

# Carbon Default Swap

## Disentangling the Exposure to Carbon Risk Through CDS

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# Motivation

# Carbon risk: Who, where and when

- Evaluation of firms' exposure to carbon risk involves quantifying effort necessary to successfully transition to a low-carbon economy.
- Carbon emissions used to codify exposure to carbon risk:
  - investors command higher returns (Bolton and Kacperczyk, 2021; Cheema-Fox et al., 2020; Görgen et al., 2020; Hsu et al., 2022; Lioui, 2022)
  - market demands changes in the capital structure (Nguyen and Phan, 2020; Kleimeier and Viehs, 2018)
- Recognition to supplement this with firm-specific information on future emissions reduction targets (Carbone et al., 2021, ECB, 2022).

# In this paper

- Utilising the information contained in the spreads of CDS, we construct a market-implied, high-frequency and forward-looking carbon risk (CR) factor.
- Provide theoretical foundation for straightforward translation of carbon risk into credit risk.
  - Disciplines firms' targets by looking at the market's.
- Document amplifying effect of a carbon risk on credit risk:
  - The effect is larger for European than North American firms
  - It varies substantially across industries
  - Lenders demand more credit protection when market-wide concern about climate change risk is elevated.
  - Lenders expect adjustments in carbon regulations in Europe will cause relatively larger policy-related costs in the near future.

## Carbon risk factor

# Building intuition: market's perception of carbon risk in CDS

# Utilising the spread of CDS to build carbon risk factor



# Data

- Single-name CDS spreads across tenors of 1, 3, 5, 10 and 30 years.
- Unbalanced panel: 137 European and 281 North American firms.
  - 229,036 and 447,640 CDS spreads-day observations (January 1, 2013 – December 31, 2019).
- Daily CDS spread log returns as:

$$s_{i,t}^m = \log(\text{CDS}_{i,t}^m) - \log(\text{CDS}_{i,t-1}^m),$$

where  $\text{CDS}_{i,t}^m$  is the  $m$ -year CDS spread of firm  $i$  at day  $t$ .

- Change in the CDS slope

$$\Delta \text{CDSSlope}_{i,t}^{mn} = \text{CDSSlope}_{i,t}^{mn} - \text{CDSSlope}_{i,t-1}^{mn},$$

where  $\text{CDSSlope}_{i,t}^{mn} = \text{CDS}_{i,t}^m - \text{CDS}_{i,t}^n$ .

