Do carbon emissions affect the cost of capital? Primary versus secondary corporate bond markets

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Background on climate finance

- The corporate sector is the largest source of carbon dioxide (CO_2) and other greenhouse gas emissions (CDP, 2017)
  - IPCC (2021) report: global net carbon emissions must be reduced to zero by 2050 in order to limit climate change
  - Global regulation would be needed to align corporate interest to the common good but it is hard to achieve and absent at this time
- Financial markets can provide firms with incentives to decrease emissions
  - Divestment or boycotts by investors can affect asset prices and the cost of capital
  - For theoretical analyses, see Henkel, Kraus and Zechner (2001), Pastor, Stambaugh and Taylor (2021), Gollier and Pouget (2022), Zerbib (2022), Broccardo, Hart, Zingales (2022), Avramov, Lioui, Liu, Tarelli (2022)
- Review papers on climate finance: Hong, Karolyi, Scheinkman (2020) and Giglio, Kelly, Stroebel (2021)

Our investigation

- Study carbon premium on primary and secondary bond markets
  - Carbon premium = Lower yields/returns for green than for brown firms
    - Green = low CO2 emissions
  - Carbon premium observed on secondary equity market... but debated
    - See, e.g., Bolton and Kacperczyk (2021, 2023) and, for more nuanced results, Aswani, Raghunandan and Rajgopal (2023) and Zhang (2022)
    - One issue is the difficulty to estimate expected returns from realized returns
  - Carbon premium observed on primary bond market... but fragile?
    - See Seltzer, Starks and Zhu (2022) on climate regulatory risk being reflected in corporate bond spreads
- Different carbon premium on primary and secondary bond markets?

Motivation

- Do green firms fully benefit from the bond carbon premium?
  - Firms' cost of capital is directly influenced by primary markets
- Bond primary market and its aftermath involve financial institutions, acting as intermediaries between firms and final investors
  - Dealers (underwriters and non-underwriters) and flipping investors (e.g., insurance companies)
- Do intermediaries pocket in part of the carbon premium?
  - Underwriters and flipping investors buy bonds from firms on the primary market and sell them to non-underwriters and final investors on the secondary market
  - Non-underwriters sell bonds to final investors on the secondary market

Focus on US corporate bond market

- Bonds are an important source of financing for firms
  - US bond issuance in 2022: $1,356 billion
    (vs $160 billion for US equity markets, source: www.sifma.org)
- Interesting test-bed
  - Easier to estimate expected (buy-and-hold) returns
  - Compare primary and secondary market outcomes for a given firm at a given time

Hypotheses from a simple model

- A priori, it is not clear whether the carbon premium should be larger or smaller on the primary than on the secondary market
- (H0) The carbon premium is the same on both markets
  - When there is **no uncertainty** about investors' green preferences and **perfect competition** among underwriters
  - Even if intermediaries have no green preferences
  - Green preferences understood in a general way to incorporate tastes and beliefs about climate change
- (H1) Higher carbon premium on the primary market
  - When **intermediaries have greener preferences** than investors
- (H1') Lower carbon premium on the primary market
  - When there is **uncertainty** about investors' green preferences or **imperfect competition** among underwriters

Other related literature

- Corporate bond market microstructure
  - Cai, Helwege, Warga (2007), Dick-Nielsen, Feldhutter, Lando (2012), Bao, O'Hara, Zhou (2018), Bessembinder, Jacobsen, Maxwell, Venkataraman (2018), Dick-Nielsen and Rossi (2019), Hendershott, Li, Livdan, Schürhoff (2020), Nikolova and Wang (2021), Nagler and Ottonello (2021), Helwege and Wang (2021), Goldstein, Hotchkiss, Nikolova (2021)
  - We focus on the carbon premium
- Green bonds
  - Zerbib (2019), Tang and Zhang (2020), Flammer (2021), Baker, Bergstresser, Serafeim, Wurgler (2018), Daubanes, Mitali, Rochet (2021), Pastor, Stambaugh, Taylor (2022)
  - We focus on bonds issued by green and brown firms
- Bonds and ESG factors
  - Jiraporn, Jiraporn, Boeprasert and Chang (2014), Amiraslani, Lins, Servaes and Tamayo (2017), Painter (2020), Garrett and Ivanov (2022), Margaretic and Pouget (2018) and Capelle-Blancard, Crifo, Diaye, Oueghlissi and Scholtens (2019), Eichholtz, Holtermans, Kok and Yönder (2019)
  - We compare the carbon premium on primary and secondary markets

Preview of the main results

- Carbon premium is lower on primary than on secondary bond markets
- Our estimates suggest intermediaries pocket in around 85% of the carbon premium
- Two equally important channels
  - Uncertainty regarding investors' green preference
  - Lack of competition among underwriting dealers
- Implications for firms' greening incentives via cost of capital

Identification strategy (1)

- Our main variable of interest: difference in carbon premium between the primary and secondary market
  - Carbon premium: sensitivity of bond spread to CO2 emissions

- Identification challenges
  - Calendar date effects (see, e.g., Ardia, Bluteau, Boudt and Inghelbrecht, 2022, Pastor, Stambaugh, and Taylor, 2022, Seltzer, Starks and Zhu, 2022)
  - Liquidity issues (see, e.g., Lin, Wang, Wu, 2011, Helwege, Huang, Wang, 2014, Helwege and Wang, 2021)
  - Credit risk issues (see, e.g., Helwege and Turner, 1999, Eom, Helwege, Huang, 2004, Teixeira, 2007)

Identification strategy (2)

Compare carbon premium of bonds on primary market to carbon premium of other bonds issued by same firms and trading on secondary market on the same day as issuance, controlling for various bond and firm characteristics, including illiquidity

Figure

Data construction

- Data sources
  - S&P Global Trucost: Scope 1, Scope 2 and Scope 3 (upstream) carbon emissions
  - Mergent FISD: Corporate bond characteritics and issuance price
  - TRACE: bond price data (less than two years after issuance and more than one year before maturity)
  - CRSP/COMPUSTAT: Firm data

- Sample period: 2005-2022

Data filters

- We initially have 666 unique firms and 9,022 unique bonds.
- Sample that our ID works: 355 unique firms and 6,036 bonds
- Remove CO2 emissions that are estimated by the vendor
  - Some CO2 emissions were estimated by data vendor, see Aswani, Raghunandan and Rajgopal (2022)
    - Trucost documents how the reported CO2 emission was derived and there are 32 different types in total
    - We assign 5 different precision levels
    - E.g., "Exact value from CDP" is assigned the most precise level, 5; "Estimate derived from production data" is assigned the most imprecise level, 1
  - We remove level 1 and have 229 unique firms and 3,687 unique bonds Precision level
- Focus on senior bonds (96% of bonds in our sample)
  - Different seniorities: senior secured, senior, senior subordinate, subordinate, junior, and junior subordinate
  - We thus have 229 unique firms and 3,586 unique bonds

Construction of variables

- Primary market spread (or offering spread)
  - Primary market yield − Yield of cash flow matched synthetic treasury bond
- Secondary market spread
  - Secondary market yield − Yield of cash flow matched synthetic treasury bond
- CO2 emission measures
  - Carbon intensity: Emissions/Sales
  - Total carbon emissions: Log(Emissions)
  - Scope 1, Scope 1+2, Scope 1+2+3
- Controls
  - Illiquidity: Amihud (2002) (see also Lin, Wang, Wu, 2011, Dick-Nielsen, Feldhutter, Lando, 2012, Bao, O'Hara, Zhou, 2018)
  - Rating (Moody's): Aaa$\rightarrow$ 21, Aa1$\rightarrow$ 20, Aa2$\rightarrow$ 19, $\cdots$
- We winsorize all the variables at top and bottom 1%

