# Firm-level Climate Change Exposure

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# Climate change

- Multifaceted impact
  - Downside vs. upside
  - Opportunities
  - Regulatory effects
  - Physical effects
- Do investors pay sufficient attention to climate change?


**3 with cheaper battery**
**oon, price drop leak $4,(**

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Poland's economy relies on coal for 80 per cent of its energy consumption © Krisztian Bocsi/Bloomberg

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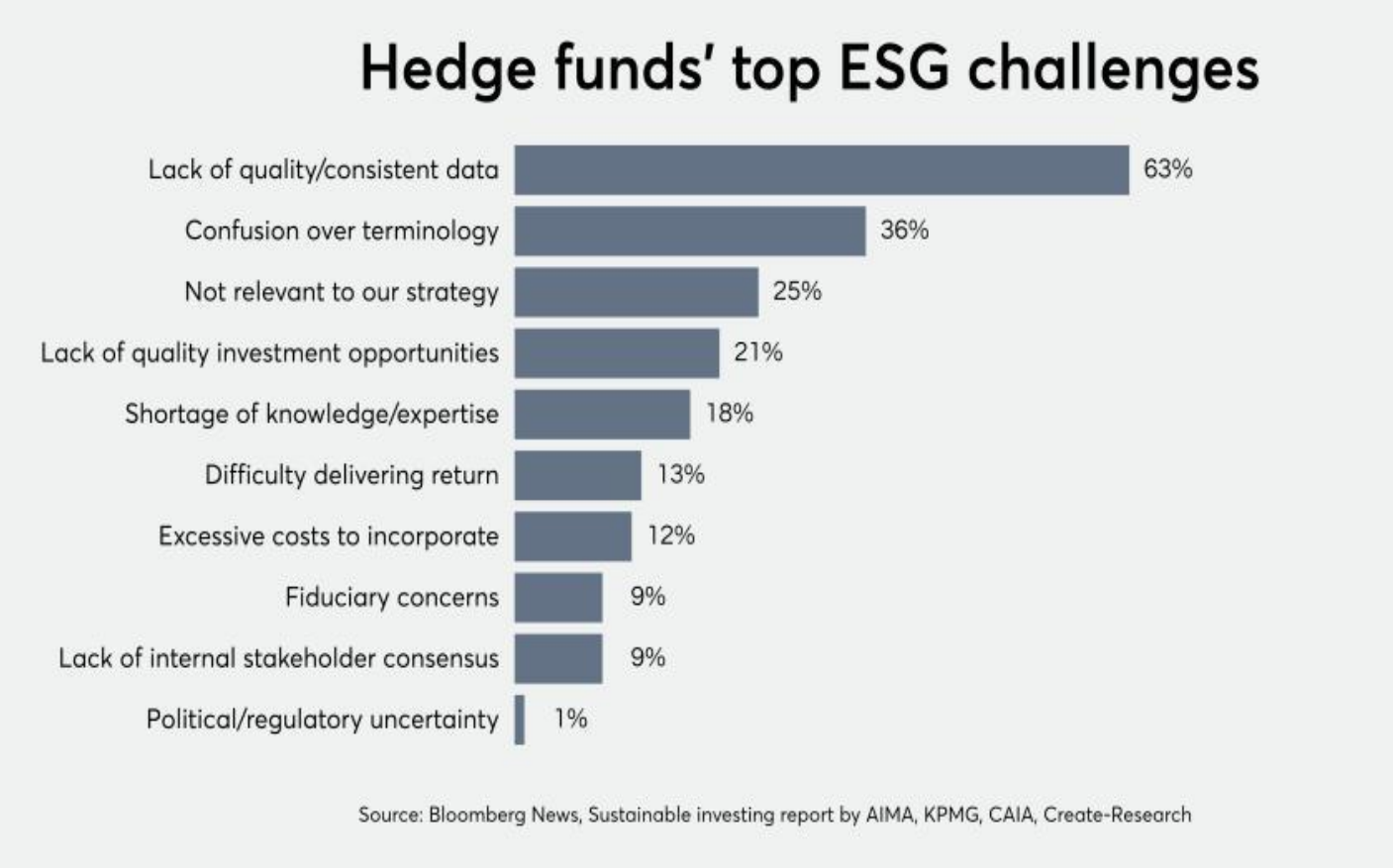
Parliament wants a 40% reduction in CO2 emissions from the shipping industry by 2030© Kara/Adobe Stock

