Firm-Level Climate Change Exposure by Sautner et al. (2023), *The Journal of Finance*

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Gap and challenges

- little evidence on the degree to which climate change impacts jobs, innovation, and risk sharing in capital markets
- impacts on individual firms are different to measure
  - challenge 1: multifaceted effects from multiple sources
  - challenge 2: firm heterogeneity $\rightarrow$ disaggregated measures

This paper:

- use transcripts of earning conference calls to construct time-varying measures of how call participants view firms' exposure to climate change
  $\Longrightarrow$ capturing the attention devoted to climate change topics at a given point in time

Built on ...

- use recent work using quarterly earning calls as a source for identifying firms' various risks and opportunities (Hassan et al. (2019, 2021, 2023a, 2023b), Jamilov, Rey, and Tahoun (2021))
- sim: define "exposure" as the share of the conversation in a transcript devoted to that topic
- dev 1: capture the market's perception of a firm's exposure to **various** upside or downside factors, e.g., physical threats, regulatory interventions, and technological opportunities...
- dev 2: to identify "niche language" of specific wordings $\rightarrow$ develop a new method that adapts the keyword discovery algorithm – four related sets of climate change bigrams
  - 1st = broadly defined aspects of climate change
  - other 3 = opportunities, physical shocks, and regulatory shocks.

  $\Rightarrow$ use these four sets of bigrams to construct firm-level measures reflecting call participants' topical attention

... for over 10k firms in 34 countries between 2002 and 2020.

Applying the measures

- on the nature of climate change exposure:
  separating the relative contributions of aggregate, sectoral, and firm-level exposure
  $\Rightarrow$ 70% - 96% of the variation plays out at the firm level
- to four real and financial market outcomes:
  - green-tech hiring and green patents
    $\rightarrow$ 1 s.d. climate expo. = 109 % increase in green jobs
    $\rightarrow$ 1 s.d. climate expo. = 72% increase in the number of green patents
  - risks and risk premiums in the options market
  - conditional pricing of a factor that reflects innovations to the aggregate level of climate change exposure
    $\rightarrow$ higher beta firms in this regard face higher uncertainty and earn higher returns

Data

- earnings conference calls: Refinitiv Eikon, 2002-2020
  excluding countries with 150 or fewer firm-year obs and drop SIC codes 9900-9999
- carbon emissions: S&P Global Trucost (emission levels)
- public attention to climate change: the WSJ CC News Index
- green-tech jobs: Bloom et al. (2021), online job postings by firms related to four technologies: hybrid vehicle electric car, lithium battery, solar power, fracking.
  number of postings for disruptive green-tech jobs in a firm-year
- green patents: Google Patents (GP) database
  number of green patents filed in a firm-year
- Risks and Risk Premiums in the Options Market: Volatility Surface File of Ivy DB OptionMetrics (S&P 500)
- Risk Premiums in the Equity Market: monthly data on the standard factors from Ken French's data library; term and default spread data from FRED library
- other from e.g., Compustat North America and Compustat Global.

Machine learning process

- adapt the keyword discovery algorithm from King, Lam and Roberts (2017):
  choose initial bigrams that are unambiguously related to climate change $\rightarrow$ use these to search for new bigrams (easy to decompose because of connectivity) $\rightarrow$ construct a predictive model and apply this model to sentences that do not include initial bigrams
- construct measures of climate change exposure for each transcript (capturing the attention):
  - Overall exposure CCExposure based on the frequency of specified bigrams in a transcript, adjusted for the call length
  - annual measure: average the quarterly measures
  - product measures for opportunities, regulatory shocks and physical shocks, respectively
- two refinements:
  - two sentiment measures (conditioning on the presence of the positive or negative tone words)
  - a measure of risk (relative frequency of climate change bigrams with "risk", "opportunity" or synonyms)
  - robustness: score bigrams for their representativeness

