(3)	(4)
Green x Disaster	-0.0032*** [0.0009]	-0.0022*** [0.0004]	-0.0796*** [0.0245]	-0.0442*** [0.0114]
Disaster	0.0029*** [0.0005]	0.0015*** [0.0004]	0.0514*** [0.0119]	0.0121 [0.0105]
Controls	Yes	No	Yes	No
Bond FE	No	Yes	No	Yes
Year-Month FE	Yes	Yes	Yes	Yes
Issuer FE	Yes	No	Yes	No
Bond issue year FE	Yes	No	Yes	No
Bond currency FE	Yes	No	Yes	No
Adjusted R-squared	0.6031	0.7526	0.6031	0.7526
Observations	1,972,974	1,972,974	1,972,974	1,972,974

Green bonds exhibit a decrease in bid-ask spread relative to brown bonds after a natural disaster → stronger demand experienced by green bonds

# Is the relative decrease in green bond yields more pronounced for “greener” bonds?



Dependent variable:  
% annualized YTM

	Affected people		Large-scale disaster	
	(1)	(2)	(3)	(4)
Green x Disaster x E score	-0.0029*** [0.0008]	-0.0021*** [0.0007]	-0.0691*** [0.0228]	-0.0528*** [0.0185]
Green x Disaster	0.2393*** [0.0692]	0.1717*** [0.0591]	5.6052*** [2.0311]	4.2985*** [1.6534]
Disaster x E score	-0.0004*** [0.0001]	-0.0003*** [0.0001]	-0.0113*** [0.0034]	-0.0087*** [0.0030]
Green x E score	0.0021 [0.0036]	0.0069 [0.0055]	0.0021 [0.0036]	0.0069 [0.0055]
E score	0.0006 [0.0016]	0.0015 [0.0017]	0.0006 [0.0016]	0.0015 [0.0017]
Disaster	0.0494*** [0.0084]	0.0410*** [0.0072]	1.0900*** [0.2202]	0.8870*** [0.1913]
Controls	Yes	No	Yes	No
Bond FE	No	Yes	No	Yes
Year-Month FE	Yes	Yes	Yes	Yes
Issuer FE	Yes	No	Yes	No
Bond issue year FE	Yes	No	Yes	No
Bond currency FE	Yes	No	Yes	No
Adjusted R-squared	0.7561	0.8141	0.7561	0.8141
Observations	518,869	518,869	518,869	518,869

The relative decrease in green bond yields in the aftermath of a disaster is larger for issuers with a better environmental score

- Immediate Aftermath of Natural Disasters
  - Green Bonds: Decrease in yields relative to brown bonds
  - Effect Magnitude: Larger after more severe disasters
  - Demand for Green Bonds: Rises immediately post-disaster
- Mechanisms Behind Price Reactions
  - Rational vs. Behavioral Mechanisms
  - Yield Spread: Widening does not revert to pre-disaster levels entirely
  - Temporary Component: Part of the spread diminishes after a few months
  - Behavioral Effect: Weaker price impact with repetitive disasters