# Descriptive Statistics

| Variable                | Mean    | Q25     | Median  | Q75    | SD     | Min       | Max      | Skew    | Kurt      |
|-------------------------|---------|---------|---------|--------|--------|-----------|----------|---------|-----------|
| <b>Europe</b>           |         |         |         |        |        |           |          |         |           |
| Dependent variables     |         |         |         |        |        |           |          |         |           |
| $s_{i,t}^1$             | -0.0005 | -0.0102 | 0.0000  | 0.0024 | 0.0731 | -5.5500   | 5.5496   | 0.7826  | 1035.5178 |
| $s_{i,t}^5$             | -0.0005 | -0.0065 | 0.0000  | 0.0011 | 0.0220 | -0.8500   | 1.0368   | 1.7549  | 81.6643   |
| $s_{i,t}^{30}$          | -0.0002 | -0.0042 | -0.0001 | 0.0019 | 0.0215 | -0.7453   | 0.8584   | 0.5971  | 100.2184  |
| Independent variables   |         |         |         |        |        |           |          |         |           |
| $r_{i,t}$               | 0.0001  | -0.0079 | 0.0000  | 0.0084 | 0.0164 | -0.4433   | 0.2898   | -0.6605 | 18.8843   |
| $\Delta\sigma_{i,t}$    | -0.0000 | -0.0003 | -0.0000 | 0.0003 | 0.0024 | -0.1980   | 0.1528   | -0.6419 | 960.5852  |
| $\Delta MRI_{i,t}^1$    | -0.0085 | -0.2000 | 0.0000  | 0.1450 | 1.1403 | -54.6870  | 60.0600  | 1.4240  | 144.7797  |
| $\Delta MRI_{i,t}^5$    | -0.0382 | -0.4800 | -0.0050 | 0.2500 | 2.2882 | -179.5608 | 174.6699 | 0.9259  | 872.4980  |
| $\Delta MRI_{i,t}^{30}$ | -0.0381 | -0.5100 | -0.0200 | 0.3750 | 2.9638 | -235.3474 | 220.5798 | -1.2745 | 809.3234  |
| $\Delta CR_{i,t}^1$     | -0.0012 | -0.2650 | 0.0000  | 0.2500 | 1.0609 | -7.4550   | 13.8300  | 0.8808  | 27.8877   |
| $\Delta CR_{i,t}^5$     | -0.0178 | -0.5150 | 0.0000  | 0.4900 | 1.6112 | -9.7500   | 11.7850  | 0.3824  | 13.2141   |
| $\Delta CR_{i,t}^{30}$  | 0.0008  | -0.5300 | 0.0000  | 0.5350 | 2.0150 | -22.0610  | 23.2250  | -0.5498 | 31.0176   |
| <b>North America</b>    |         |         |         |        |        |           |          |         |           |
| Dependent variables     |         |         |         |        |        |           |          |         |           |
| $s_{i,t}^1$             | -0.0003 | -0.0014 | 0.0000  | 0.0010 | 0.0708 | -3.1463   | 3.7168   | 0.9617  | 165.0717  |
| $s_{i,t}^5$             | -0.0003 | -0.0012 | 0.0000  | 0.0005 | 0.0240 | -0.8493   | 1.0881   | 1.4242  | 95.7743   |
| $s_{i,t}^{30}$          | -0.0001 | -0.0013 | 0.0000  | 0.0006 | 0.0316 | -2.1832   | 2.9252   | 2.3172  | 499.6704  |
| Independent variables   |         |         |         |        |        |           |          |         |           |
| $r_{i,t}$               | 0.0003  | -0.0070 | 0.0001  | 0.0081 | 0.0173 | -0.4279   | 0.4314   | -0.3636 | 26.3819   |
| $\Delta\sigma_{i,t}$    | 0.0000  | -0.0003 | 0.0000  | 0.0003 | 0.0027 | -0.2581   | 0.2489   | -0.8374 | 1082.4504 |
| $\Delta MRI_{i,t}^1$    | -0.0088 | -0.1500 | 0.0000  | 0.0900 | 0.8179 | -34.6300  | 38.2100  | 1.4513  | 110.5850  |
| $\Delta MRI_{i,t}^5$    | -0.0286 | -0.3600 | 0.0000  | 0.1601 | 2.1001 | -159.0600 | 170.6299 | -0.1703 | 947.9878  |
| $\Delta MRI_{i,t}^{30}$ | -0.0260 | -0.5100 | -0.0100 | 0.3700 | 2.6434 | -174.6449 | 197.5998 | -0.6980 | 859.7066  |
| $\Delta CR_{i,t}^1$     | 0.0058  | -0.2100 | 0.0000  | 0.2400 | 0.7026 | -3.6350   | 6.8000   | 0.6150  | 12.6785   |
| $\Delta CR_{i,t}^5$     | 0.0073  | -0.4900 | 0.0000  | 0.4850 | 1.5795 | -10.8250  | 16.1800  | 0.5890  | 17.5335   |
| $\Delta CR_{i,t}^{30}$  | 0.0072  | -0.8850 | -0.0050 | 0.8100 | 3.2101 | -20.1700  | 23.5050  | 0.1211  | 12.2978   |



# Relationship between carbon risk (CR) and CDS

- Higher CR corresponds to a higher perceived carbon risk
  - High exposure to CR  $\Rightarrow$   $\downarrow$  valuation,  $\uparrow$  probability of default,  $\uparrow$  CDS spread
- Higher costs are represented by an increase in  $\delta$  (Merton (1974))
- **Hypothesis 1a.** *There is a positive relationship between carbon risk and CDS spread returns.*

$$Q_{s_{i,t}^m}(\tau|\mathbf{x}_{i,t}) = \alpha_{\tau,i} + \beta_{\tau,1}r_{i,t} + \beta_{\tau,2}\Delta\sigma_{i,t} + \beta_{\tau,3}\Delta\text{MRI}_{i,t} + \beta_{\tau,4}\Delta\text{CR}_t + \varepsilon_{i,t},$$

with firm-specific factors (i.e. stock return  $r_{i,t}$  and volatility  $\Delta\sigma_{i,t}$ ), a common factor (i.e. the market condition  $\Delta\text{MRI}_{i,t}$ ).