summary stats

	Mean	STD	25%	Median	75%	N
CC Measures ($\times 10^3$)						
$CCExposure_{i,t}$	1.01	2.53	0.10	0.30	0.78	86,152
$CCExposure_{i,t}^{Opp}$	0.31	1.23	0.00	0.00	0.15	86,152
$CCExposure_{i,t}^{Reg}$	0.04	0.23	0.00	0.00	0.00	86,152
$CCExposure_{i,t}^{Phy}$	0.01	0.11	0.00	0.00	0.00	86,152
CC Measures (TFIDF Version) ($\times 10^3$)						
$CCExposure_{i,t}$	7.99	19.69	0.77	2.44	6.26	86,152
$CCExposure_{i,t}^{Opp}$	2.35	9.08	0.00	0.00	1.18	86,152
$CCExposure_{i,t}^{Reg}$	0.32	1.68	0.00	0.00	0.00	86,152
$CCExposure_{i,t}^{Phy}$	0.10	0.81	0.00	0.00	0.00	86,152
CC Q&A Measure ($\times 10^3$)						
$CCExposure_{i,t}^{Q\&A}$	0.67	1.95	0.00	0.12	0.54	86,152
CC Sentiment and Risk Measures ($\times 10^3$)						
$CCSentiment_{i,t}^{Pos}$	0.38	1.10	0.00	0.07	0.32	86,152
$CCSentiment_{i,t}^{Neg}$	0.19	0.55	0.00	0.00	0.16	86,152
$CCRisk_{i,t}$	0.04	0.17	0.00	0.00	0.00	86,152
Carbon Emissions and Climate Change Attention						
$Total\ Emissions_{i,t}$	2,961,549	13,608,989	27,472	133,847	751,772	33,789
$WSJ\ CC\ News\ Index_t$	0.007	0.001	0.006	0.006	0.008	68,794

Validation (Too technical details are skipped)

Panel A: Carbon Emissions

	$CCExposure_{i,t}$	$CCExposure^{Opp}_{i,t}$	$CCExposure^{Reg}_{i,t}$	$CCExposure^{Phy}_{i,t}$
	(1)	(2)	(3)	(4)
$Log(1 + Total\ Emissions_{i,t-1})$	0.169***	0.036***	0.023***	−0.000
	(0.023)	(0.009)	(0.003)	(0.001)
Model	OLS	OLS	OLS	OLS
Sample	All	All	All	All
Controls	Yes	Yes	Yes	Yes
Industry × Year Fixed Effects	Yes	Yes	Yes	Yes
Industry Fixed Effects	No	No	No	No
Country Fixed Effects	Yes	Yes	Yes	Yes
N	30,905	30,905	30,905	30,905
Adj. R^2	0.390	0.267	0.145	0.035

Panel B: Public Attention to Climate Change

	$CCExposure_{i,t}$	$CCExposure^{Opp}_{i,t}$	$CCExposure^{Reg}_{i,t}$	$CCExposure^{Phy}_{i,t}$
	(1)	(2)	(3)	(4)
$WSJ\ CC\ News\ Index_t$	0.427**	0.154*	0.034***	0.002
	(0.168)	(0.089)	(0.010)	(0.004)
Model	OLS	OLS	OLS	OLS
Sample	All	All	All	All
Controls	Yes	Yes	Yes	Yes
Industry × Year Fixed Effects	No	No	No	No
Industry Fixed Effects	Yes	Yes	Yes	Yes
Country Fixed Effects	Yes	Yes	Yes	Yes
N	54,824	54,824	54,824	54,824
Adj. R^2	0.298	0.185	0.090	0.024

Variance Decomposition:

to examine the extent to which CCExposure and its components quantify firm-level variation in climate change exposure

Variance Decomposition of Climate Change Exposure Measures

This table provides a variance decomposition of the climate change exposure measures. Regressions are estimated at the firm-year level. In Panel A, the table reports the incremental R^2 from adding a specific fixed effect. In Panel B, the table decomposes the variation into a firm fixed effect and a residual component. *CCExposure* measures the relative frequency with which climate change bigrams occur in earnings calls. $CCExposure^{Opp}$ measures the relative frequency with which bigrams that capture opportunities related to climate change occur in earnings calls. $CCExposure^{Reg}$ measures the relative frequency with which bigrams that capture regulatory shocks related to climate change occur in earnings calls. $CCExposure^{Phy}$ measures the relative frequency with which bigrams that capture physical shocks related to climate change occur in earnings calls. For all measures, we average values of the four earnings calls during the year. Table A.1 defines all variables in detail.