SummaryStatistics

Main Result (1)

- Specification for firm f, bond i and time t

$$Spread_{f,i,t} = \alpha + \beta \cdot CO2_{f,t} + Controls + \epsilon_{f,i,t}$$

  - t corresponds to days
  - $CO2_{f,t}$ is the last outstanding value (previous year)
  - We have 1,638 different days at which bonds were issued
  - Fixed effects: Industry, Year, Month-of-the-year, Day-of-the-week, Lead underwriters

Main Result (2)

	(1)	(2)	(3)	(4)	(5)	(6)
	Scope 1		Scope 1 and 2		Scope 1, 2, and 3	
	Primary	Secondary	Primary	Secondary	Primary	Secondary
CO2	0.00251**	0.0158***	0.00273***	0.0180***	0.00267***	0.0183***
	(2.418)	(6.514)	(2.723)	(7.632)	(2.901)	(8.543)
⋮					⋮	
Observations	2,428	8,525	2,428	8,525	2,428	8,525
R-squared	0.839	0.630	0.839	0.631	0.839	0.631
Industry FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Month FE	YES	YES	YES	YES	YES	YES
DOW FE	YES	YES	YES	YES	YES	YES
LeadUnderwriter1-10 FE	YES	YES	YES	YES	YES	YES

Robust t-statistics in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Coefficients of other variables

Main Result (3)

Test of significance of the difference in sensitivity between secondary and primary market

$$\begin{aligned} Spread_{f,i,t} =& \alpha + \beta_1 \cdot Secondary_{f,i,t} \\ &+ \beta_2 \cdot CO2_{f,t} + \beta_3 \cdot Secondary_{f,i,t} \times CO2_{f,t} \\ &+ Controls + Secondary_{f,i,t} \times Controls \\ &+ FE + Secondary_{f,i,t} \times FE + \epsilon_{f,i,t} \end{aligned}$$

	(1) Scope 1 Primary + Secondary	(2) Scope 1 and 2 Primary + Secondary	(3) Scope 1, 2, and 3 Primary + Secondary
CO2	0.00251	0.00273	0.00267
	(1.024)	(1.153)	(1.230)
CO2 X Secondary	0.0133***	0.0153***	0.0156***
	(4.053)	(4.793)	(5.380)
Observations	10,953	10,953	10,953
R-squared	0.649	0.649	0.650

Main Result (4)

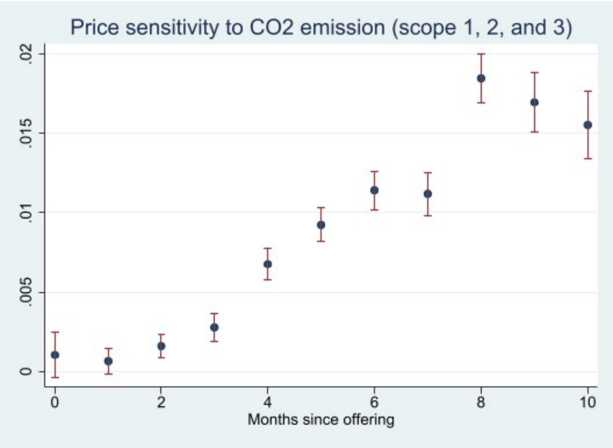
Back-of-the-envelope calculation for economic significance

- Define green (brown) firms as those with CO_2 emissions one standard deviation below (above) the average
- Carbon premium on the primary market
  - Green firms' primary market bond spreads are lower than brown firms' one by 2.4 bp ($= 2 \cdot 0.00267 \cdot 4.662 \cdot 100$)
- Carbon premium on the secondary market
  - Green firms' secondary market bonds are lower than brown firms' one by 17 bp ($= 2 \cdot 0.0183 \cdot 4.662 \cdot 100$)
- The carbon premium is larger by 14.6 bp on the secondary than on the primary market
- To be compared to average bond spreads of 64 bp on the primary market and 74 bp on the secondary markets

1. Introduction
2. Method
3. Main Result
4. **Other analyses and robustness tests**
5. Economic channels
   - A simple model
   - Empirical evidence
6. Conclusion

Time-series analysis (monthly)

$$Spread_{f,i,t} = \alpha + \beta \cdot CO2_{f,t} + Controls + \epsilon_{f,i,t}$$



Other analyses and robustness tests

1. Pooled regression with restriction
2. Interaction with MCCC shock
3. Investment grade bonds
4. Brown industry indicator as main regressor
5. Different subsamples based on time
6. Absolute emissions
7. Liquidity risk
8. More precise definition of CO2
9. Additional lag
10. Winsorization
11. More granular fixed effects
12. Without data filters

Model set up

- Three dates and three types of agents

$t = 1$

- **Firm** issues an asset at price $\widetilde{p_1}$ on the primary market
- Two types of **agents without green preferences**
  - Mass 1- π_1- π_2 of **dealers who liquidate at *t*=2**
  - Mass π_1 of type-1 **investors who hold up to *t*=3**

$t = 2$

- Climate concerns $\tilde{e}$ are realized
- Trading at price $\widetilde{p_2}$ on the secondary market
- Two types of agents
  - **Dealers** who liquidate
  - Mass π_2 of type-2 **investors with green preferences who hold up to *t*=3**

$t = 3$

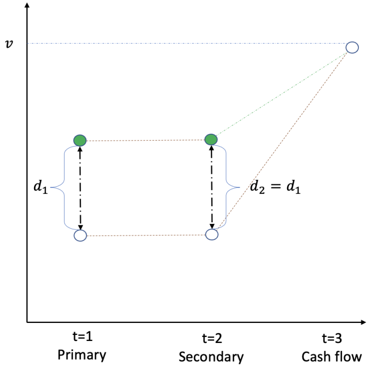
- Asset cash flow $\tilde{v}$ is realized

- $\tilde{e} \sim N(\mu_e, \sigma_e^2)$ and $\tilde{v} \sim N(\mu_v, \sigma_v^2)$
- Agents have CARA parameter A and normally distributed final wealth
  - Dealer: $\tilde{w}_d = q_d(\tilde{p}_2 - \tilde{p}_1)$
  - Type-1 investor: $\tilde{w}_1 = q_1(\tilde{v} - \tilde{p}_1)$
  - Type-2 investor: $\tilde{w}_2 = q_2(\tilde{v} + \tilde{e} - \tilde{p}_2)$

Benchmark case

- Benchmark case corresponds to (H0): carbon premium is identical on primary and secondary market
- Benchmark case:
  - No uncertainty regarding future climate change concerns
  - Competitive dealers
- Intuition: dealers speculate on secondary market prices and thus on future climate concerns which thus affect primary market prices
- Remark: absent dealers, there would be no carbon premium <u>at all</u> on the primary market

Equilibrium: illustration



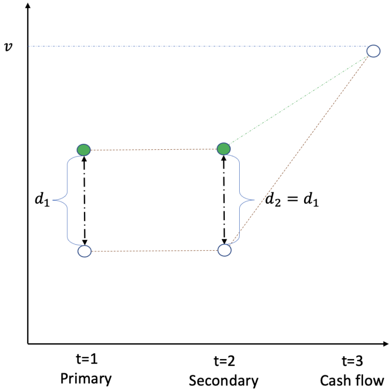
Benchmark: No uncertainty and perfect competition between dealers

