Online Appendix to

"Climate Change News Risk and Corporate Bond Returns"

Thanh D. Huynh and Ying Xia*

* Huynh, Department of Banking and Finance, Monash Business School, Monash University, 900 Dandenong Road, Caulfield East, VIC 3145, Australia, E-mail: thanh.huynh@monash.edu, Tel: (61)3 99031474; Xia (corresponding author), Department of Banking and Finance, Monash Business School, Monash University, 900 Dandenong Road, Caulfield East, VIC 3145, Australia, E-mail: ying.xia@monash.edu, Tel: (61)3 99031257. We are grateful to Michael Barnett (the referee) and Hendrik Bessembinder (the editor) for their extremely helpful comments and suggestions. We also thank Stephen Brown, Neal Galpin, Michael Gofman, Roger Edelen, Bart Frijns, Zhiguo He, Juhani Linnainmaa, Christian Lundblad, Lyndon Moore, and Phong Ngo for their constructive comments. We thank Stefano Giglio and Johannes Stroebel for making the climate change news index data available. All errors are our own.

Section A of this online appendix discusses a battery of tests to check the robustness of our findings. In Section B, we describe the calculation of the environmental score using data from the MSCI ESG database. The tables in Section A are organized as follows.

Section A: Robustness Tests

A1. Fama-MacBeth Regression Approach

We first examine whether our findings hold when we use the Fama and MacBeth (1973) cross-sectional regression approach to estimate the relation between β^{CCN} and future excess bond returns. Table A1 presents the time-series averages of the slope coefficients and Newey and West (1987) *t*-statistics from the regressions of one-month-ahead excess bond returns on β^{CCN} and control variables. We find that the coefficient on β^{CCN} is negative and statistically significant at the 1% level. These results confirm that our findings do not qualitatively change under this alternative regression framework.

A2. Return Predictability

We next examine whether β^{CCN} has long-term predictive power for future bond returns. We do so by regressing future excess bond returns from month $t + 2$ to month $t + 12$ on β^{CCN} measured in month t. The results in Table A2 indicate that the predictive power of β^{CCN} remains significant when predicting future two- to eight-month returns (i.e., Columns 1 to 7). The predictability, however, becomes insignificant from month $t + 9$ onward and does not reverse. The fact that the negative effect is significant beyond month $t + 1$ suggests that our results are not driven by a short-run reversal effect or a mechanical effect arising from bid-ask bounce (Jegadeesh (1990) and Lehman (1990)).

A condition for β^{CCN} to predict future returns is that β^{CCN} computed in month t must be a good predictor of future β^{CCN}. This is because, to feasibly hedge against climate change risk in the bond market, investors should be able to infer a bond's future exposure from its past exposure. We examine this question by regressing future β^{CCN} from month t + 1 to month t + 8 on β^{CCN} in month t. The results are reported in Panel B of Table A2. We find that the coefficient on β^{CCN} in month t is large, positive, and statistically significant in all the predictive models, suggesting that investors can feasibly use the current beta of a bond to hedge against climate change news risk.

A3. Corporate Bond Yield Spreads

We examine the effect of climate change news risk on corporate bond yields. In contrast to bond returns, which have a number of common cross-sectional determinants related to bond and firm characteristics (Fama and French (1992), (1993) and Bai, Bali, and Wen (2019)), bond yields are chiefly determined by credit risk and liquidity risk (Longstaff, Mithal, and Neis (2005) and Bao, Pan, and Wang (2011)). Since a factor that affects bond returns might not necessarily drive yields (Campbell (1995)), it would be useful to examine whether our baseline findings hold for bond yields. This test also provides guidance as to whether the effect of β^{CCN} likely comes from changes in the bond principal or changes in yields. The intertemporal hedging hypothesis posits that investors prefer bonds with a high β^{CCN} and thus, these bonds should have higher prices than those with a low β^{CCN}. Due to the inverse relation between prices and yields, this prediction suggests that β^{CCN} is negatively associated with yields.

We follow Nanda, Wu, and Zhou (2019) to compute yield spreads as the difference between volume-weighted yields on corporate bonds and the estimated yield on government bonds for the period from January 2005 to December 2016. The monthly trading yield on a corporate bond is the volume-weighted average of the yield to maturity across intraday transactions at the end of each month, where transactions data are obtained from TRACE and are cleaned following the procedure described in the main text of our paper. To estimate yields on government bonds that are matched with the maturity of corporate bonds, we employ Nelson and Siegel's (1987) model as extended by Bliss (1997).

We estimate the regression of bond yield spreads in month $t + 1$ on β_t^{CCN}, the control variables, and various fixed effects as in the baseline specification. We report the estimation results in Table A3. The coefficients on β^{CCN} are negative and statistically significant at the 1% level, indicating that bonds with higher climate change news betas have lower yield spreads. The effect is also economically meaningful. For example, the coefficient on β^{CCN} in Column 2 is -0.037, which means that a one-standard-deviation increase in the climate change news beta is associated with a drop of 7.75 bps ($= -0.037 \times 2.095$) in the next month's bond yield spreads, which is equivalent to a decrease of 3.36% relative to the sample mean of bond yield spreads. These results suggest that investors perceive a bond with a higher climate change news beta to be less risky, confirming our central hypothesis that bonds with higher climate change news betas provide greater potential for investors to hedge against climate change news risk.

A4. Alternative Climate Change News Index

We next employ an alternative climate change news index provided by Engle, Giglio, Kelly, Lee, and Stroebel (2020), the CH negative climate change news index. The CH index is obtained from the data analytics vendor Crimson Hexagon and is only available from June 2008. It is calculated as the share of all news articles that focus on climate change and which have been categorized by Crimson Hexagon as news with negative sentiment.