# Relationship between carbon risk and CDS

|             | 1                           | 2                           | 3                           | 4                           | 5                           | 6                           | 7                           | 8                           | 9                           |
|-------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
|             | 1Y                          |                             |                             |                             |                             |                             |                             |                             |                             |
| StockReturn | −2813.1013***<br>(139.9219) | −2475.9177***<br>(82.2491)  | −1782.1948***<br>(62.4759)  | −1121.0542***<br>(42.8245)  | −608.5685***<br>(27.8006)   | −991.7090***<br>(36.8465)   | −1756.1596***<br>(57.7830)  | −2671.9875***<br>(108.0672) | −3128.7498***<br>(194.7602) |
| ΔVolatility | −4274.7446***<br>(460.3142) | −3695.7626***<br>(347.2594) | −2306.0271***<br>(352.4623) | −764.9061***<br>(181.3375)  | 266.5424**<br>(98.8442)     | 2757.4848***<br>(209.0362)  | 5551.1425***<br>(254.0433)  | 8280.1851***<br>(230.4429)  | 9808.6211***<br>(342.6009)  |
| ΔMRI        | 13721.8249***<br>(373.2123) | 14045.1386***<br>(303.7631) | 13628.6968***<br>(347.7626) | 12875.7413***<br>(363.0188) | 12392.9998***<br>(346.7277) | 12566.2592***<br>(335.3771) | 13480.3516***<br>(422.9287) | 14622.8172***<br>(482.6289) | 15509.7703***<br>(695.8750) |
| ΔCR         | 4726.9818***<br>(279.7992)  | 3472.0502***<br>(157.1982)  | 2440.3621***<br>(141.8296)  | 1748.7648***<br>(117.7814)  | 1227.1696***<br>(98.6217)   | 1501.7224***<br>(115.5169)  | 2315.4231***<br>(152.7866)  | 3474.8825***<br>(226.0797)  | 4984.1680***<br>(315.2712)  |
|             | 5Y                          |                             |                             |                             |                             |                             |                             |                             |                             |
| StockReturn | −1431.4272***<br>(45.4985)  | −1243.5695***<br>(36.0400)  | −989.2465***<br>(29.4363)   | −669.0875***<br>(22.9102)   | −421.8787***<br>(17.1727)   | −566.3594***<br>(19.3774)   | −943.1713***<br>(28.1784)   | −1328.9566***<br>(46.7892)  | −1747.4626***<br>(91.4094)  |
| ΔVolatility | −2797.0873***<br>(111.0102) | −2019.9952***<br>(256.3426) | −1373.5869***<br>(195.7319) | −589.6069***<br>(126.7942)  | 143.3300*<br>(67.2026)      | 1368.0841***<br>(106.8712)  | 2796.7305***<br>(118.3761)  | 4305.1064***<br>(83.0717)   | 5649.6390***<br>(47.1807)   |
| ΔMRI        | 3036.5972***<br>(55.4270)   | 3320.0615***<br>(76.6869)   | 3365.4151***<br>(80.6731)   | 3348.4655***<br>(77.5422)   | 3328.6519***<br>(70.4261)   | 3302.8284***<br>(78.2523)   | 3460.4287***<br>(95.8322)   | 3656.1865***<br>(96.9259)   | 3742.1779***<br>(166.2358)  |
| ΔCR         | 1923.3511***<br>(64.6720)   | 1682.3568***<br>(48.6634)   | 1401.5602***<br>(45.4284)   | 1139.1609***<br>(46.5043)   | 942.4890***<br>(42.8167)    | 995.6671***<br>(43.1381)    | 1270.3066***<br>(47.3776)   | 1526.2217***<br>(52.9217)   | 1809.8070***<br>(82.9075)   |
|             | 30Y                         |                             |                             |                             |                             |                             |                             |                             |                             |
| StockReturn | −1029.2084***<br>(25.7815)  | −836.9985***<br>(22.5596)   | −671.4932***<br>(18.6042)   | −489.9141***<br>(15.2733)   | −363.2771***<br>(13.1710)   | −441.1067***<br>(13.8528)   | −666.2780***<br>(19.4709)   | −920.9882***<br>(33.0693)   | −1263.5757***<br>(66.4235)  |
| ΔVolatility | −2202.5086***<br>(60.4093)  | −1583.3672***<br>(121.3353) | −1027.0805***<br>(132.3896) | −484.6439***<br>(108.8929)  | 59.2316<br>(41.9010)        | 885.3015***<br>(67.9409)    | 1897.1700***<br>(91.2098)   | 2779.5849***<br>(72.6700)   | 3951.8120***<br>(66.5893)   |
| ΔMRI        | 2545.3132***<br>(51.3401)   | 2480.1349***<br>(49.5423)   | 2423.4117***<br>(48.5620)   | 2409.4864***<br>(47.6939)   | 2405.0538***<br>(55.9228)   | 2412.2025***<br>(54.6579)   | 2488.4924***<br>(61.3370)   | 2631.9306***<br>(67.7189)   | 2858.7221***<br>(99.9094)   |
| ΔCR         | 709.6480***<br>(26.0843)    | 635.5352***<br>(22.2194)    | 543.0912***<br>(18.2504)    | 448.8688***<br>(16.0082)    | 365.0738***<br>(16.9317)    | 390.4501***<br>(16.2949)    | 472.7183***<br>(19.5555)    | 599.8139***<br>(22.8457)    | 798.5791***<br>(42.1687)    |