**To decarbonise maritime transport, Parliament voted to include CO2 emissions from the sector in the EU Emissions Trading System.**

# Challenge: lack of quality measures




"Climate Finance: A Research Agenda"

[…] On the empirical side, there is substantial scope for improvements of the **measures of climate risk exposure** in different asset classes, and in particular for equity assets."

Giglio, Kelly, and Stroebel, Climate Finance, 2020

# Why is quantification of firm-level exposure challenging?

- Effects of climate change are uncertain
  - How the climate will eventually change
  - Whether, how, and when policymakers will tighten regulation
- Heterogeneous effects across firms, even *within* industries
- Result is lack of common practice to quantify firm-level climate change exposure
  - Emissions data
    - Limited and selected sample (half of S&P 500 does not report)
    - Good vs. bad emission
    - Past instead of future
  - Professional data vendors (ISS, Sustainalytics)

# Our work

- Introduce a method that identifies firm-level climate change exposure from earnings conference calls
- Coverage: 2002-2020 (regularly updated) / more than 10,000 firms from 34 countries
- Multifaceted topics: opportunity, physical, and regulatory shocks
- Measure is publicly available at https://osf.io/fd6jq/
- Validation of our measure: exhibits cross-sectional and time-series variation that aligns with reasonable priors

# Firm-level climate change exposure

- Identify the proportion of a conference call that discusses climate change topics
- Represents a measure of the firm's exposure to climate change
  - Terminology (“exposure”) and logic follows Hassan et al., (2019, 2020a,b)
- Allows creation of risk & sentiment measures (*not included in this presentation*)
  - Conditional on the target sentence including “risk” synonyms / sentiment words

1. Why using conference call?
2. How to identify keywords related to climate change?
3. How to separate multifaceted effects of climate change?

# 1. Why conference calls?

- Management presentation and participants (e.g., analysts) Q&A
- Less susceptible to “greenwashing” by management
  - Different from CSR reports or press releases
- Broad coverage
  - International sample, many years
  - Less concerns about selection

# 2. How to identify climate change?

- Use pre-specified training library?
  - Hassan et al. (2019): compare political textbook/news with non-political texts
  - Hassan et al. (2020a, b): self-evident words, e.g., Brexit or Covid
- Hard to apply when identifying climate change (we tried!)
  - Climate change reports (e.g., IPCC reports) include too much content related to other areas (e.g., science, economics, technology), making it hard to isolate climate change bigrams
  - Climate change experts tend to talk differently from conference call participants
- Keyword searching algorithm (King et al., 2017)

# Keyword searching algorithm: intuition and face validity

- When mentioning general climate change terms, people likely also use detailed climate change bigrams that are hard to specify ex ante.
- Input: ~50 “Initial” climate change bigrams
  - E.g., climate change, global warming, renewable energy, carbon tax, etc.
- Output: Train ML model to create additional bigrams
  - Electric vehicle => “tesla battery” and “hybrid plug”
  - Renewable energy => “nuclear power” and “event fukushima”
  - Also project/location names related to climate change
    - “kibby wind”, “joaquin valley”, and “coughlin power”

# 3. How to separate multifaceted effects?

- Adapt the keyword searching algorithm to find unique sets of climate change bigrams capturing different climate change topics
- Simply change the inputs (“initial” bigrams)
  - Drop overlapping bigrams yielded by the algorithm