As before, we estimate bond-level exposure to the climate change index, denoted β^{CH}, which captures a bond's covariance with the CH index. A high β^{CH} indicates that the bond performs better when the CH index is higher (i.e., a more negative sentiment). Since we require 30 months of valid returns to estimate the betas, the sample period is reduced to six years, from January 2011 to December 2016. We re-estimate our baseline regression of future bond returns on β^{CH}, the controls, and various fixed effects. We expect the coefficient on β^{CH} to be negative, because investors' preference for high-β^{CH} bonds will bid up the prices of these bonds, causing future returns to be lower.

We report the estimation results in Table A4. The sample size is reduced by 50% compared to the sample of the WSJ index. The estimation results show that the coefficient on β^{CH} remains negative and statistically significant at the 1% level. These results reassure that our findings are not specific to the WSJ climate change news index and are also consistent with Engle et al. (2020), who show that both indexes produce qualitatively consistent conclusions.

A5. Credit Ratings

A potential concern regarding our results is that the pricing of β^{CCN} could be specific to a category of credit ratings such as non-investment-grade bonds, which are riskier and less liquid (Chen, Lesmond, and Wei (2007)). We thus partition the sample into two groups, based on whether the bond's credit rating is investment grade (i.e., an S&P credit rating from BBB− to AAA) or non-investment grade (i.e., an S&P credit rating from B− to BB+). We present the results in Table A5. We find that the coefficient on β^{CCN} is negative and statistically significant in both subsamples. Moreover, a Z-statistics test shows that the estimated coefficients in the two subsamples are not statistically different from each other, suggesting that the effect of β^{CCN} is equally strong among both investment-grade and non-investment-grade bonds.

A6. Discount Rate Risk versus Cash Flow Risk

Since a bond's future cash flows are relatively stable due to the fixed coupon rate and the principal amount, one could argue that the pricing of the climate change news beta comes from changes in the discount rate (i.e., yield to maturity), rather than cash flows. However, the climate change news risk could still be positively associated with a bond's cash flow risk, such as changes to the issuer's bankruptcy risk or cash flows. In this section, we conduct further tests to investigate whether the climate change news premium comes from changes in the cash flow risk. We do so by examining the effects of the issuer's overall climate change news beta aggregated across the issuer' bond betas on firm-level expected default risk and future cash flows.

Following prior studies (Bharath and Shumway (2008) and Brogaard, Li, and Xia (2017)), we measure default risk as the expected default frequency (EDF), which captures the probability of the firm's cash flows not meeting its debt obligations. Specifically, we compute a firm's EDF as follows:

$$\text{DISTANCE\_TO\_DEFAULT}_{j,t} = \frac{log\left(\frac{\text{EQUITY}_{j,t} + \text{DEBT}_{j,t}}{\text{DEBT}_{j,t}}\right) + (r_{j,t-1} - \frac{\sigma_{Vj,t}^2}{2}) \times T_{j,t}}{\sigma_{Vj,t} \times \sqrt{T_{j,t}}},$$

$$\sigma_{Vj,t} = \frac{\text{EQUITY}_{j,t}}{\text{EQUITY}_{j,t} + \text{DEBT}_{j,t}} \times \sigma_{Ej,t} + \frac{\text{DEBT}_{j,t}}{\text{EQUITY}_{j,t} + \text{DEBT}_{j,t}} \times \left(0.05 + 0.25 \times \sigma_{Ej,t}\right),$$

$$\text{EDF}_{j,t} = N\left(-\text{DISTANCE\_TO\_DEFAULT}_{j,t}\right),$$

where $\text{EQUITY}_{j,t}$ is the market value of equity; $\text{DEBT}_{j,t}$ is the face value of debt, computed as the sum of debt in current liabilities and one-half of the long-term debt at the end of the year; $r_{j,t-1}$ is firm *j*'s past annual return; $\sigma_{Ej,t}$ is the stock return volatility of firm *j* during year *t*; $\sigma_{Vj,t}$, calculated from $\sigma_{Ej,t}$, is an approximation of the volatility of the firm's assets; $T_{j,t}$ is set to one year; and, finally, *N(.)* is the cumulative standard normal distribution function.

We also examine whether the firm's future cash flows are affected by the firm's overall climate change news beta. We measure a firm's cash flow (CF) as operating income before depreciation (OIBDP), scaled by the book value of total assets (AT). We estimate panel regressions at the firm–year level in which the firm's EDF or future CF is regressed on the annual climate change news beta and other known factors that affect EDF and CF. The annual firm-level climate change news beta, $\beta^{\text{CCN\_FIRM}}$, is computed as the weighted average of the monthly climate change news betas of the firm's bonds, using the ratio of a bond's issuing dollar amount over the total dollar amount of all bonds as the weight.

The results in Table A6 reveal an insignificant relation between the climate change news beta and either the expected default risk or future cash flows. A possible reason for the insignificant relation between β^{CCN_FIRM} and EDF is that the right-hand side variable in this regression is the firm-level climate change news beta, which is the weighted average of β^{CCN} across all bonds of the firm. The variable EDF captures the probability of default in year $t + 1$, given the firm's observable fundamentals in year t (Bharath and Shumway, 2008). While a bond's β^{CCN} can be associated with the market's perception about the credit risk of the bond per se, the average beta of a firm's bonds (β^{CCN_FIRM}) might not affect the firm's overall default risk computed by using its fundamentals.