Identical carbon premium on primary and secondary market when there is no uncertainty on future climate change concerns and when there is perfect competition among dealers Details

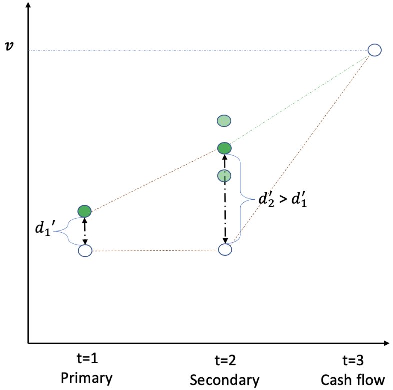
Two Economic Channels

- Two channels can rationalize our main empirical finding that carbon premium is lower on primary market (H1')
- Uncertainty regarding future climate change concerns
  - Intuition: When there is more uncertainty on climate concerns, risk averse dealers are less aggressive and the views of investors without green preferences weigh more in primary market price
- Imperfect competition
  - Intuition: To avoid adverse price impact, a strategic dealer is less aggressive than a competitive one and the views of investors without green preferences weigh more in primary market price
- In both cases, the carbon premium is lower on the primary than on the secondary market

Uncertainty Channel: Illustration



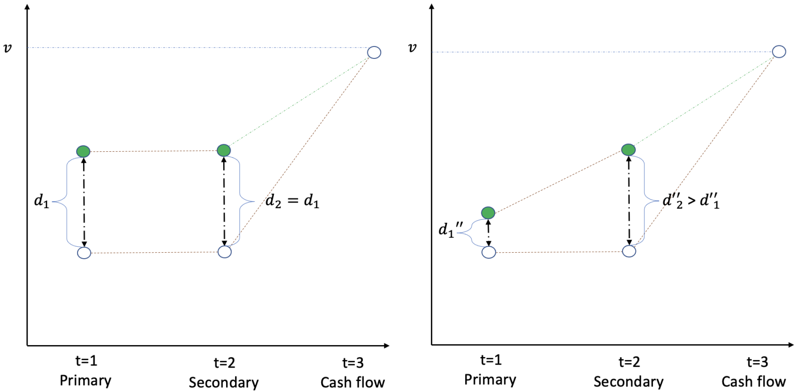
Panel A: Benchmark, no uncertainty and perfect competition between dealers



Panel B: Uncertainty and perfect competition between dealers

Higher difference between secondary and primary market carbon premium when uncertainty on future climate change concerns is higher Details

Competition Channel: Illustration



Panel A: Benchmark, no uncertainty and perfect competition between dealers

Panel B: No uncertainty and imperfect competition between dealers

Higher difference between secondary and primary market carbon premium when competition is lower Details

Uncertainty Channel: Our test

- We construct a dummy variable HV_t to proxy for the uncertainty of future climate concerns at time t
- For this, we use daily MCCC index, see Ardia, Bluteau, Boudt, Inghelbrecht (2022)
- We use ARCH model to estimate the conditional volatility at day t based on all the daily data between $t-1$ and $t-30$
- We set $HV_t = 1$ if the measure is above the median, and $HV_t = 0$, otherwise

Uncertainty Channel: Triple-Interaction results

	(1) Scope 1	(2) Scope 1 and 2	(3) Scope 1,2, and 3
CO2	0.00186	0.00178	0.00221
	(0.524)	(0.522)	(0.704)
HV	-0.0310	-0.0312	-0.0314
	(-0.953)	(-0.961)	(-0.962)
CO2 X Secondary	0.00977**	0.0131***	0.0131***
	(2.069)	(2.895)	(3.156)
CO2 X HV	0.00734	0.00693	0.00464
	(1.293)	(1.286)	(0.970)
HV X Secondary	-0.0517	-0.0510	-0.0487
	(-1.424)	(-1.402)	(-1.334)
CO2 X Secondary X HV	0.0258***	0.0222***	0.0204***
	(3.343)	(3.033)	(3.207)
Observations	8,495	8,495	8,495
R-squared	0.662	0.663	0.664
Bond controls	YES	YES	YES
Firm controls	YES	YES	YES
Bond controls X Secondary	YES	YES	YES
Firm controls X Secondary	YES	YES	YES
Industry FE	YES	YES	YES
Year FE	YES	YES	YES
Month FE	YES	YES	YES
DOW FE	YES	YES	YES
LeadUnderwriter1-10 FE	YES	YES	YES
Industry X Secondary FE	YES	YES	YES
Year X Secondary FE	YES	YES	YES
Month X Secondary FE	YES	YES	YES
DOW X Secondary FE	YES	YES	YES
LeadUnderwriter1-10 X Secondary FE	YES	YES	YES

Robust t-statistics in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Higher difference between secondary and primary market carbon premium when uncertainty on future climate change concerns is

Competition Channel: Our test

- We construct a dummy variable $LC_{f,i,t}$ to proxy for the degree of competition among the underwriters for the bond i that is issued by firm f at time t
- We use the number of lead underwriters because they determine the issuance price
- Bond issues with larger amount offered would mechanically have larger number of lead underwriters
- We thus define $Ratio = \frac{\text{Number of lead underwriters}}{\text{Amount offered}}$
- We set $LC_{f,i,t} = 1$ if the ratio is below the median, and $LC_{f,i,t} = 0$, otherwise

Competition Channel: Triple-Interaction results

	(1) Scope 1	(2) Scope 1 and 2	(3) Scope 1,2, and 3
CO_2	0.00259	0.00269	0.00295
	(0.623)	(0.658)	(0.767)
LC	0.0175	0.0172	0.0178
	(0.351)	(0.342)	(0.346)
CO_2 X Secondary	0.00767	0.00745	0.00788
	(1.395)	(1.382)	(1.560)
CO_2 X LC	0.00334	0.00257	0.00162
	(0.603)	(0.483)	(0.326)
LC X Secondary	0.0548	0.0451	0.0311
	(0.903)	(0.741)	(0.498)
CO_2 X Secondary X LC	0.0213***	0.0251***	0.0232***
	(2.831)	(3.510)	(3.507)
Observations	8,495	8,495	8,495
R-squared	0.661	0.662	0.663
Bond controls	YES	YES	YES
Firm controls	YES	YES	YES
Bond controls X Secondary	YES	YES	YES
Firm controls X Secondary	YES	YES	YES
Industry FE	YES	YES	YES
Year FE	YES	YES	YES
Month FE	YES	YES	YES
DOW FE	YES	YES	YES
LeadUnderwriter1-10 FE	YES	YES	YES
Industry X Secondary FE	YES	YES	YES
Year X Secondary FE	YES	YES	YES
Month X Secondary FE	YES	YES	YES
DOW X Secondary FE	YES	YES	YES
LeadUnderwriter1-10 X Secondary FE	YES	YES	YES

Robust t-statistics in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Higher difference between secondary and primary market carbon premium when competition is low Alternative Definition Two Channels

Summary

- We study the carbon premium in US bond markets
- We find that there is a carbon premium but it is lower on primary than on secondary markets
- Financial intermediaries pocket in 14.6 bp, which is around 85% of the carbon premium
- Due to two equally important microstructure channels
  - Uncertainty regarding investors' climate concerns
  - Lack of competition among lead underwriting dealers