	$CCExposure_{i,t}$ (1)	$CCExposure^{Opp}_{i,t}$ (2)	$CCExposure^{Reg}_{i,t}$ (3)	$CCExposure^{Phy}_{i,t}$ (4)
Panel A: Incremental R^2				
Year Fixed Effect	0.7%	0.7%	0.5%	0.05%
Industry Fixed Effect	27.1%	16.9%	7.8%	2.0%
Industry × Year Fixed Effect	1.9%	2.6%	1.4%	1.5%
Country Fixed Effect	0.6%	0.7%	0.4%	0.3%
"Firm Level"	69.7%	79.1%	89.9%	96.2%
Sum	100.0%	100.0%	100.0%	100.0%
Panel B: Fraction of Variation				
Firm Fixed Effect: Permanent differences across firms within sector and countries	51.6%	56.4%	44.7%	45.1%
Residual: Variation over time in the identity of firms within industries and countries most affected by exposure variable	48.4%	43.7%	55.3%	54.9%
Sum	100.0%	100.0%	100.0%	100.0%

Measurement error

Main interpretation: a firmâs idiosyncratic exposure to climate change is the key determinant of the measured variation

Alternative concerns: part of the firm-level variation reflects idiosyncratic measurement error?

Several tests that dispel this alternative:

- robust associations between CCExposure and important real and financial outcomes (as do other papers) $\Longrightarrow$ the variation reflected in firm-level CCExposure is not simply noise
- quantify the amount of measurement error contained in the firm-level variation:
  - (i) assuming true exposure follows AR(1) and CCExposure measures this true exposure with classical (i.i.d.) measurement error.
  - (ii) IV with the lagged variable
  - (iii) compare coef. from OLS and IV estimation

  $\Rightarrow$ measurement error in the firm-level dimension is higher than in the overall panel, but only modestly.

Real outcomes: Green-Tech Jobs and Green Patents

Exposure measures help predict real outcomes related to the net-zero transition? Relate next yearâs creation of disruptive green-tech jobs and green patents to this yearâs values of climate change exposure.

$$\textit{Green Outcome}_{i,t+1} = \exp(\alpha_i + \beta \log(1 + \textit{CCExposure}_{i,t}) + \gamma \mathbf{X}_{i,t} + \delta_j \times \delta_t + \epsilon_{i,t+1}), \tag{5}$$

where $\textit{Green Outcome}_{i,t+1}$ is $\#\textit{Green-Tech Jobs}_{i,t+1}$ or $\#\textit{Green Patents}_{i,t+1}$ in year $t+1$ and $\textit{CCExposure}_{i,t}$ is the climate change exposure measure in year t (we include the overall and topic-based measures). The vector $\mathbf{X}_{i,t}$ includes *Log(Assets)*, *Debt/Assets*, *Cash/Assets*, *PP&E/Assets*, *EBIT/Assets*, *CAPEX/Assets*, and *R&D/Assets*. The variables $\delta_j \times \delta_t$ represent industry-year fixed effects. We account for industry shocks that vary over time, as firm-

Green job results

	$\#Green\text{-}Tech\ Jobs_{i,t+1}$				$I(\#Green\text{-}TechJobs)_{i,t+1}$	$Green\text{-}TechRatio_{i,t+1}$	$\#Nongreen\text{-}TechJobs_{i,t+1}$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$Log(1+CCExposure_{i,t})$	1.564***				0.077***	0.015***	−0.204***
	(0.199)				(0.006)	(0.003)	(0.060)
$Log(1+CCExposure^{Opp}_{i,t})$		1.833***					
		(0.229)					
$Log(1+CCExposure^{Reg}_{i,t})$			1.458***				
			(0.445)				
$Log(1+CCExposure^{Phy}_{i,t})$				1.079			
				(1.217)			
Model	Poisson	Poisson	Poisson	Poisson	OLS	OLS	Poisson
Sample	U.S.	U.S.	U.S.	U.S.	U.S.	U.S.	U.S.
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry x Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	23,870	23,870	23,870	23,870	23,870	23,870	23,870
Adj./ps. R^2	0.754	0.767	0.687	0.684	0.116	0.049	0.526
Dep. Variable: Mean	2.82	2.82	2.82	2.82	0.07	0.003	845.09
Dep. Variable: STD	89.56	89.56	89.56	89.56	0.26	0.042	3613.42
Economic Effect, %	108.7	79.5	20.0	6.8	14.0	16.9	−9.1