Overall, these results provide suggestive evidence that the effect of β^{CCN} is potentially driven by investors' perceptions about a bond's exposure to climate change risk, but the firm's fundamentals are not necessarily affected by changes in β^{CCN}.

A7. Placebo Test

A potential concern is that our findings could be driven by the potential systematic measurement error arising from the method to estimate the climate change news beta.[1] To mitigate this concern, we conduct a placebo test by repeating the same analysis on a sample of U.S. government bonds over the period from 2005 to 2016.

[1] The results of the subsample analysis in Table 6 also serve to rule out these mechanical explanations. For example, we find an insignificant effect in the subsample of top polluting industries.

On the one hand, government bonds could also be exposed to the climate change news index, because, for example, governments' revenues can decline when severe disasters hit a large number of businesses. In this case, government bonds could be a negative hedging asset. On the other hand, the government might not be as vulnerable to regulatory risk as companies are. Government bonds can serve as a positive hedging asset when investors are concerned about the climate risk exposure of individual corporate bonds. We therefore would expect the relation between β^{CCN_GOV} and future returns on government bonds to be negative, because investors are willing to accept lower returns on these government bonds to hedge against climate change news risk.

If we find a significant relation between β^{CCN_GOV} and future returns on government bonds, then the mechanics of beta estimation could play a role. In contrast, if the effect is insignificant in the sample of government bonds, then we have reason to believe that the estimation error of beta is not systematic, and it does not necessarily give rise to a mechanical result. In this case, the insignificant effect on government bonds could possibly be due to the climate change news index being dominated by news on the climate change risk faced by U.S. corporations or that is simply specific to the U.S. market.[2]

[2] An alternative explanation for the insignificant result of government bonds is that a fair comparison cannot be made between short-term and long-term U.S. government bonds. Rather, the comparison should be between U.S. government bonds and similar sovereign bonds of other developed countries, which is an interesting venue for future research. FTSE Russell recently launched the world's first Climate Risk Government Bond Index, which quantifies the climate risk of sovereign debt (see, https://www.ftserussell.com/press/ftse-russell-launches-first-climate-risk-government-bond-index).

We obtain data on U.S. Treasury bonds from Bloomberg and construct a sample of monthly returns on two-, five-, seven-, 10-, 20-, and 30-year Treasury bonds. Similar to our baseline analysis, we compute the climate change news beta for each government bond in a given month by estimating monthly rolling regressions of excess returns on government bonds on innovations in the monthly climate change news index over the past 60 months, controlling for the term spread, the default spread, and the TED spread.

Table A7 reports the results of these tests. Column 1 shows the results from the regression of monthly returns on government bonds (in excess of the one-month T-bill) on contemporaneous innovations in the climate change news index and controls. Column 2 presents the results for the regression of one-month-ahead excess returns on government bonds on the estimated climate change news beta and controls. We control for bond, year, and month fixed effects in both regressions. We find that the relation between future government bond returns and climate change news (or its beta) is statistically insignificant. These findings indicate that the negative relation for corporate bonds is not a mechanical result.

A8. Alternative Climate Change News Betas

We next examine whether our findings still hold when using a shorter rolling window to estimate β^{CCN}. Specifically, for each bond *i* in each month *t*, we estimate equation (2) in the main text of the paper over a 36-month window (or 24-month window) and obtain the $\beta^{CCN,\ 36}$ ($\beta^{CCN,\ 24}$) estimates from these regressions as alternative climate change news betas. To maintain a meaningful estimation, we require bonds to have at least 18 (or 12) valid monthly return observations over the past 36 (or 24) months. We re-estimate the baseline regression of one-month-ahead future excess bond returns on these alternative betas and report the estimation results in Table A8.

Across all models, the relation between alternate β^{CCN} (i.e., $\beta^{CCN,\,36}$ and $\beta^{CCN,\,24}$) and future excess bond returns is negative and statistically significant at the 1% level, suggesting that the effect of β^{CCN} is not specific to a choice of estimation windows. These results are also consistent with those reported in Panel B of Table A2, which indicate that the current β^{CCN} is a good predictor of future β^{CCN}. This is helpful for the intertemporal β^{CCN} hypothesis because, to feasibly hedge against climate change risk using a bond's β^{CCN}, investors should be able to infer the bond's future β^{CCN} from its past β^{CCN} (Bali, Brown, and Tang (2017)).

A9. Sensitivity Analysis Using A Sample of All Rated Bonds

Our baseline analysis does not consider junk bonds with "substantial risks" according to S&P ratings (i.e., a rating of CCC+ or below) to avoid the contamination of these relatively illiquid and risky bonds on our results. In this section, we examine whether our conclusions hold when using a sample of all bonds with all ratings, that is, S&P ratings from AAA to D. We re-estimate the baseline regression of future excess bond returns on β^{CCN} and controls and report the estimation results in Table A9. We continue to find a negative coefficient on β^{CCN}, suggesting that our headline findings are robust.

A10. Controlling for Stock-Level Climate Change News Beta

To ensure that the effect of bond-level climate change news beta is not confounded by the stock-level effect, we control for the stock-level climate change news beta (β^{CCN_EQUITY}), which is estimated from the monthly rolling regressions of equity excess returns on innovations in the monthly Climate Change News Index over a 60-month window, controlling for Fama and French's (2015) five risk factors and momentum factor. We include β^{CCN_EQUITY} as an additional control variable in the baseline regression and report the estimation results in Table A10. Consistently, we find that the coefficient on bond β^{CCN} remains negative and statistically significant even after we include β^{CCN_EQUITY} in the regressions. The coefficient on β^{CCN_EQUITY} is, however, statistically and economically insignificant, suggesting that β^{CCN_EQUITY} plays an insignificant role in the pricing of individual corporate bonds. This result is also consistent with the well-established notion that one cannot infer the behavior of bond investors by observing stock investors' behavior (Hendershott, Kozhan, and Raman (2020)).