\*\*\*  $p < 0.001$ ; \*\*  $p < 0.01$ ; \*  $p < 0.05$ ;  $p < 0.1$

# Regional impact of carbon risk

**Hypothesis 1b.** *The effect of carbon risk on CDS spread returns is stronger in Europe than in North America.*

|                  | 1                           | 2                           | 3                           | 4                          | 5                          | 6                          | 7                          | 8                          | 9                           |
|------------------|-----------------------------|-----------------------------|-----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|-----------------------------|
| 3Y Europe        |                             |                             |                             |                            |                            |                            |                            |                            |                             |
| StockReturn      | −2180.5358***<br>(77.9492)  | −2044.2562***<br>(57.9941)  | −1641.6912***<br>(49.5336)  | −1098.8512***<br>(36.9750) | −649.2602***<br>(26.6673)  | −956.5401***<br>(32.4704)  | −1637.4636***<br>(46.5041) | −2176.9058***<br>(77.2980) | −2736.8544***<br>(128.2038) |
| ΔVolatility      | −3919.9075***<br>(525.1170) | −2914.6899***<br>(485.3885) | −1852.5884***<br>(231.0973) | −832.9977***<br>(186.4021) | 262.3336*<br>(117.3238)    | 2381.5681***<br>(189.1591) | 4651.5161***<br>(204.9740) | 6390.1063***<br>(152.1751) | 8570.6078***<br>(77.5836)   |
| ΔMRI             | 5587.7228***<br>(152.9752)  | 6084.3243***<br>(128.9365)  | 6067.6308***<br>(135.8853)  | 5866.8447***<br>(134.7539) | 5715.6504***<br>(122.2034) | 5805.2386***<br>(142.4036) | 6126.6961***<br>(141.0683) | 6487.6381***<br>(208.5571) | 6799.8564***<br>(273.2274)  |
| ΔCR              | 2831.7579***<br>(96.0112)   | 2286.9444***<br>(73.5120)   | 1824.3538***<br>(73.3671)   | 1322.6756***<br>(65.3022)  | 921.7764***<br>(54.1534)   | 1146.5768***<br>(57.3865)  | 1687.8044***<br>(69.9222)  | 2212.5842***<br>(91.1792)  | 2728.3651***<br>(149.5206)  |
| 3Y North America |                             |                             |                             |                            |                            |                            |                            |                            |                             |
| StockReturn      | −485.2725***<br>(34.1442)   | −257.5818***<br>(15.0392)   | −144.5534***<br>(8.3312)    | −82.2322***<br>(5.3740)    | −34.9670***<br>(2.2205)    | −86.3466***<br>(4.8892)    | −164.0014***<br>(9.9650)   | −305.2146***<br>(23.2979)  | −587.9764***<br>(61.6549)   |
| ΔVolatility      | −1946.8016***<br>(186.1784) | −796.6869***<br>(58.8265)   | −276.0238***<br>(40.7247)   | −55.8295***<br>(10.9659)   | 6.5094<br>(7.0596)         | 315.2211***<br>(28.1924)   | 779.0859***<br>(49.6938)   | 1695.3448***<br>(103.1907) | 3665.0337***<br>(183.0197)  |
| ΔMRI             | 970.5989***<br>(78.2512)    | 703.5376***<br>(49.6733)    | 418.6028***<br>(38.1021)    | 272.4056***<br>(26.5851)   | 134.3913***<br>(11.7668)   | 287.0606***<br>(25.1502)   | 507.8265***<br>(41.9525)   | 945.1899***<br>(75.9296)   | 1861.7097***<br>(153.8506)  |
| ΔCR              | 39.6850***<br>(6.5984)      | 22.9529***<br>(3.7510)      | 14.7799***<br>(2.3998)      | 8.3469***<br>(1.3934)      | 3.1598***<br>(0.7028)      | 6.4881***<br>(1.3539)      | 14.5605***<br>(2.5310)     | 35.9165***<br>(5.3408)     | 100.0866***<br>(17.1675)    |