Implications and future research

- Main implications
  - Lower greening incentives than what secondary markets suggest
    - Helps explain the findings of Heath, Macciocchi, Michaely and Ringgenberg (2023) that SRI has little impact on firm environmental behavior
  - Improve market microstructure of corporate bond primary market
  - Green/ESG/impact investors could try and participate more directly in primary bond markets in order to increase their impact on firms' financial incentives to become green
- Future research?
  - Downstream Scope 3 CO2 emissions but data available only for recent period
  - Application to equity markets (SEOs)
  - Other exogenous shocks to better identify the economic channels
  - Structural estimations of green preferences

Additional Analysis

Main Result other variables

	(1)	(2)	(3)	(4)	(5)	(6)
	Scope 1		Scope 1 and 2		Scope 1, 2, and 3	
	Primary	Secondary	Primary	Secondary	Primary	Secondary
CO2	0.00251**	0.0158***	0.00273***	0.0180***	0.00267***	0.0183***
	(2.418)	(6.514)	(2.723)	(7.632)	(2.901)	(8.543)
Years to maturity	0.0154***	0.0543***	0.0154***	0.0544***	0.0154***	0.0545***
	(22.71)	(49.59)	(22.76)	(49.72)	(22.78)	(49.84)
Log(Amount)	0.0305***	-0.0243***	0.0304***	-0.0245***	0.0304***	-0.0246***
	(7.176)	(-4.715)	(7.169)	(-4.742)	(7.162)	(-4.769)
$\mathbb{1}${Redeemable}	0.0588***	0.173***	0.0588***	0.174***	0.0589***	0.175***
	(2.986)	(7.742)	(2.990)	(7.777)	(2.992)	(7.829)
Rating (Moody's)	-0.0156***	-0.0611***	-0.0156***	-0.0609***	-0.0156***	-0.0603***
	(-5.656)	(-11.50)	(-5.656)	(-11.46)	(-5.657)	(-11.37)
Number of all underwriters	-0.00564	-0.0160**	-0.00563	-0.0160**	-0.00564	-0.0159**
	(-1.210)	(-2.466)	(-1.209)	(-2.463)	(-1.210)	(-2.447)
Illiquidity		0.0242**		0.0243**		0.0244**
		(2.284)		(2.297)		(2.306)
Coupon	0.342***	-0.00491	0.342***	-0.00553	0.342***	-0.00582
	(51.35)	(-0.534)	(51.33)	(-0.602)	(51.28)	(-0.635)
VIX (daily)	0.00688***	0.0325***	0.00689***	0.0325***	0.00689***	0.0325***
	(7.350)	(21.41)	(7.370)	(21.41)	(7.372)	(21.45)
Equity return mean	-0.0943***	-0.466***	-0.0940***	-0.462***	-0.0934***	-0.460***
	(-3.105)	(-9.136)	(-3.096)	(-9.081)	(-3.078)	(-9.040)
Log(Equity return vol)	0.0699***	0.282***	0.0703***	0.283***	0.0708***	0.287***
	(3.829)	(8.997)	(3.850)	(9.059)	(3.877)	(9.175)
Book leverage	0.0749	0.303***	0.0747	0.303***	0.0706	0.288***
	(1.479)	(3.890)	(1.477)	(3.904)	(1.398)	(3.708)
ROA	-0.0335	-0.763***	-0.0267	-0.717***	-0.0189	-0.666***
	(-0.332)	(-3.768)	(-0.264)	(-3.541)	(-0.186)	(-3.284)
Interest coverage ratio	-0.205***	-0.662***	-0.206***	-0.661***	-0.205***	-0.656***
	(-4.040)	(-10.80)	(-4.062)	(-10.80)	(-4.043)	(-10.74)
Firm sale	0.0150	0.0200	0.0154	0.0235	0.0149	0.0219
	(1.473)	(1.001)	(1.515)	(1.179)	(1.467)	(1.105)
Firm size	-0.00204	-0.000757	-0.00179	0.000530	-0.000956	0.00553
	(-0.209)	(-0.0398)	(-0.184)	(0.0278)	(-0.0978)	(0.291)
Observations	2,428	8,525	2,428	8,525	2,428	8,525
R-squared	0.839	0.630	0.839	0.631	0.839	0.631
Industry FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Month FE	YES	YES	YES	YES	YES	YES
DOW FE	YES	YES	YES	YES	YES	YES
LeadUnderwriter1-10 FE	YES	YES	YES	YES	YES	YES

Robust t-statistics in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Back

Pooled regression with restriction

	(1) Scope 1 Primary + Secondary	(2) Scope 1 and 2 Primary + Secondary	(3) Scope 1, 2, and 3 Primary + Secondary
CO2	0.00850***	0.00898***	0.00974***
	(3.688)	(4.042)	(4.803)
CO2 X Secondary	0.00562*	0.00702**	0.00568**
	(1.874)	(2.440)	(2.192)
Years to maturity	0.0360***	0.0361***	0.0362***
	(27.76)	(27.85)	(27.91)
Log(Amount)	0.0335***	0.0340***	0.0339***
	(4.452)	(4.516)	(4.491)
$\mathbb{1}${Redeemable}	0.171***	0.171***	0.172***
	(8.989)	(9.016)	(9.057)
Rating (Moody's)	-0.0737***	-0.0740***	-0.0736***
	(-14.65)	(-14.70)	(-14.61)
Number of all underwriters	-0.00705	-0.00668	-0.00621
	(-0.745)	(-0.706)	(-0.656)
Coupon	0.0416***	0.0411***	0.0408***
	(5.668)	(5.604)	(5.567)
VIX (daily)	0.0285***	0.0285***	0.0285***
	(23.90)	(23.91)	(23.94)
Equity return mean	-0.393***	-0.391***	-0.389***
	(-9.915)	(-9.866)	(-9.811)
Log(Equity return vol)	0.251***	0.252***	0.255***
	(10.29)	(10.35)	(10.47)
Book leverage	0.291***	0.291***	0.278***
	(4.669)	(4.685)	(4.471)
ROA	-0.805***	-0.773***	-0.736***
	(-5.386)	(-5.168)	(-4.908)
Interest coverage ratio	-0.610***	-0.610***	-0.605***
	(-11.85)	(-11.86)	(-11.78)
Firm sale	0.0228	0.0251*	0.0236
	(1.526)	(1.683)	(1.587)
Firm size	-0.00783	-0.00678	-0.00308
	(-0.551)	(-0.477)	(-0.217)
Illiquidity X Secondary	0.0334***	0.0334***	0.0336***
	(3.352)	(3.362)	(3.380)
Rating (Moody's) X Secondary	0.0374***	0.0381***	0.0379***
	(7.734)	(7.849)	(7.806)
Log(Amount) X Secondary	-0.0543***	-0.0549***	-0.0547***
	(-7.073)	(-7.155)	(-7.125)
(Years to maturity) X Secondary	0.0152***	0.0152***	0.0152***
	(11.12)	(11.11)	(11.13)
(Number of all underwriters) X Secondary	-0.0145	-0.0149	-0.0154
	(-1.407)	(-1.450)	(-1.493)
Observations	10,953	10,953	10,953
R-squared	0.613	0.614	0.614
FE	YES	YES	YES