Section B: Calculation of firm-level environmental performance using MSCI ESG data (ESCORE)

Following prior research (e.g., Engle et al. (2020)), we compute the environmental performance, ESCORE, for each firm in a given year as the difference between environmental strengths and concerns.

Specifically, using the information from the MSCI ESG database, strengths are the sum of the following sub-categories: environmental opportunities (MSCI variable: ENV_STR_A), waste management (MSCI variable: ENV_STR_B), packaging materials and waste (MSCI variable: ENV_STR_C), climate change (MSCI variable: ENV_STR_D), property, plant, equipment (MSCI variable: ENV_STR_F), environmental management systems (MSCI variable: ENV_STR_G), water stress (MSCI variable: ENV_STR_H), biodiversity and land use (MSCI variable: ENV_STR_I), raw material sourcing (MSCI variable: ENV_STR_J), natural resource use (MSCI variable: ENV_STR_K), environmental opportunities—green buildings (MSCI variable: ENV_STR_L), environmental opportunities in renewable energy (MSCI variable: ENV_STR_M), waste management—electronic waste (MSCI variable: ENV_STR_N), climate change—energy efficiency (MSCI variable: ENV_STR_O), climate change—product carbon footprint (MSCI variable: ENV_STR_P), climate change—insuring climate change risk (MSCI variable: ENV_STR_Q), and other strengths (MSCI variable: ENV_STR_X);

Concerns are the sum of the following sub-categories: regulatory compliance (MSCI variable: ENV_CON_B), toxic spills and releases (MSCI variable: ENV_CON_D), climate change (MSCI variable: ENV_CON_F), impact of products and services (MSCI variable: ENV_CON_G), biodiversity and land use (MSCI variable: ENV_CON_H), operational waste (MSCI variable: ENV_CON_I), supply chain management (MSCI variable: ENV_CON_J), water management (MSCI variable: ENV_CON_K), and other concerns (MSCI variable: ENV_CON_X).

Reference

Bali, T. G.; S. J. Brown; and Y. Tang. "Is economic uncertainty priced in the cross-section of stock returns?" *Journal of Financial Economics*, 126 (2017), 471–489.

Bali, T. G.; A. Subrahmanyam; and Q. Wen. "The economic uncertainty premium in corporate bond returns: An empirical investigation." Working Paper, Georgetown University (2019).

Bao, J.; J. Pan; and J. Wang. "The illiquidity of corporate bonds." *Journal of Finance*, 66 (2011), 911–946.

Bharath, S. T., and T. Shumway. "Forecasting default with the Merton distance to default model." *Review of Financial Studies*, 21 (2008), 1339–1369.

Bliss, R. R. "Testing term structure estimation methods." *Advances in Futures and Options Research,* 9 (1997), 197–232.

Brogaard, J.; D. Li; and Y. Xia. "Stock liquidity and default risk." *Journal of Financial Economics*, 124 (2017), 486–502.

Campbell, J. Y. "Some lessons from the yield curve." *Journal of Economic Perspectives*, 9 (1995), 129–152.

Engle, R. F.; S. Giglio; B. T. Kelly; H. Lee; and J. Stroebel. "Hedging climate change news." *Review of Financial Studies*, 33 (2020), 1184–1216.

Fama, E. F., and J. D. MacBeth. "Risk, return, and equilibrium: Empirical tests." *Journal of Political Economy*, 81 (1973), 607–636.

Fama, E. F., and K. R. French. "The cross-section of expected stock returns." *Journal of Finance,* 47 (1992), 427–465.

Fama, E. F., and K. R. French. "Common risk factors in the returns on stocks and bonds." *Journal of Financial Economics*, 33 (1993), 3–56.

Fama, E. F., and K. R. French. "A five-factor asset pricing model." *Journal of Financial Economics*, 116 (2015), 1–22.

Gormley, T.A., and D.A. Matsa. "Common errors: How to (and not to) control for unobserved heterogeneity." *Review of Financial Studies,* 27 (2013), 617–661.

Hendershott, T.; R. Kozhan; and V. Raman. Short selling and price discovery in corporate bonds. *Journal of Financial and Quantitative Analysis 55* (2020), 77–115.

Jegadeesh, N. "Evidence of predictable behavior of security returns." *Journal of Finance*, 45 (1990), 881–898.

Lehmann, B. N. "Fads, martingales, and market efficiency." *Quarterly Journal of Economics*, 105 (1990), 1–28.

Longstaff, F. A.; S. Mithal; and E. Neis. "Corporate yield spreads: Default risk or liquidity? New evidence from the credit default swap market." *Journal of Finance,* 60 (2005), 2213–2253.

Nanda, V.; W. Wu; and X. A. Zhou. "Investment commonality across insurance companies: Fire sale risk and corporate yield spreads." *Journal of Financial and Quantitative Analysis*, 54 (2019), 2543–2574.

Nelson, C. R., and A. F. Siegel. "Parsimonious modeling of yield curves." *Journal of Business,* 60 (1987), 473–489.

Newey, W. K., and K. D. West. "Hypothesis testing with efficient method of moments estimation." *International Economic Review* 28 (1987), 777–787.