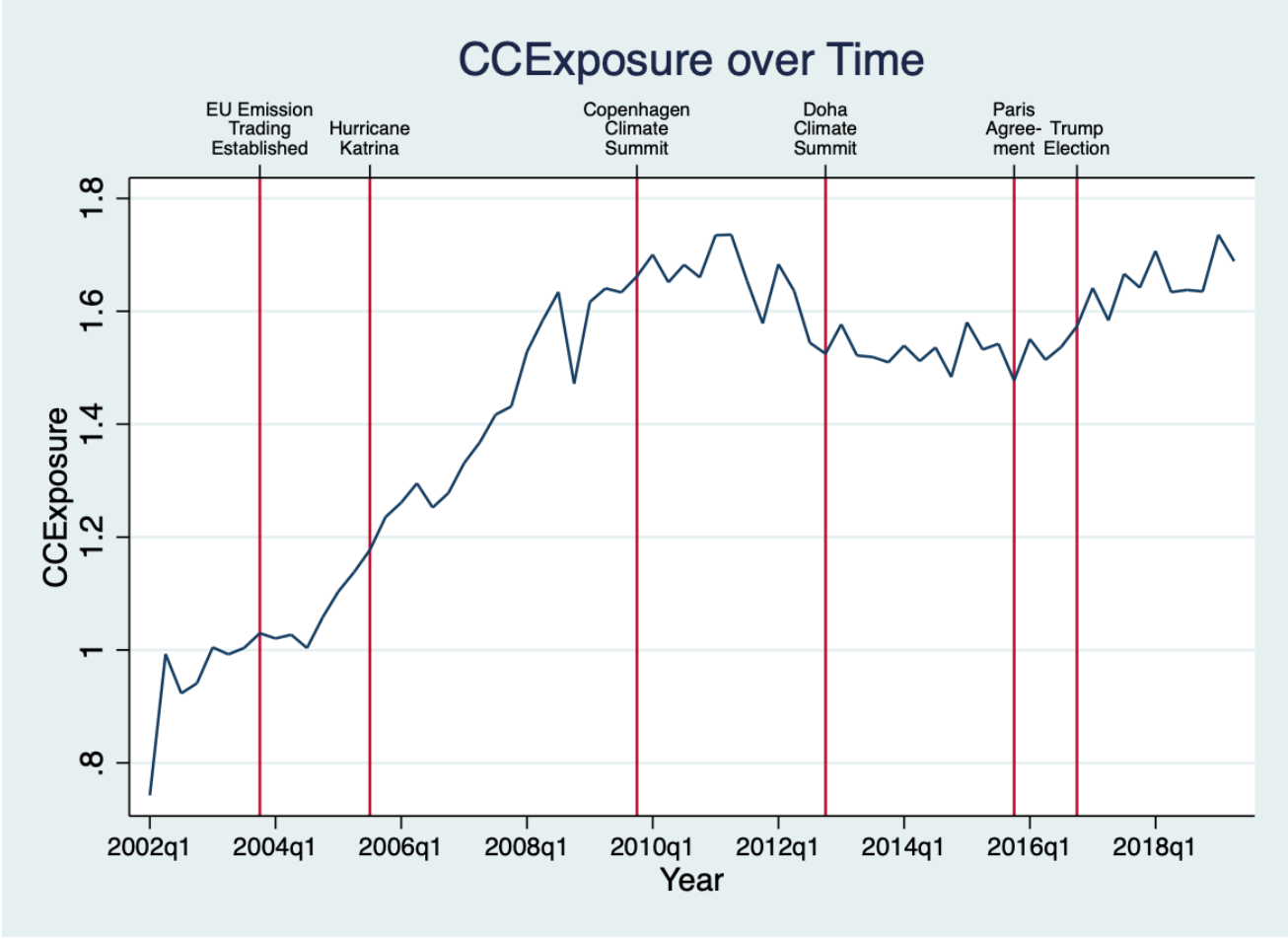
- Opportunities: solar energy => “photovoltaic panel”
- Regulation: “air quality” => “epa regulation”
- Physical: “sea level” => “island costal” and “large desalination”