\*\*\* $p < 0.001$ ; \*\* $p < 0.01$ ; \* $p < 0.05$ ;  $p < 0.1$

# Term structure

- Carbon risk depends on the speed at which a transition to a low-carbon economy is expected to occur.
  - If new carbon regulation more pressing deadline, one would expect higher costs in the short-term than in the long-term.
  - The relative adjustment in the spread of the CDS with shorter tenor would be higher (steeper sloped) than in the spread of the CDS with longer tenor
- **Hypothesis 3.** *There is a positive relationship between the term structure of carbon risk and CDS spread slopes.*

$$Q_{\Delta \text{CDSSlope}_{i,t}^{mn}}(\tau | \mathbf{x}_{i,t}) = \alpha_{\tau,i} + \beta_{\tau,1} \Delta \sigma_{i,t} + \beta_{\tau,2} \Delta \text{MRISlope}_{i,t}^{mn} + \beta_{\tau,3} \Delta \text{IR}_t + \beta_{\tau,4} \Delta \text{IR}_t^2 \\ + \beta_{\tau,5} \Delta \text{Term}_t + \beta_{\tau,6} \Delta \text{CRSlope}_t^{mn} + \varepsilon_{i,t}.$$

# Term structure

|                        | 1                        | 2                        | 3                       | 4                      | 5                      | 6                      | 7                      | 8                        | 9                        |
|------------------------|--------------------------|--------------------------|-------------------------|------------------------|------------------------|------------------------|------------------------|--------------------------|--------------------------|
| <b>Europe</b>          |                          |                          |                         |                        |                        |                        |                        |                          |                          |
| 5Y-1Y                  |                          |                          |                         |                        |                        |                        |                        |                          |                          |
| $\Delta\text{CRSlope}$ | 353.5945***<br>(16.7947) | 215.2007***<br>(13.7138) | 113.0193***<br>(8.6147) | 58.2896***<br>(3.8606) | 39.9731***<br>(2.6112) | 44.2500***<br>(2.9025) | 78.7251***<br>(6.1190) | 179.0507***<br>(14.6170) | 298.5107***<br>(28.7738) |
| 30Y-5Y                 |                          |                          |                         |                        |                        |                        |                        |                          |                          |
| $\Delta\text{CRSlope}$ | 42.5578***<br>(4.5275)   | 22.9695***<br>(2.3894)   | 15.8313***<br>(1.4085)  | 12.1217***<br>(1.1429) | 10.2112***<br>(1.2485) | 10.6767***<br>(1.4320) | 14.5013***<br>(2.1351) | 23.5321***<br>(3.2717)   | 51.0791***<br>(8.7277)   |
| <b>North America</b>   |                          |                          |                         |                        |                        |                        |                        |                          |                          |
| 5Y-1Y                  |                          |                          |                         |                        |                        |                        |                        |                          |                          |
| $\Delta\text{CRSlope}$ | 5.9315*<br>(2.4082)      | 1.6704<br>(1.0545)       | 0.8668<br>(0.4838)      | 0.1435<br>(0.2528)     | 0.1358<br>(0.1345)     | 0.8133***<br>(0.2302)  | 0.0150<br>(0.5059)     | 3.8252**<br>(1.2494)     | 7.6882*<br>(3.8445)      |
| 30Y-5Y                 |                          |                          |                         |                        |                        |                        |                        |                          |                          |
| $\Delta\text{CRSlope}$ | 19.8645***<br>(2.4591)   | 6.9094***<br>(1.1527)    | 1.5547***<br>(0.4535)   | 0.2661<br>(0.1497)     | 0.0000<br>(0.0000)     | 0.0000<br>(0.0000)     | 2.1909***<br>(0.3512)  | 9.5158***<br>(1.1435)    | 22.2039***<br>(4.3056)   |

\*\*\*  $p < 0.001$ ; \*\*  $p < 0.01$ ; \*  $p < 0.05$ ;  $\cdot$   $p < 0.1$

## Conclusion

# Conclusion

- Using CDS, we construct a market-implied, forward-looking carbon risk (CR) factor that is frequently observable.
- Theory-motivated series of testable hypotheses:
  - CR effect is larger for European than North American firms
  - It varies substantially across industries, suggesting the market recognises where and which sectors are better positioned for a transition.
  - Lenders demand more credit protection when market-wide concern about climate change risk is elevated.
  - Lenders expect that adjustments in carbon regulations in Europe will cause relatively larger policy-related costs in the near future.