Table A1. Robustness Test: Fama-Macbeth Cross-Sectional Regressions

This table reports the average Fama-MacBeth regression slopes and their corresponding *t*-statistics from the cross-sectional regressions of one-month-ahead corporate bond excess returns on β^{CCN} over the sample period of January 2005 to December 2016. Column 1 presents results for the regression in which all variables are demeaned by firm. Column 2 presents results for the regression in which all variables are demeaned by bond. The demeaning method controls for unobservable time-invariant cross-sectional differences in betas across firms and across bonds (Gormley and Matsa (2013)). Newey and West (1987) *t*-statistics are presented in parentheses. *, **, and *** indicates statistical significance at the 10%, 5%, and 1% level, respectively. Variables are defined in the main text of the paper.

	Dependent Variable: Future EXCESS_RETURN	
Variable	(1)	(2)
β^{CCN}	-0.018***	-0.039***
	(-2.966)	(-2.944)
DOWNSIDE_RISK	0.058***	0.062**
	(3.379)	(2.145)
ln(MATURITY)	0.147**	0.253
	(2.452)	(1.433)
ln(1+RATING)	0.184*	0.346**
	(1.736)	(2.132)
ln(AMOUNT_OUT)	0.016	0.298***
	(0.774)	(2.717)
REVERSAL	-0.110***	-0.103***
	(-6.780)	(-5.455)
ILLIQUIDITY	0.028***	0.020**
	(7.330)	(2.373)
β^{BOND_MARKET}	-0.026	0.009
	(-0.426)	(0.112)
β^{TERM}	0.009***	0.009***
	(4.453)	(3.199)
$\beta^{DEFAULT}$	-0.001**	-0.001
	(-2.218)	(-0.879)
β^{TED}	-0.002	-0.004
	(-0.270)	(-0.244)
IDIO_RISK	0.091**	0.106***
	(2.425)	(2.663)
LEVERAGE	0.103	0.328*
	(0.562)	(1.780)
ln(MARKET_CAP)	-0.022	-0.038
	(-0.708)	(-0.579)
ROE	0.000	-0.001
	(-0.041)	(-0.199)
Number of Obs	239,164	239,164
Adj. R-squared	0.071	0.058

Table A2. Return Predictability and Climate Change News Beta Predictability

This table presents the results from the panel regressions of future excess bond returns in month *t*+2 to month *t*+12 on β^{CCN} and control variables measured in month *t* (i.e., skipping at least one month between the dependent variable and independent variables). In Panel A, the dependent variables in Columns 1 to 11 are the bond's excess returns in month *t*+2 to month *t*+12, respectively. The independent variables are β^{CCN} and control variables measured in month *t*. In Panel B, the dependent variables in Columns 1 to 8 are a bond's β^{CCN} in month *t*+1 to month *t*+8, respectively. The independent variables are β^{CCN} and control variables, in month *t*. Both bond and year fixed effects are included in all regressions. Standard errors are clustered at the issuer level in all regressions. *t*-statistics are presented in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively. Variables are defined in the main text of the paper.

Panel A: Return predictability

	Dependent Variable: Future EXCESS_RETURN										
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Variable	*t*+2	*t*+3	*t*+4	*t*+5	*t*+6	*t*+7	*t*+8	*t*+9	*t*+10	*t*+11	*t*+12
β^{CCN}	-0.041***	-0.039***	-0.045***	-0.034***	-0.025***	-0.022***	-0.012**	-0.000	-0.001	0.004	0.012
	(-6.832)	(-7.353)	(-8.123)	(-6.545)	(-6.054)	(-4.936)	(-2.372)	(-0.019)	(-0.141)	(0.692)	(1.593)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bond fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of Obs	233,796	228,370	222,963	217,511	211,980	204,788	197,750	190,870	184,177	177,676	171,345
Adj. R-squared	0.070	0.062	0.058	0.053	0.056	0.056	0.058	0.063	0.038	0.032	0.033

Panel B: Climate change news beta predictability

	Dependent Variable: Future β^{CCN}							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variable	*t*+1	*t*+2	*t*+3	*t*+4	*t*+5	*t*+6	*t*+7	*t*+8
β^{CCN}	0.888***	0.794***	0.708***	0.638***	0.574***	0.515***	0.463***	0.416***
	(246.829)	(122.427)	(81.713)	(60.726)	(47.422)	(37.970)	(31.377)	(26.375)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bond fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of Obs	236,917	228,511	220,338	212,379	204,681	197,180	189,926	182,883
Adj. R-squared	0.838	0.714	0.607	0.522	0.450	0.389	0.337	0.297

Table A3. Climate Change News Beta and Corporate Bond Yield Spreads

This table presents the results from the panel regressions of one-month-ahead bond yield spreads on β^{CCN} over the sample period from January 2005 to December 2016. The dependent variable, YIELD_SPREAD, is measured in month *t*+1. Standard errors are clustered at the firm level in all regressions. *t*-statistics are presented in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively. Variables are defined in the main text of the paper.