firms with higher overall exposure post more vacancies for jobs in disruptive green technologies over the subsequent year.

Green patent results

	$\#Green\ Patents_{i,t+1}$				$I(Green\ Patents)_{i,t+1}$	$Green\ Patents\ Ratio_{i,t+1}$	$\#Nongreen\ Patents_{i,t+1}$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$Log(1+CCExposure_{i,t})$	1.102***				0.025***	0.006***	−0.436***
	(0.231)				(0.003)	(0.001)	(0.118)
$Log(1+CCExposure^{Opp}_{i,t})$		0.854***					
		(0.312)					
$Log(1+CCExposure^{Reg}_{i,t})$			3.061***				
			(0.272)				
$Log(1+CCExposure^{Phy}_{i,t})$				−1.155			
				(2.865)			
Model	Poisson	Poisson	Poisson	Poisson	OLS	OLS	Poisson
Sample	U.S.	U.S.	U.S.	U.S.	U.S.	U.S.	U.S.
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry × Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	21,914	21,914	21,914	21,914	21,914	21,914	21,776
Adj./ps. R^2	0.617	0.603	0.614	0.598	0.078	0.023	0.752
Dep. Variable: Mean	0.28	0.28	0.28	0.28	0.03	0.003	22.10
Dep. Variable: STD	4.07	4.07	4.07	4.07	0.18	0.040	224.23
Economic Effect, %	71.7	32.0	47.3	−6.9	7.0	7.4	−19.3

firms with greater climate change exposure show more green patenting in the next year.

Financial market outcomes

test whether climate change exposure is related to option-implied risks and risk premiums

three sets of risk variables:

- three implied central moments, namely, variance (IVar), skewness (ISkew), and kurtosis (IKurt)
- calculate two heuristic measures quantifying the relative expensiveness of protection against left (SlopeD) and right (SlopeU) tail risks
- the variance risk premium (VRP) to measure the premiums that investors are willing to pay to hedge against general climate-related variance risk

$$OI\ Outcome_{i,t+1} = \alpha_i + \beta\ Log(1 + CCExposure_{i,t}) + \gamma \mathbf{X}_{i,t} + \delta_j \times \delta_t + \epsilon_{i,t+1}, \quad (6)$$

where $OI\ Outcome_{i,t+1}$ is an option-implied measure for firm i measured at the end of quarter t (i.e., a conditional expectation of some quantity over the period