Robust t-statistics in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Back

Interaction with MCCC shock

	(1)	(2)	(3)	(4)	(5)	(6)
	Scope 1		Scope 1 and 2		Scope 1, 2, and 3	
	Primary	Secondary	Primary	Secondary	Primary	Secondary
CO_2	0.00434***	0.0213***	0.00442***	0.0238***	0.00419***	0.0236***
	(3.312)	(7.129)	(3.507)	(8.276)	(3.623)	(8.959)
CO_2 X CS	0.0194***	0.0317***	0.0204***	0.0323***	0.0191***	0.0258***
	(4.922)	(3.408)	(5.345)	(3.613)	(5.551)	(3.326)
Observations	1,709	6,739	1,709	6,739	1,709	6,739
R-squared	0.844	0.645	0.845	0.646	0.845	0.647
Bond controls	YES	YES	YES	YES	YES	YES
Firm controls	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Month FE	YES	YES	YES	YES	YES	YES
DOW FE	YES	YES	YES	YES	YES	YES
LeadUnderwriter1-10 FE	YES	YES	YES	YES	YES	YES

Robust t-statistics in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

- Media Climate Change Concerns (MCCC) index, see Ardia, Bluteau, Boudt, Inghelbrecht (2022)
- MCCC shock: prediction error to the realized MCCC index to AR(1) model's predicted based on the past 36 months data, see Pastor, Stambaugh, Taylor (2022)

- Difference in CO_2 sensitivity between secondary and primary market
  - Scope 1 : 0.0172*** (4.175)
  - Scope 1 and scope 2: 0.0196*** (4.957)
  - Scope 1 and scope 2 and scope 3: 0.0196*** (5.409)

Back

Investment grade bonds

	(1)	(2)	(3)	(4)	(5)	(6)
	Scope 1		Scope 1 and 2		Scope 1, 2, and 3	
	Primary	Secondary	Primary	Secondary	Primary	Secondary
CO2	0.00155	0.0132***	0.00186*	0.0161***	0.00193*	0.0169***
	(1.346)	(4.755)	(1.679)	(6.066)	(1.921)	(7.072)
Observations	2,367	8,466	2,367	8,466	2,367	8,466
R-squared	0.838	0.634	0.838	0.635	0.838	0.635
Bond controls	YES	YES	YES	YES	YES	YES
Firm controls	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Month FE	YES	YES	YES	YES	YES	YES
DOW FE	YES	YES	YES	YES	YES	YES
LeadUnderwriter1-10 FE	YES	YES	YES	YES	YES	YES

Robust t-statistics in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Difference in CO2 sensitivity between secondary and primary market

- 0.0116*** (3.095), 0.0143*** (3.965), and 0.0150*** (4.602)

Back

Brown industry indicator as main regressor

	(1)	(2)	(3)	(4)	(5)	(6)
	Scope 1		Scope 1 and 2		Scope 1, 2, and 3	
	Primary	Secondary	Primary	Secondary	Primary	Secondary
Brown industry indicator	0.214***	2.239***	0.0210	0.871***	0.181***	1.940***
	(4.695)	(27.36)	(0.868)	(15.85)	(4.204)	(23.90)
Observations	2,563	9,025	2,563	9,025	2,563	9,025
R-squared	0.845	0.629	0.843	0.609	0.844	0.623
Bond controls	YES	YES	YES	YES	YES	YES
Firm controls	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Month FE	YES	YES	YES	YES	YES	YES
DOW FE	YES	YES	YES	YES	YES	YES
Seniority FE	YES	YES	YES	YES	YES	YES
LeadUnderwriter1-10 FE	YES	YES	YES	YES	YES	YES

Robust t-statistics in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Difference in CO2 sensitivity between secondary and primary market

- 2.025*** (14.86), 0.850*** (10.70), and 1.759*** (13.39)

Back

Different subsamples based on time

	(1)	(2)	(3)	(4)	(5)	(6)
	Scope 1		Scope 1 and 2		Scope 1, 2, and 3	
	Primary	Secondary	Primary	Secondary	Primary	Secondary
Panel A1: 2005-2013						
CO2	0.00637**	0.0161***	0.00514**	0.0208***	0.00484**	0.0197***
	(2.560)	(3.053)	(2.222)	(4.253)	(2.296)	(4.429)
Observations	749	3,306	749	3,306	749	3,306
R-squared	0.831	0.674	0.831	0.675	0.831	0.675
Panel A2: 2014-2022						
CO2	-0.00160	0.00559**	-0.000984	0.00670***	-0.000687	0.00817***
	(-1.494)	(2.444)	(-0.933)	(2.958)	(-0.706)	(3.946)
Observations	1,679	5,219	1,679	5,219	1,679	5,219
R-squared	0.856	0.642	0.856	0.642	0.856	0.643
Panel B1: Odd Years						
CO2	0.00441**	0.0193***	0.00429***	0.0227***	0.00398***	0.0216***
	(2.543)	(5.218)	(2.583)	(6.436)	(2.693)	(6.862)
Observations	1,162	4,322	1,162	4,322	1,162	4,322
R-squared	0.832	0.555	0.832	0.557	0.832	0.557
Panel B2: Even Years						
CO2	0.000548	0.0101***	0.000872	0.0108***	0.000947	0.0115***
	(0.415)	(3.126)	(0.677)	(3.416)	(0.782)	(3.925)
Observations	1,265	4,203	1,265	4,203	1,265	4,203
R-squared	0.858	0.705	0.858	0.705	0.858	0.705
Bond/Firm controls	YES	YES	YES	YES	YES	YES
FE	YES	YES	YES	YES	YES	YES

Robust t-statistics in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Difference in CO2 sensitivity between secondary and primary market

- Panel A1: 0.00970 (1.300), 0.0157** (2.265), 0.0149** (2.360)
- Panel A2: 0.00718** (2.337), 0.00769** (2.530), 0.00886*** (3.174)
- Panel B1: 0.0149*** (2.892), 0.0185*** (3.752), 0.0176*** (4.014)
- Panel B2: 0.00953** (2.203), 0.00995** (2.352), 0.0106*** (2.680)

Back

Absolute Emissions

	(1)	(2)	(3)	(4)	(5)	(6)
	Scope 1		Scope 1 and 2		Scope 1, 2, and 3	
	Primary	Secondary	Primary	Secondary	Primary	Secondary
CO2	0.00705*	0.0499***	0.0121**	0.0649***	0.0157**	0.117***
	(1.831)	(6.378)	(2.274)	(5.831)	(1.979)	(6.981)
Observations	2,428	8,525	2,428	8,525	2,428	8,525
R-squared	0.839	0.630	0.839	0.630	0.839	0.630
Bond controls	YES	YES	YES	YES	YES	YES
Firm controls	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Month FE	YES	YES	YES	YES	YES	YES
DOW FE	YES	YES	YES	YES	YES	YES
LeadUnderwriter1-10 FE	YES	YES	YES	YES	YES	YES

Robust t-statistics in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

- t-statistics for difference in spreads' sensitivity to CO2
  - Scope 1 : 0.0428*** (3.723)
  - Scope 1 and scope 2: 0.0527*** (3.275)
  - Scope 1, scope 2 and scope 3: 0.101*** (4.208)

Back

Liquidity Risk (1)

- Possible concern: outstanding bonds' liquidity, and thus spreads, might be affected by a new bond issuance
- To study this issue
  - Focus only on on the secondary market
  - Offer two pieces of evidence
    1. For a given firm, illiquidity on the secondary market appears not affected by issuance of a new bond
    2. Use secondary market spreads on the day before or the day after a firm issues a new bond, see next slide