	Dependent Variable: Future YIELD_SPREAD	
Variable	(1)	(2)
β^{CCN}	-0.034***	-0.037***
	(-4.380)	(-3.831)
DOWNSIDE_RISK	0.209***	0.207***
	(11.141)	(10.552)
ln(MATURITY)	-0.317***	-0.208
	(-6.940)	(-1.433)
ln(1+RATING)	0.612**	0.143
	(2.378)	(0.538)
ln(AMOUNT_OUT)	-0.083**	0.342***
	(-2.554)	(3.289)
REVERSAL	-0.070***	-0.065***
	(-8.764)	(-8.719)
ILLIQUIDITY	0.151***	0.146***
	(5.547)	(5.861)
β^{BOND_MARKET}	-0.284***	-0.357***
	(-5.668)	(-4.097)
β^{TERM}	-0.006*	-0.006*
	(-1.671)	(-1.690)
$\beta^{DEFAULT}$	-0.003***	-0.004***
	(-5.397)	(-4.602)
β^{TED}	-0.003	0.004
	(-0.628)	(0.776)
IDIO_RISK	0.478***	0.425***
	(11.881)	(11.083)
LEVERAGE	0.162	-1.070
	(0.287)	(-1.595)
ln(MARKET_CAP)	-1.805***	-2.028***
	(-13.422)	(-13.891)
ROE	-0.000	-0.004*
	(-0.182)	(-1.812)
Firm fixed effects	Yes	No
Bond fixed effects	No	Yes
State fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
Month fixed effects	Yes	Yes
Number of Obs	224,510	224,510
Adj. R-squared	0.393	0.397

Table A4. Crimson Hexagon Climate Change News Beta and Corporate Bond Returns
This table presents the results from the panel regressions of one-month-ahead bond excess returns (EXCESS_RETURN) on β^{CH} with and without control variables over the sample period from January 2011 to December 2016, where β^{CH} captures a bond's covariance with the Crimson Hexagon (CH) negative climate change news index. Standard errors are clustered at the issuer level in all regressions. *t*-statistics are presented in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively. Variables are defined in the main text of the paper.

	Dependent Variable: Future EXCESS_RETURN			
Variable	(1)	(2)	(3)	(4)
β^{CH}	-0.023***	-0.029***	-0.010***	-0.021***
	(-8.687)	(-6.076)	(-4.294)	(-4.985)
DOWNSIDE_RISK			-0.002	-0.022**
			(-0.238)	(-2.163)
ln(MATURITY)			0.148***	-0.240**
			(7.353)	(-2.343)
ln(1+RATING)			0.260	0.692
			(1.483)	(1.619)
ln(AMOUNT_OUT)			-0.035***	0.342*
			(-3.897)	(1.781)
REVERSAL			-0.049***	-0.067***
			(-4.750)	(-6.446)
ILLIQUIDITY			0.032***	0.026***
			(3.716)	(2.926)
β^{BOND_MARKET}			0.198***	0.461***
			(7.733)	(7.266)
β^{TERM}			0.007***	0.013***
			(4.471)	(4.863)
$\beta^{DEFAULT}$			-0.003***	-0.005***
			(-4.797)	(-4.908)
β^{TED}			-0.003	-0.010*
			(-1.020)	(-1.854)
IDIO_RISK			0.168***	0.169***
			(4.470)	(4.551)
LEVERAGE			0.065	0.081
			(0.200)	(0.208)
ln(MARKET_CAP)			-0.087	-0.104
			(-1.133)	(-1.432)
ROE			-0.002	-0.004
			(-0.505)	(-0.718)
Firm fixed effects	Yes	No	Yes	No
Bond fixed effects	No	Yes	No	Yes
State fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes
Number of Obs	113,129	113,129	112,760	112,760
Adj. R-squared	0.091	0.095	0.106	0.110

Table A5. Credit Rating, Climate Change News Beta, and Future Bond Returns

This table presents the results from regressions in subsamples partitioned based on the credit ratings of corporate bonds. Columns 1 and 3 report results for the subsample of bonds with investment-grade ratings, i.e., S&P credit rating from BBB− to AAA. Columns 2 and 4 report results for bonds below investment grade ratings, i.e., S&P credit rating from B− to BB+. *Z*-statistics are for the statistical test of the difference between the coefficient estimate on β^{CCN} in the investment-grade subsample and the coefficient estimate on β^{CCN} in the non-investment-grade subsample. Standard errors are clustered at the firm level in all regressions. *t*-statistics are presented in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively. Variables are defined in the main text of the paper.

	Dependent Variable: Future EXCESS_RETURN			
	(1)	(2)	(3)	(4)
Variable	*Investment Grade*	*Non-Investment Grade*	*Investment Grade*	*Non-Investment Grade*
β^{CCN}	-0.016***	-0.012**	-0.028***	-0.024**
	(-4.445)	(-2.058)	(-4.792)	(-2.191)
DOWNSIDE_RISK	0.075***	0.027***	0.097***	0.061***
	(11.922)	(3.486)	(11.372)	(6.973)
ln(MATURITY)	0.120***	0.029	0.438***	0.550***
	(10.078)	(1.408)	(14.050)	(5.684)
ln(1+RATING)	0.218***	-0.072	0.469***	-0.013
	(2.798)	(-0.509)	(3.160)	(-0.054)
ln(AMOUNT_OUT)	0.025***	0.035**	0.392*	0.474***
	(3.267)	(2.212)	(1.905)	(4.426)
REVERSAL	-0.084***	-0.028***	-0.096***	-0.057***
	(-11.093)	(-5.734)	(-12.927)	(-10.024)
ILLIQUIDITY	0.037***	0.049***	0.042***	0.017*
	(6.633)	(3.419)	(6.662)	(1.900)
β^{BOND_MARKET}	-0.115***	0.007	-0.164***	0.080**
	(-4.133)	(0.260)	(-3.238)	(2.340)
β^{TERM}	0.004***	0.009***	0.007***	0.013***
	(4.512)	(6.754)	(5.300)	(6.766)
$\beta^{DEFAULT}$	-0.001***	-0.001*	-0.001***	-0.000
	(-3.313)	(-1.696)	(-3.976)	(-0.379)
β^{TED}	-0.001	-0.008***	-0.001	-0.013***
	(-0.411)	(-3.241)	(-0.368)	(-3.717)
IDIO_RISK	0.145***	0.140***	0.168***	0.171***
	(5.593)	(6.462)	(6.263)	(11.012)
LEVERAGE	-0.068	0.513**	-0.076	1.377***
	(-0.349)	(2.442)	(-0.322)	(4.774)
ln(MARKET_CAP)	-0.077*	0.108***	-0.103**	-0.061
	(-1.679)	(3.261)	(-2.364)	(-1.232)
ROE	0.002	-0.285***	0.002	0.004
	(0.831)	(-4.018)	(0.717)	(1.347)