# Appendix

# Sectoral impact of carbon risk in Europe

|                                | 1                           | 2                           | 3                          | 4                          | 5                          | 6                          | 7                          | 8                           | 9                           |
|--------------------------------|-----------------------------|-----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|-----------------------------|-----------------------------|
|                                | 5Y Europe                   |                             |                            |                            |                            |                            |                            |                             |                             |
| BM $\times \Delta CR$          | 2635.0486***<br>(136.7416)  | 2039.9369***<br>(106.5365)  | 1622.3060***<br>(135.5422) | 1367.5791***<br>(124.2347) | 1163.9357***<br>(112.7050) | 1190.2961***<br>(116.7957) | 1506.2928***<br>(135.4464) | 1879.5701***<br>(139.6958)  | 2483.2993***<br>(150.0698)  |
| CCGS $\times \Delta CR$        | -1259.7501***<br>(186.8435) | -550.6241**<br>(169.0188)   | -414.3314*<br>(170.7295)   | -392.3054*<br>(160.5331)   | -374.2969*<br>(150.1221)   | -294.4811*<br>(147.4457)   | -329.8327*<br>(170.2029)   | -515.3413**<br>(198.9443)   | -979.0483***<br>(285.9997)  |
| Energy $\times \Delta CR$      | 3210.7447***<br>(258.3090)  | 3799.4465***<br>(236.0132)  | 4157.7234***<br>(312.9424) | 3977.4627***<br>(315.6460) | 4054.9884***<br>(380.8357) | 3927.4447***<br>(379.2532) | 3946.0388***<br>(392.9081) | 4143.1285***<br>(380.1269)  | 4155.7876***<br>(327.2889)  |
| Healthcare $\times \Delta CR$  | -533.2219<br>(410.3258)     | -430.5320<br>(224.7841)     | -693.9169**<br>(244.6901)  | -868.8361***<br>(181.9179) | -860.3701***<br>(153.7825) | -798.8671***<br>(160.4410) | -818.0790***<br>(217.7761) | -613.5303*<br>(243.1472)    | -624.4180***<br>(189.2104)  |
| Industrials $\times \Delta CR$ | -1534.8434***<br>(197.4163) | -1161.9663***<br>(153.9924) | -871.1393***<br>(171.7992) | -855.6191***<br>(149.7449) | -811.7809***<br>(132.8161) | -783.8478***<br>(141.2375) | -907.5344***<br>(160.4856) | -1134.5597***<br>(192.0243) | -1448.4525***<br>(238.4280) |
| NCGS $\times \Delta CR$        | -876.7949***<br>(191.0114)  | -647.6615***<br>(171.8185)  | -505.2052**<br>(174.0847)  | -594.3343***<br>(149.9326) | -535.3725***<br>(143.6876) | -508.6939***<br>(144.5947) | -505.6673**<br>(165.2040)  | -472.8208*<br>(199.2531)    | -574.4579*<br>(226.6391)    |
| Real Estate $\times \Delta CR$ | -503.5066<br>(685.1819)     | -759.4896**<br>(264.2884)   | -621.3419**<br>(204.5723)  | -661.4681**<br>(245.6483)  | -612.1811**<br>(216.4927)  | -645.3724***<br>(188.6989) | -846.4117***<br>(242.3864) | -853.1448**<br>(307.6265)   | -1038.1584***<br>(182.4528) |
| Technology $\times \Delta CR$  | -1188.0459***<br>(270.8479) | -750.1539***<br>(181.6456)  | -380.0095*<br>(174.4791)   | -319.9056<br>(166.0959)    | -322.3208*<br>(152.6769)   | -302.4374*<br>(149.5409)   | -449.9964**<br>(172.3128)  | -718.6014**<br>(223.3768)   | -1287.2472***<br>(323.7639) |
| Utilities $\times \Delta CR$   | 643.0311**<br>(244.3077)    | 1062.6126***<br>(295.3825)  | 1315.7241***<br>(237.3967) | 1243.0808***<br>(240.7925) | 1183.2474***<br>(237.2373) | 1159.0320***<br>(222.9624) | 1144.1407***<br>(218.9913) | 944.3103**<br>(293.1890)    | 379.7177<br>(442.3661)      |