Risk result

	$IVar_{i,t+1}$ (1)	$ISkew_{i,t+1}$ (2)	$IKurt_{i,t+1}$ (3)	$SlopeD_{i,t+1}$ (4)	$SlopeU_{i,t+1}$ (5)	$VRP_{i,t+1}$ (6)
Panel A: *CCExposure*						
$Log(1+CCExposure_{i,t})$	−0.002	−0.049***	0.303***	0.033***	−0.026***	0.003
	(0.005)	(0.009)	(0.049)	(0.007)	(0.006)	(0.002)
N	42,093	42,093	42,093	42,093	42,093	42,089
Adj. R^2	0.424	0.140	0.349	0.231	0.236	0.094
Economic Effect, %	−0.42	−4.57	7.01	4.46	−4.14	0.89
Panel B: $CCExposure^{Opp}$						
$Log(1+CCExposure^{Opp}_{i,t})$	0.004	−0.053***	0.403***	0.048***	−0.037***	0.006*
	(0.009)	(0.012)	(0.067)	(0.011)	(0.010)	(0.003)
N	42,093	42,093	42,093	42,093	42,093	42,089
Adj. R^2	0.424	0.140	0.348	0.231	0.236	0.094
Economic Effect, %	0.56	−3.27	6.18	4.30	−3.91	1.19
Panel C: $CCExposure^{Reg}$						
$Log(1+CCExposure^{Reg}_{i,t})$	−0.007	−0.075***	0.453***	0.054**	−0.053***	0.005
	(0.014)	(0.024)	(0.146)	(0.027)	(0.019)	(0.008)
N	42,093	42,093	42,093	42,093	42,093	42,089
Adj. R^2	0.424	0.139	0.346	0.230	0.235	0.094
Economic Effect, %	−0.46	−2.19	3.28	2.28	−2.64	0.47
Panel D: $CCExposure^{Phy}$						
$Log(1+CCExposure^{Phy}_{i,t})$	−0.033	−0.083	1.336***	0.145***	−0.175***	−0.012
	(0.020)	(0.059)	(0.319)	(0.048)	(0.048)	(0.011)
N	42,093	42,093	42,093	42,093	42,093	42,089
Adj. R^2	0.424	0.139	0.347	0.230	0.236	0.094
Economic Effect, %	−1.02	−1.13	4.51	2.85	−4.06	−0.52

(*Continued*)

Cross-section stock return

investigate the conditional pricing of CCEXPOSURE in the cross-section of stocks:

- construct the factor as an unexpected shock to the aggregate value of CCExposure
  - (i) convert quarterly transcript-level values of CCExposure for U.S-traded firms to a monthly frequency by propagating the last exposure values for up to three months forward
  - (ii) compute cross-sectional monthly averages of CCExposure
  - (iii) take the first differences in these monthly averages as a proxy for unexpected monthly shocks to the aggregate exposure level, and use them as the CCEXPOSURE factor.

the conditional expected return on stock i in month m is

$$E[R_{i,m}|Z_{i,m-1}, Z_{m-1}] = \beta_{i,m}^{\mathsf{T}} \lambda_m, \tag{7}$$

where the risk premium λ_m is the sum of the conditional factor expectation $E[F_m|Z_{m-1}]$ and the process ν_m, estimated from the cross section of stocks. The

Result

Climate Change Exposure Factor: Components of F and ν

This table reports the estimated annualized components of F and ν for the four-factor Carhart (1997) model augmented by a *CCEXPOSURE* factor. The estimation is based on the conditional framework by Gagliardini, Ossola, and Scaillet (2016). The factor is constructed as the monthly change in the cross-sectional average of *CCExposure* across U.S.-traded sample firms. The factor is standardized to have zero mean and an annual volatility of 10%. All instruments are centered and standardized in the time series. The common instruments are the default spread and the term spread, and the firm-specific instrument is the log of the book-to-market ratio. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Factors	*Instruments*	F (1)	$SE(F)$ (2)	ν (3)	$SE(\nu)$ (4)
Market	Constant	8.9838***	3.4981	2.3908***	0.7110
	Default Spread	−1.0201	5.4550	2.4676***	0.8715
	Term Spread	−1.9715	3.3962	1.4489**	0.6705
SMB	Constant	2.3669	1.9164	2.6523*	1.3459
	Default Spread	2.5406	2.0404	−1.3983	1.0227
	Term Spread	2.1356	1.8985	−4.6391***	0.9302
HML	Constant	−2.1553	2.0893	−3.5959***	1.0965
	Default Spread	−3.6834	3.9437	3.7360***	0.8545
	Term Spread	4.8748**	2.2504	−0.0444	0.8434
MOM	Constant	1.3199	3.5668	7.2011***	1.6444
	Default Spread	−14.359*	8.2567	7.8356***	1.7552
	Term Spread	2.4766	2.9728	−0.6825	1.2843
CCEXPOSURE	Constant	−0.0032	2.3008	3.7273***	1.1654
	Default Spread	0.0805	2.7644	3.1262***	1.0855
	Term Spread	−0.2941	2.6282	−0.1834	0.9978

Reference I