Z-statistics for the difference in the coefficients on β^{CCN}	0.551		0.341	
Firm fixed effects	Yes	Yes	No	No
Bond fixed effects	No	No	Yes	Yes
State fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes
Number of Obs	195,249	43,915	195,249	43,915
Adj. R-squared	0.087	0.095	0.086	0.106

Table A6. Default Risk, Cash Flow Risk, and Firm-Level Climate Change News Beta
This table presents the results from the regressions of cash flow risk measures on climate change news exposure. EDF is a firm's expected default frequency calculated following Bharath and Shumway (2008) and Brogaard, Li, and Xia (2017). CF is calculated as operating income before depreciation (OIBDP) scaled by book value of total assets (AT). β^{CCN_FIRM} is the weighted average of β^{CCN} across all bonds of the firm using the amount outstanding as weight. Standard errors are clustered at the firm level in all regressions. *t*-statistics are presented in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively. Variables are defined in the main text of the paper.

Variable	EDF_{t+1} (1)	CF_{t+1} (2)
β^{CCN_FIRM}	0.001	-0.001
	(0.907)	(-1.101)
ANNUAL_RETURN	-0.003	0.013***
	(-0.552)	(4.046)
ASSET_VOLATILITY	-0.084***	-0.012
	(-3.904)	(-1.240)
LEVERAGE	0.054	0.093***
	(1.369)	(4.578)
ln(MARKET CAP)	-0.153***	0.042***
	(-15.443)	(7.171)
NET_INCOME	0.064	-0.033
	(1.397)	(-0.312)
Firm fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
Number of Obs	6,163	6,152
Adj. R-squared	0.288	0.093

Table A7. Government Bond Returns and Climate Change News Risk

This table presents the results for tests using returns on individual government bonds over the sample period from January 2005 to December 2016. The dependent variables in Columns 1 and 2 are, respectively, excess returns government bond in month t and t+1. CCN is innovations in the monthly Climate Change News Index. β^{CCN_GOV} is the climate change news beta estimated from 60-month rolling regressions of excess return on government bonds on CCN controlling for term spread, default spread, and ted spread. Standard errors are clustered at year level in all regressions. t-statistics are presented in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively. Variables are defined in the main text of the paper.

Variable	$GOV\_EXCESS\_RETURN_t$ (1)	$GOV\_EXCESS\_RETURN_{t+1}$ (2)
CCN	-0.007	
	(-1.115)	
TERM_SPREAD	-9.490	
	(-1.729)	
DEFAULT_SPREAD	8.373	
	(0.344)	
TED_SPREAD	0.370	
	(0.306)	
β^{CCN_GOV}		-0.340
		(-1.081)
β^{TERM}		0.131**
		(2.755)
$\beta^{DEFAULT}$		-0.010
		(-0.938)
β^{TED}		0.001
		(0.017)
ln(MATURITY)	0.165	0.443**
	(0.880)	(2.311)
Bond fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
Month fixed effects	Yes	Yes
Number of Obs	864	858
Adj. R-squared	0.112	0.081

Table A8. Alternative Climate Change News Betas

This table presents the results from the panel regressions of one-month-ahead bond excess returns (EXCESS_RETURN) on alternative climate change news betas. Columns 1 and 2 report the regression results using $\beta^{CCN,\,24}$, is estimated over a 24-month window requiring at least 12 valid observations. Columns 3 and 4 report the regression results using $\beta^{CCN,\,36}$, which is estimated over a 36-month window requiring at least 18 valid observations. Standard errors are clustered at the issuer level in all regressions. *t*-statistics are presented in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively. Variables are defined in the main text of the paper.

	Dependent Variable: Future EXCESS_RETURN			
Variable	(1)	(2)	(3)	(4)
$\beta^{CCN,\,24}$	-0.012***	-0.017***		
	(-7.311)	(-7.171)		
$\beta^{CCN,\,36}$			-0.016***	-0.024***
			(-6.739)	(-7.406)
DOWNSIDE_RISK	0.057***	0.081***	0.060***	0.083***
	(13.626)	(13.159)	(12.778)	(11.758)
ln(MATURITY)	0.115***	0.258***	0.103***	0.300***
	(8.971)	(9.723)	(8.086)	(8.877)
ln(1+RATING)	0.111**	0.212**	0.115**	0.234**
	(2.474)	(2.313)	(2.246)	(2.351)
ln(AMOUNT_OUT)	0.007	0.394***	0.008	0.430***
	(1.224)	(3.943)	(1.040)	(3.761)
REVERSAL	-0.063***	-0.074***	-0.062***	-0.074***
	(-11.815)	(-13.892)	(-11.172)	(-13.344)
ILLIQUIDITY	0.023***	0.025***	0.026***	0.028***
	(5.826)	(5.981)	(5.395)	(5.554)
β^{BOND_MARKET}	-0.027*	-0.026	-0.035**	-0.029
	(-1.865)	(-1.344)	(-2.295)	(-1.368)
β^{TERM}	0.001***	0.001***	0.002***	0.002***
	(3.084)	(2.810)	(4.849)	(3.698)
$\beta^{DEFAULT}$	0.000	0.000	-0.000	0.000
	(0.655)	(0.635)	(-0.410)	(0.344)
β^{TED}	-0.004***	-0.006***	-0.005***	-0.006***
	(-6.469)	(-6.775)	(-5.153)	(-4.996)
IDIO_RISK	0.140***	0.157***	0.145***	0.161***
	(8.514)	(9.633)	(8.031)	(9.239)
LEVERAGE	0.069	0.145	0.038	0.095
	(0.453)	(0.750)	(0.213)	(0.412)
ln(MARKET_CAP)	-0.040	-0.044	-0.028	-0.057*
	(-1.350)	(-1.600)	(-0.881)	(-1.935)
ROE	0.002	0.002	0.002	0.002
	(1.288)	(1.363)	(1.425)	(1.466)
Firm fixed effects	Yes	No	Yes	No
Bond fixed effects	No	Yes	No	Yes
State fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes

Month fixed effects	Yes	Yes	Yes	Yes
Number of Obs	349,679	349,679	302,721	302,721
Adj. R-squared	0.085	0.084	0.083	0.081

Table A9. Robustness Test: All Rated Bonds

This table presents the results from panel regressions of one-month-ahead individual corporate bond excess returns on β^{CCN} for all rated bonds, i.e., corporate bonds with S&P rating from D to AAA, over the sample period of January 2005 to December 2016. Standard errors are clustered at the firm level in all regressions. *t*-statistics are presented in parentheses. *, **, and *** indicates statistical significance at the 10%, 5%, and 1% level, respectively. Variables are defined in the main text of the paper.

	Dependent Variable: Future EXCESS_RETURN	
Variable	(1)	(2)
β^{CCN}	-0.010**	-0.023***
	(-2.564)	(-3.370)
DOWNSIDE_RISK	0.058***	0.077***
	(11.172)	(11.023)
ln(MATURITY)	0.087***	0.376***
	(4.981)	(10.428)
ln(1+RATING)	0.148**	0.351**
	(2.084)	(2.556)
ln(AMOUNT_OUT)	-0.001	0.263*
	(-0.127)	(1.947)
REVERSAL	-0.047***	-0.059***
	(-8.359)	(-10.825)
ILLIQUIDITY	0.021***	0.024***
	(2.626)	(2.827)
β^{BOND_MARKET}	0.026	0.087*
	(0.839)	(1.694)
β^{TERM}	0.006***	0.009***
	(5.638)	(6.293)
$\beta^{DEFAULT}$	-0.001***	-0.001**
	(-2.706)	(-2.539)
β^{TED}	-0.002	-0.004
	(-0.871)	(-1.255)
IDIO_RISK	0.126***	0.136***
	(7.054)	(7.018)
LEVERAGE	0.443*	0.708**
	(1.836)	(2.350)
LN(MARKET_CAP)	-0.026	-0.062*
	(-0.719)	(-1.655)
ROE	-0.001	-0.001
	(-0.560)	(-0.548)
Firm fixed effects	Yes	No
Bond fixed effects	No	Yes
State fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
Month fixed effects	Yes	Yes
Number of Obs	246,394	246,394
Adj. R-squared	0.082	0.081

Table A10. Robustness Test: Controlling for Stock Climate Change News Beta

This table presents the results from panel regressions of one-month-ahead individual corporate bond excess returns on β^{CCN}, controlling for equity climate change news beta, β^{CCN_EQUITY}. Standard errors are clustered at the firm level in all regressions. *t*-statistics are presented in parentheses. *, **, and *** indicates statistical significance at the 10%, 5%, and 1% level, respectively. Variables are defined in the main text of the paper.

	Dependent Variable: Future EXCESS_RETURN	
Variable	(1)	(2)
β^{CCN}	-0.014***	-0.030***
	(-3.970)	(-4.703)
DOWNSIDE_RISK	0.064***	0.084***
	(10.164)	(9.564)
ln(MATURITY)	0.113***	0.379***
	(10.121)	(11.421)
ln(1+RATING)	0.127*	0.323***
	(1.958)	(2.701)
ln(AMOUNT_OUT)	0.018**	0.410***
	(2.576)	(3.290)
REVERSAL	-0.063***	-0.075***
	(-11.118)	(-13.704)
ILLIQUIDITY	0.031***	0.033***
	(5.291)	(5.393)
β^{BOND_MARKET}	-0.050**	-0.039
	(-2.110)	(-0.891)
β^{TERM}	0.006***	0.009***
	(7.008)	(7.657)
$\beta^{DEFAULT}$	-0.001***	-0.001***
	(-4.214)	(-4.089)
β^{TED}	-0.003	-0.006*
	(-1.297)	(-1.863)
IDIO_RISK	0.150***	0.168***
	(7.901)	(8.943)
LEVERAGE	0.076	0.212
	(0.347)	(0.699)
ln(MARKET_CAP)	-0.050	-0.100***
	(-1.435)	(-2.706)
ROE	0.002	0.002
	(1.334)	(1.429)
β^{CCN_EQUITY}	0.002	0.002
	(0.820)	(0.566)
Firm fixed effects	Yes	No
Bond fixed effects	No	Yes
State fixed effects	Yes	Yes
Year and Month fixed effects	Yes	Yes
Number of Obs	238,717	238,717
Adj. R-squared	0.085	0.084