\*\*\* $p < 0.001$ ; \*\* $p < 0.01$ ; \* $p < 0.05$ ;  $p < 0.1$

# Sectoral impact of carbon risk in North America

|                                  | 1                         | 2                         | 3                       | 4                       | 5                     | 6                       | 7                        | 8                         | 9                         |
|----------------------------------|---------------------------|---------------------------|-------------------------|-------------------------|-----------------------|-------------------------|--------------------------|---------------------------|---------------------------|
|                                  | 5Y North America          |                           |                         |                         |                       |                         |                          |                           |                           |
| BM $\times$ $\Delta$ CR          | 134.2020***<br>(22.1422)  | 73.1739***<br>(20.9819)   | 26.8565***<br>(6.6120)  | 9.0143**<br>(3.2642)    | 5.2372**<br>(1.9342)  | 17.5819***<br>(3.4828)  | 51.1306***<br>(8.7129)   | 158.1895***<br>(25.6145)  | 475.9486***<br>(87.2863)  |
| CCGS $\times$ $\Delta$ CR        | -268.7929***<br>(47.8668) | -108.5144***<br>(29.4108) | -42.6414***<br>(8.8490) | -17.3914***<br>(4.6684) | -8.5014**<br>(2.6916) | -15.7105***<br>(4.6614) | -40.4371***<br>(10.3433) | -98.6536***<br>(29.0669)  | -292.2269**<br>(104.3841) |
| Energy $\times$ $\Delta$ CR      | 359.8501**<br>(120.3118)  | 107.4149***<br>(28.1971)  | 25.8948**<br>(9.3342)   | 13.1895**<br>(5.0826)   | 6.7350*<br>(3.0811)   | 6.9067<br>(5.3902)      | 17.9016<br>(14.0167)     | 75.3827<br>(53.1914)      | 290.5323*<br>(129.5484)   |
| Healthcare $\times$ $\Delta$ CR  | -317.8247***<br>(61.7660) | -120.5179***<br>(23.9990) | -42.8808***<br>(9.9823) | -15.9604***<br>(4.3905) | -9.0386**<br>(2.8878) | -22.7586***<br>(4.8634) | -51.3124***<br>(9.9657)  | -129.3479***<br>(27.8857) | -352.6220***<br>(88.5933) |
| Industrials $\times$ $\Delta$ CR | -58.8887<br>(33.6827)     | -50.5460*<br>(24.3064)    | -18.7295*<br>(7.7620)   | -4.7886<br>(4.1003)     | -4.5672<br>(2.3497)   | -15.3120***<br>(4.0888) | -39.6480***<br>(9.3944)  | -100.7536***<br>(27.4467) | -244.6251*<br>(99.1527)   |
| NCGS $\times$ $\Delta$ CR        | -205.7833***<br>(34.1753) | -96.9792***<br>(24.9324)  | -38.2219***<br>(8.3607) | -12.9917**<br>(4.1360)  | -6.9182**<br>(2.4371) | -21.6799***<br>(4.2366) | -49.6078***<br>(9.8039)  | -126.5685***<br>(28.4296) | -387.1775***<br>(96.0439) |
| Real Estate $\times$ $\Delta$ CR | -89.3786<br>(76.9430)     | -59.2645*<br>(28.9494)    | -21.4444**<br>(8.2484)  | -5.8514<br>(3.9829)     | -3.7921<br>(2.2483)   | -16.6158***<br>(3.9881) | -46.8042***<br>(9.7225)  | -129.6556***<br>(33.2288) | -317.8760**<br>(104.5899) |
| Technology $\times$ $\Delta$ CR  | -130.9529***<br>(27.5800) | -88.7422***<br>(23.0913)  | -35.2402***<br>(7.3059) | -11.7445***<br>(3.5327) | -6.1426**<br>(2.1177) | -16.5987***<br>(3.6782) | -45.9432***<br>(9.1158)  | -119.4893***<br>(27.2033) | -365.7520***<br>(88.3408) |
| Utilities $\times$ $\Delta$ CR   | -55.8306*<br>(27.6215)    | -37.7196<br>(22.0511)     | -15.3568*<br>(7.2314)   | -3.5060<br>(3.5885)     | -2.7018<br>(2.1130)   | -11.4889**<br>(3.7820)  | -36.8113***<br>(9.1991)  | -113.8019***<br>(26.2388) | -324.5950***<br>(89.9750) |

\*\*\* $p < 0.001$ ; \*\* $p < 0.01$ ; \* $p < 0.05$ ; '  $p < 0.1$

# Attention to climate change

- Climate policies continually evolve within a rapidly changing environment.
- As new information arrives, lenders update their expectations accordingly.
- **Hypothesis 2.** *The effect of carbon risk on CDS spread returns is stronger during times of heightened attention to climate change.*

$$Q_{s_{i,t}^m}(\tau | \mathbf{x}_{i,t}) = \alpha_{\tau,i} + \beta_{\tau,1}r_{i,t} + \beta_{\tau,2}\Delta\sigma_{i,t} + \beta_{\tau,3}\Delta\text{MRI}_{i,t} + \beta_{\tau,4}\Delta\text{CR}_t \\ + \beta_{\tau,5}\text{HCNA}_t + \beta_{\tau,6}\text{HCNA}_t \times \Delta\text{CR}_t + \varepsilon_{i,t},$$

where High Climate News Attention  $\text{HCNA}_t$  is

- Transition Risk Concern (TRC) index of Bua et al. (2022) for Europe
- Media Climate Change Concerns (MCCC) index of Ardia et al. (2020) for North America