Liquidity Risk (2)

	(1)	(2)	(3)	(4)	(5)	(6)
	Scope 1		Scope 1 and 2		Scope 1, 2, and 3	
CO2	0.0158***	0.0155***	0.0180***	0.0169***	0.0183***	0.0172***
	(6.514)	(8.466)	(7.632)	(9.586)	(8.543)	(10.75)
Observations	8,525	15,693	8,525	15,693	8,525	15,693
R-squared	0.630	0.568	0.631	0.568	0.631	0.569
Bond controls	YES	YES	YES	YES	YES	YES
Firm controls	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Month FE	YES	YES	YES	YES	YES	YES
DOW FE	YES	YES	YES	YES	YES	YES
LeadUnderwriter1-10 FE	YES	YES	YES	YES	YES	YES

Robust t-statistics in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

- Columns (1),(3),(5): Reproduction of our main result on secondary bond market
- Columns (2),(4),(6): Use spreads one day before and after days when a given firm issues new bonds
- t-statistics for difference in spreads' sensitivity to CO2
  - Scope 1: 0.10
  - Scope 1 and scope 2: 0.37
  - Scope 1, scope 2, and scope 3: 0.41

Back

More precise definition of CO_2 (1)

- Possible concern: some CO_2 emissions were estimated, to different degrees, by data vendors, see Aswani, Raghunandan and Rajgopal (2022)
- To study this issue
  - Trucost documents how the reported CO_2 emission was derived and there are 32 different types in total
  - We assign 5 different precision levels
  - E.g., "Exact value from CDP" is assigned the most precise level, 5; "Estimate derived from production data" is assigned the most imprecise level, 1

More precise definition of CO2 (2)

	(1)	(2)	(3)	(4)	(5)	(6)
	Scope 1		Scope 1 and 2		Scope 1, 2, and 3	
	Primary	Secondary	Primary	Secondary	Primary	Secondary
Panel A: Precision level 4 or above						
CO2	0.00234**	0.0157***	0.00252**	0.0178***	0.00245***	0.0182***
	(2.257)	(6.443)	(2.521)	(7.544)	(2.663)	(8.474)
Observations	2,404	8,506	2,404	8,506	2,404	8,506
R-squared	0.841	0.631	0.841	0.631	0.841	0.632
Panel B: Precision level 5						
CO2	0.00227**	0.0163***	0.00247**	0.0184***	0.00240***	0.0187***
	(2.170)	(6.785)	(2.444)	(7.900)	(2.589)	(8.844)
Observations	2,353	8,102	2,353	8,102	2,353	8,102
R-squared	0.841	0.648	0.841	0.648	0.841	0.649
Bond controls	YES	YES	YES	YES	YES	YES
Firm controls	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Month FE	YES	YES	YES	YES	YES	YES
DOW FE	YES	YES	YES	YES	YES	YES
LeadUnderwriter1-10 FE	YES	YES	YES	YES	YES	YES

Robust t-statistics in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Difference in CO2 sensitivity between secondary and primary market

- Panel A: 0.0133*** (4.050), 0.0153*** (4.789), 0.0157*** (5.400)
- Panel B: 0.0140*** (4.330), 0.0159*** (5.078), 0.0163*** (5.696)

Back

Additional lag

See Zhang (2023)

	(1)	(2)	(3)	(4)	(5)	(6)
	Scope 1		Scope 1 and 2		Scope 1, 2, and 3	
	Primary	Secondary	Primary	Secondary	Primary	Secondary
CO2	0.00288***	0.0149***	0.00286***	0.0166***	0.00274***	0.0167***
	(2.927)	(6.411)	(3.004)	(7.383)	(3.154)	(8.175)
Observations	2,428	8,525	2,428	8,525	2,428	8,525
R-squared	0.839	0.630	0.839	0.631	0.839	0.631
Bond controls	YES	YES	YES	YES	YES	YES
Firm controls	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Month FE	YES	YES	YES	YES	YES	YES
DOW FE	YES	YES	YES	YES	YES	YES
Seniority FE	YES	YES	YES	YES	YES	YES
LeadUnderwriter1-10 FE	YES	YES	YES	YES	YES	YES

Robust t-statistics in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Difference in CO2 sensitivity between secondary and primary market

- Scope 1: 0.0121*** (3.844)
- Scope 1 and scope 2: 0.0138*** (4.544)
- Scope 1, scope 2, and scope 3: 0.0140*** (5.063)

Back

Winsorization

	(1)	(2)	(3)	(4)	(5)	(6)
	Scope 1		Scope 1 and 2		Scope 1, 2, and 3	
	Primary	Secondary	Primary	Secondary	Primary	Secondary
Panel A: No winsorization						
CO2	0.00171**	0.0110***	0.00180**	0.0126***	0.00177**	0.0132***
	(2.041)	(5.381)	(2.238)	(6.366)	(2.365)	(7.252)
Observations	2,428	8,525	2,428	8,525	2,428	8,525
R-squared	0.845	0.631	0.845	0.632	0.845	0.632
Panel B: 2.5% winsorization on both ends						
CO2	0.00412***	0.0267***	0.00427***	0.0285***	0.00394***	0.0270***
	(2.688)	(7.767)	(3.036)	(9.004)	(3.201)	(9.851)
Observations	2,428	8,525	2,428	8,525	2,428	8,525
R-squared	0.835	0.627	0.836	0.628	0.836	0.628
Bond controls	YES	YES	YES	YES	YES	YES
Firm controls	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Month FE	YES	YES	YES	YES	YES	YES
DOW FE	YES	YES	YES	YES	YES	YES
Seniority FE	YES	YES	YES	YES	YES	YES
LeadUnderwriter1-10 FE	YES	YES	YES	YES	YES	YES

Robust t-statistics in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Difference in CO2 sensitivity between secondary and primary market

- Panel A: 0.00927*** (3.408), 0.0108*** (4.105), 0.0114*** (4.707)
- Panel B: 0.0226*** (4.752), 0.0242*** (5.550), 0.0231*** (6.073)

Back

More granular fixed effects

	(1)	(2)	(3)	(4)	(5)	(6)
	Scope 1		Scope 1 and 2		Scope 1, 2, and 3	
	Primary	Secondary	Primary	Secondary	Primary	Secondary
Panel A: (One digit SIC industry) X (Year) FE						
CO2	0.00204*	0.0168***	0.00233**	0.0187***	0.00246***	0.0190***
	(1.912)	(6.873)	(2.251)	(7.870)	(2.593)	(8.739)
Observations	2,420	8,518	2,420	8,518	2,420	8,518
R-squared	0.848	0.656	0.849	0.657	0.849	0.657
Panel B: Two digit SIC industry FE						
CO2	-0.00158	0.00283	-0.00139	0.00781**	-0.00110	0.00971***
	(-1.120)	(0.779)	(-1.012)	(2.212)	(-0.852)	(2.960)
Observations	2,426	8,522	2,426	8,522	2,426	8,522
R-squared	0.846	0.638	0.846	0.638	0.846	0.638
Bond controls	YES	YES	YES	YES	YES	YES
Firm controls	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Month FE	YES	YES	YES	YES	YES	YES
DOW FE	YES	YES	YES	YES	YES	YES
Seniority FE	YES	YES	YES	YES	YES	YES
LeadUnderwriter1-10 FE	YES	YES	YES	YES	YES	YES

Robust t-statistics in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Difference in CO2 sensitivity between secondary and primary market

- Panel A: 0.0148*** (4.448), 0.0164*** (5.082), 0.0165*** (5.590)
- Panel B: 0.00441 (0.937), 0.00919** (2.012), 0.0108** (2.532)

Back

Without data filters

	(1)	(2)	(3)	(4)	(5)	(6)
	Scope 1		Scope 1 and 2		Scope 1, 2, and 3	
	Primary	Secondary	Primary	Secondary	Primary	Secondary
CO2	-0.000686	0.00920***	-0.000461	0.0107***	-0.000593	0.0105***
	(-0.878)	(5.701)	(-0.607)	(6.816)	(-0.845)	(7.228)
Observations	4,788	17,459	4,788	17,459	4,788	17,459
R-squared	0.812	0.559	0.812	0.560	0.812	0.560
Bond controls	YES	YES	YES	YES	YES	YES
Firm controls	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Month FE	YES	YES	YES	YES	YES	YES
DOW FE	YES	YES	YES	YES	YES	YES
Seniority FE	YES	YES	YES	YES	YES	YES
LeadUnderwriter1-10 FE	YES	YES	YES	YES	YES	YES

Robust t-statistics in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Difference in CO2 sensitivity between secondary and primary market

- Scope 1: 0.00988*** (4.257)
- Scope 1 and scope 2: 0.0112*** (4.952)
- Scope 1, scope 2, and scope 3: 0.0111*** (5.325)

Back

Robustness: Competition Channel

Using alternative measure of Manconi, Neretina and Renneboog (2019)

	(1) Scope 1	(2) Scope 1 and 2	(3) Scope 1,2, and 3
CO2	0.00168	0.00169	0.00231
	(0.283)	(0.294)	(0.432)
LC	-0.0884	-0.0891	-0.0906
	(-1.162)	(-1.173)	(-1.173)
CO2 X Secondary	0.0198**	0.0187**	0.0191**
	(2.326)	(2.281)	(2.557)
CO2 X LC	0.00896	0.00780	0.00578
	(1.055)	(0.967)	(0.797)
LC X Secondary	-0.110	-0.104	-0.100
	(-1.290)	(-1.214)	(-1.158)
CO2 X Secondary X LC	0.0280**	0.0389***	0.0279***
	(2.295)	(3.410)	(2.812)
Observations	6,403	6,403	6,403
R-squared	0.678	0.681	0.681
Controls	YES	YES	YES
Controls X Secondary	YES	YES	YES
Industry FE	YES	YES	YES
Year FE	YES	YES	YES
Month FE	YES	YES	YES
DOW FE	YES	YES	YES
LeadUnderwriter1-10 FE	YES	YES	YES
Industry X Secondary FE	YES	YES	YES
Year X Secondary FE	YES	YES	YES
Month X Secondary FE	YES	YES	YES
DOW X Secondary FE	YES	YES	YES
LeadUnderwriter1-10 X Secondary FE	YES	YES	YES

Robust t-statistics in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Higher difference between secondary and primary market carbon premium when competition is low Back

Precision level of Trucost's carbon disclosure

Trucost's carbon disclosure	Precision
Derived from previous year	1
Estimate based on partial data disclosure in Annual Report/10-K/Financial Accounts	1
Estimate based on partial data disclosure in CDP	1
Estimate based on partial data disclosure in Environmental/CSR	1
Estimate based on partial data disclosure in personal communication	1
Estimate derived from production data	1
Estimate scaled according to company-specific data	1
Estimate used instead of disclosure - data does not cover global operations	1
Estimate used instead of disclosure - data is normalised and no aggregating factor is available	1
Estimated data	1
Value derived from data provided in Annual Report/Financial Accounts Disclosure	2
Value derived from data provided in CDP	2
Value derived from data provided in Environmental/CSR	2
Value derived from data provided in personal communication	2
Value derived from fuel use provided in Annual Report/Financial Accounts Disclosure	2
Value derived from fuel use provided in CDP	2
Value derived from fuel use provided in Environmental/CSR	2
Value derived from fuel use provided in personal communication	2
Value split from data provided in Annual Report/Financial Accounts Disclosure	3
Value split from data provided in CDP	3
Value split from data provided in Environmental/CSR	3
Value split from data provided in personal communication	3
Value summed up from data provided in Annual Report/Financial Accounts Disclosure	4
Value summed up from data provided in CDP	4
Value summed up from data provided in Environmental/CSR	4
Value summed up from data provided in personal communication	4
Data approximated from chart/graph in Annual Report/10-K/Financial Accounts	5
Data approximated from chart/graph in Environmental Report/CSR Report/Website	5
Exact Value from Annual Report/10K/Financial Accounts Disclosure	5
Exact Value from CDP	5
Exact Value from Environmental/CSR	5
Exact Value from personal communication	5

Back

Solving via backward induction

- On the secondary market:
  - Type-2 investors demand is $q_2 = \frac{\mu_v + e - p_2}{A\sigma_v^2}$
  - Market clearing imposes $\pi_2 q_2 = (1-\pi)q_d'$ because the supply comes from dealers liquidating their position
  - This yields the implicit secondary market price: $p_2 = \mu_v + e - \frac{1-\pi}{\pi_2} q_d A\sigma_v^2$
- On the primary market:
  - Type-1 investors demand a quantity $q_1 = \frac{\mu_v - p_1}{A\sigma_v^2}$
  - A dealer's optimal trade depends on the anticipated quantity liquidated at date 2, denoted by $(1-\pi)q_d'$: $q_d = \frac{\mu_v + \mu_e - \frac{1-\pi}{\pi_2} q_d' A\sigma_v^2 - p_1}{A\sigma_e^2}$
  - Rational expectations require that $q_d' = q_d$ and yield: $q_d = \frac{\mu_v + \mu_e - p_1}{A(\sigma_e^2 + \frac{1-\pi}{\pi_2}\sigma_v^2)}$
  - Market-clearing imposes $(1-\pi)q_d + \pi_1 q_1 = 1$
  - This yields the explicit primary price: $p_1 = \mu_v + \frac{X}{X+Y}\mu_e - \frac{1}{X+Y}$
  - $X = \frac{1-\pi}{A(\sigma_e^2 + \frac{1-\pi}{\pi_2}\sigma_v^2)}$ and $Y = \frac{\pi_1}{A\sigma_v^2}$
- Use p_1 to get q_d; then use q_d to get the explicit value of p_2

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Model with a strategic dealer

- The dealer who knows that liquidation at date 2 will affect prices maximizes $q_d(\mu_v + \mu_e - \frac{1-\pi}{\pi_2} q_d A\sigma_v^2 - p_1) - \frac{A}{2} q_d^2 \sigma_e^2$
- Dealer's demand is thus $q_d = \frac{\mu_v + \mu_e - p_1}{A(\sigma_e^2 + 2\frac{1-\pi}{\pi_2}\sigma_v^2)}$
- Same demand as before except for the number '2' in the denominator which implies that dealer trades less aggressively when being strategic than when behaving competitively
- All results we obtained previously hold by replacing X by $X' = \frac{1-\pi}{A(\sigma_e^2 + 2\frac{1-\pi}{\pi_2}\sigma_v^2)} < X$