# Attention to climate change

|                         | 1                          | 2                          | 3                          | 4                          | 5                          | 6                          | 7                          | 8                          | 9                          |
|-------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| 1Y Europe               |                            |                            |                            |                            |                            |                            |                            |                            |                            |
| $\Delta CR$             | 5717.8850***<br>(319.8717) | 3965.8575***<br>(255.6186) | 2673.6630***<br>(192.2794) | 1765.3885***<br>(156.5043) | 1262.2707***<br>(135.2532) | 1550.9662***<br>(141.2297) | 2357.2314***<br>(186.7367) | 3487.6357***<br>(245.7772) | 4468.5534***<br>(460.8092) |
| $\Delta CR \times HCNA$ | -985.1238**<br>(355.8699)  | -391.0539<br>(266.7684)    | -218.5212<br>(203.4612)    | 38.8150<br>(160.9244)      | -46.3508<br>(128.1137)     | -107.7487<br>(127.3920)    | 50.4729<br>(137.6822)      | 667.7404***<br>(139.6417)  | 1730.7586***<br>(251.1084) |
| 3Y Europe               |                            |                            |                            |                            |                            |                            |                            |                            |                            |
| $\Delta CR$             | 3261.0629***<br>(108.4249) | 2302.9732***<br>(78.2846)  | 1785.1299***<br>(85.3139)  | 1205.2986***<br>(68.1468)  | 825.8216***<br>(56.4582)   | 990.3798***<br>(58.0675)   | 1535.5337***<br>(73.3855)  | 2015.6911***<br>(107.5739) | 2210.8436***<br>(253.7940) |
| $\Delta CR \times HCNA$ | -504.7779**<br>(160.5650)  | 195.7595<br>(102.4994)     | 234.7306*<br>(97.2718)     | 287.0357***<br>(81.3742)   | 180.7526**<br>(66.0090)    | 304.2399***<br>(71.2028)   | 381.2684***<br>(83.3265)   | 727.2008***<br>(89.5893)   | 1376.9828***<br>(214.4336) |
| 1Y North America        |                            |                            |                            |                            |                            |                            |                            |                            |                            |
| $\Delta CR$             | -656.3680***<br>(74.7403)  | -61.4624***<br>(9.1420)    | -3.1401***<br>(0.7412)     | -0.0081<br>(0.0103)        | 0.0000<br>(0.0000)         | 0.0352<br>(0.0434)         | 2.3247<br>(1.3157)         | 56.8682***<br>(14.8713)    | 579.9773***<br>(96.1729)   |
| $\Delta CR \times HCNA$ | 1116.7416***<br>(120.0891) | 143.1274***<br>(17.4037)   | 14.4600***<br>(1.7005)     | 0.1125***<br>(0.0305)      | 0.0000<br>(0.0000)         | 0.4390***<br>(0.1060)      | 20.7003***<br>(2.8864)     | 192.4156***<br>(26.1761)   | 1033.9511***<br>(214.9742) |
| 3Y North America        |                            |                            |                            |                            |                            |                            |                            |                            |                            |
| $\Delta CR$             | 172.6840***<br>(15.5473)   | 28.9189***<br>(6.6014)     | 7.3353***<br>(1.7831)      | 2.0569**<br>(0.7000)       | 0.5431<br>(0.3170)         | 2.4999**<br>(0.7847)       | 6.4782***<br>(1.8823)      | 31.9517***<br>(7.0728)     | 232.0533***<br>(38.2421)   |
| $\Delta CR \times HCNA$ | 39.6069<br>(24.2134)       | 34.3766***<br>(8.1508)     | 11.1717***<br>(2.3028)     | 4.6609***<br>(1.0228)      | 1.4623**<br>(0.5097)       | 3.6201**<br>(1.1831)       | 12.5709***<br>(3.2296)     | 26.6548**<br>(10.0049)     | 53.6492<br>(44.7806)       |

\*\*\* $p < 0.001$ ; \*\* $p < 0.01$ ; \* $p < 0.05$ ;  $p < 0.1$