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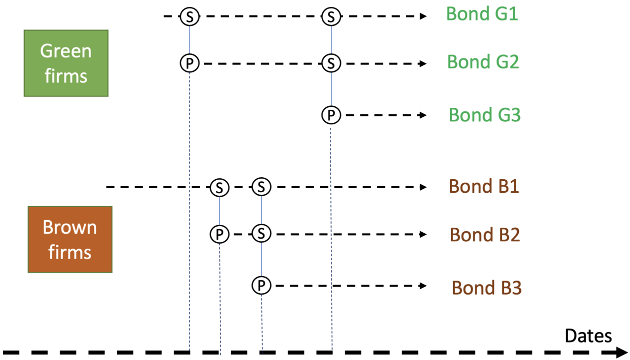
Identification strategy (2)

Compare carbon premium of bonds on primary market to carbon premium of other bonds issued by same firms and trading on secondary market on the same day as issuance, controlling for various bond and firm characteristics, including illiquidity



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Summary stats (1)

	N	Mean	SD	Median
CO2 emission measures				
Log(Carbon Emission Scope 1 (tons CO2e))	219	11.67	2.104	11.50
Log(Carbon Emission Scope 1 and 2 (tons CO2e))	219	13.81	1.514	13.84
Log(Carbon Emission Scope 1, 2, and 3 (tons CO2e))	219	15.16	1.229	15.17
Carbon intensity Scope 1 (tons CO2e/USD m.)/100	219	0.746	3.912	0.0104
Carbon intensity Scope 1 and 2 (tons CO2e/USD m.)/100	219	0.979	4.092	0.133
Carbon intensity Scope 1, 2, and 3 (tons CO2e/USD m.)/100	219	1.796	4.662	0.429
Firm characteristics				
Book leverage	219	0.354	0.160	0.364
Interest coverage ratio	219	0.189	0.216	0.118
Firm size	219	12.67	1.521	13.21
ROA	219	0.0942	0.0920	0.0343
Firm sale	219	10.89	0.873	10.83
Equity return mean	219	0.109	0.278	0.125
Log(Equity return vol)	219	-1.523	0.415	-1.594

Summary stats (2)

Bond characteristics				
Offering spread (%)	2536	0.641	0.599	0.471
Secondary spread (%)	2579	0.741	1.046	0.702
Number of lead underwriters	3586	2.163	1.293	2
Number of all underwriters	3586	4.495	1.708	5
Illiquidity	3586	0.0970	0.592	0.000567
Rating (Moody's)	3586	15.24	2.225	15
$\mathbb{1}$\{Redeemable\}	3586	0.673	0.469	1
Years to maturity	3586	11.85	9.886	8.764
Amount outstanding (millions)	3586	1,002	954.1	768.9
Coupon (%)	3586	3.843	1.454	3.850
$\mathbb{1}$\{Lead underwritten by J.P. Morgan\}	3586	0.211	0.408	0
$\mathbb{1}$\{Lead underwritten by Citi\}	3586	0.184	0.387	0
$\mathbb{1}$\{Lead underwritten by Merrill Lynch\}	3586	0.215	0.411	0
$\mathbb{1}$\{Lead underwritten by Barclays\}	3586	0.112	0.315	0
$\mathbb{1}$\{Lead underwritten by Morgan Stanley\}	3586	0.244	0.430	0
$\mathbb{1}$\{Lead underwritten by Goldman Sachs\}	3586	0.164	0.371	0
$\mathbb{1}$\{Lead underwritten by Wells Fargo\}	3586	0.0735	0.261	0
$\mathbb{1}$\{Lead underwritten by Deutsche bank\}	3586	0.0833	0.276	0
$\mathbb{1}$\{Lead underwritten by Bank of America\}	3586	0.0406	0.197	0

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Equilibrium

- We solve backwards for primary and secondary market prices
  - $p_1 = \mu_v + \frac{X}{X+Y}\mu_e - \frac{1}{X+Y}$
  - $\mathbb{E}(p_2) = \mu_v + \mu_e - \frac{\pi_1}{\pi_2}\frac{X+XY\mu_e}{XY+Y^2}$
  - with $X = \frac{1-\pi}{A(\sigma_e^2 + \frac{1-\pi}{\pi_2}\sigma_v^2)}$, $Y = \frac{\pi_1}{A\sigma_v^2}$, and $\pi = \pi_1 + \pi_2$ Details
- Prices reflect expected financial cash flows and climate concerns
  - On the secondary market, because type-2 investors have green preferences
  - And even on the primary market, because dealers speculate on the future secondary market price p_2
  - Note that primary market price reflects expected climate concerns even if no market participant at this stage has green preferences

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Uncertainty Channel

- The expression for the difference in sensitivity to climate concerns is:

$$\frac{\partial \mathbb{E}(p_2)}{\partial \mu_e} - \frac{\partial p_1}{\partial \mu_e} = \frac{\pi_1 \pi_2 \sigma_e^2}{\pi_1 \pi_2 \sigma_e^2 + \pi(1-\pi)\sigma_v^2}$$

- This difference increases with σ_e^2
- Intuition: When there is more uncertainty on climate concerns, risk averse dealers are less aggressive and the views of investors without green preferences weigh more in primary market price

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Competition Channel

- We modified our model to introduce low competition Details
  - Only one dealer who accounts for price impact at date 2
- Difference in sensitivity of prices to climate concerns is now:

$$\frac{\partial \mathbb{E}(p_2')}{\partial \mu_e} - \frac{\partial p_1'}{\partial \mu_e} = \frac{\pi_1\pi_2\sigma_e^2 + \pi_1(1-\pi)\sigma_v^2}{\pi_1\pi_2\sigma_e^2 + \pi(1-\pi)\sigma_v^2 + \pi_1(1-\pi)\sigma_v^2}$$

- The difference in sensitivity of prices to climate concerns is larger with low than with high competition
- Intuition: To avoid adversely affecting prices, a strategic dealer is less aggressive than a competitive one and the views of investors without green preferences weigh more in primary market price

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Both Channels: Triple-Interaction results

	(1) Scope 1	(2) Scope 1 and 2	(3) Scope 1,2, and 3
CO2	-0.000215	4.70e-05	0.00113
	(-0.0466)	(0.0104)	(0.266)
LC	0.0162	0.0155	0.0168
	(0.325)	(0.309)	(0.325)
HV	-0.0325	-0.0326	-0.0328
	(-1.002)	(-1.005)	(-1.005)
CO2 X Secondary	-0.0101	-0.00899	-0.00573
	(-1.597)	(-1.460)	(-1.006)
CO2 X LC	0.00413	0.00325	0.00207
	(0.745)	(0.612)	(0.418)
LC X Secondary	0.0558	0.0450	0.0281
	(0.923)	(0.743)	(0.452)
CO2 X Secondary X LC	0.0350***	0.0376***	0.0318***
	(4.545)	(5.135)	(4.743)
CO2 X HV	0.00764	0.00711	0.00468
	(1.344)	(1.319)	(0.978)
HV X Secondary	-0.0449	-0.0433	-0.0414
	(-1.238)	(-1.194)	(-1.137)
CO2 X Secondary X HV	0.0397***	0.0365***	0.0299***
	(5.010)	(4.877)	(4.619)
Observations	8,495	8,495	8,495
R-squared	0.665	0.666	0.666
Controls	YES	YES	YES
Controls X Secondary	YES	YES	YES
FE	YES	YES	YES
Secondary X FE	YES	YES	YES

Robust t-statistics in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

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