# Formal representation

$$CCExposure_{it} = \frac{1}{B_{it}} \sum_{b}^{B_{it}} (1[b \in \mathbb{C}])$$

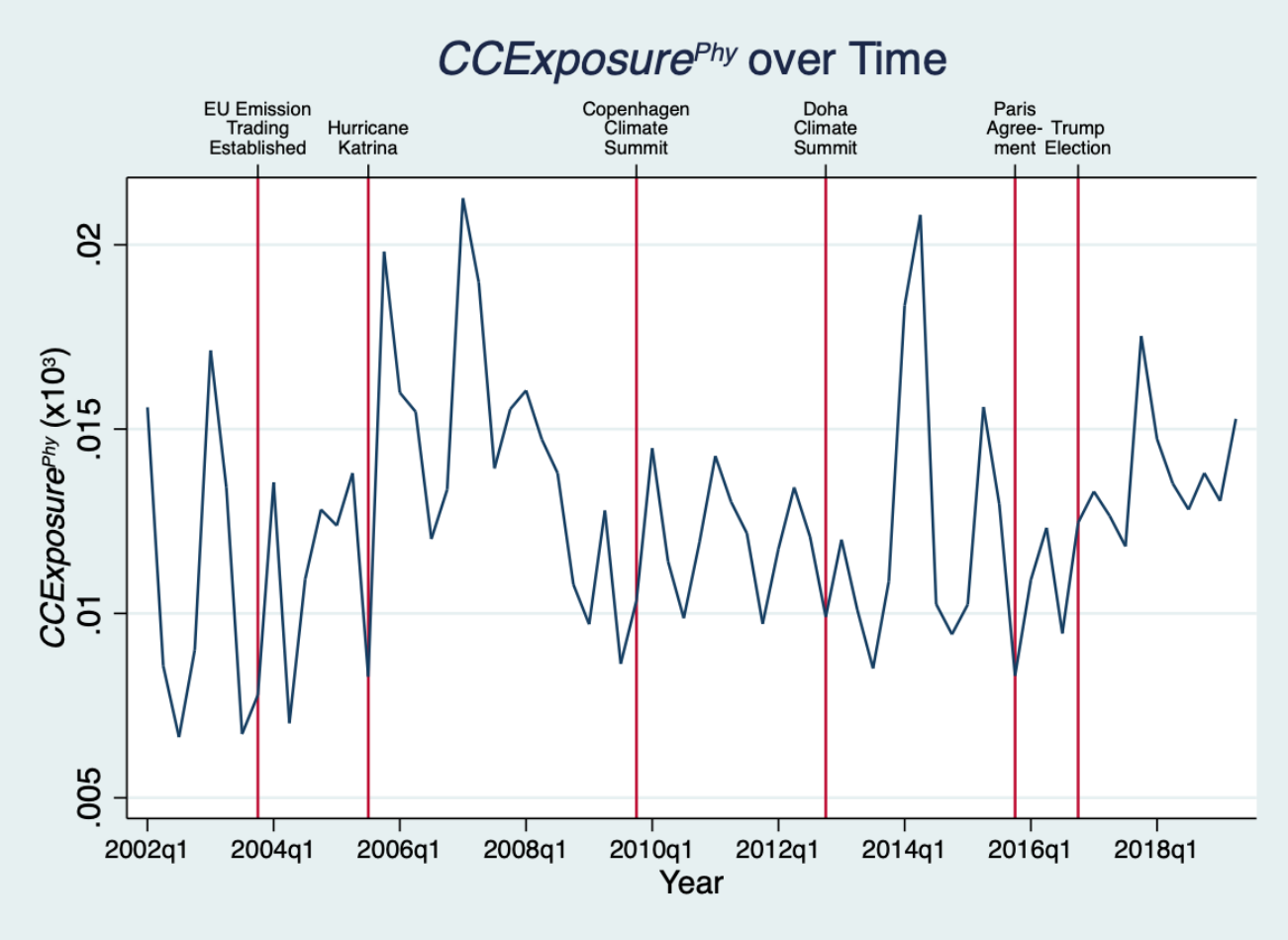
- $b = 0, 1, 2, \ldots, B_{it}$ are the bigrams in the conference call transcripts of firm $i$ in quarter $t$
- $1[\cdot]$ is an indicator function
- $\mathbb{C}$ is the set of climate change bigrams
- How frequently the specified bigrams appear in a given transcript
- Simply replace $\mathbb{C}$ when constructing topic measures

# Validation: time series pattern




- Exposure to climate change increases sharply over time
- Mild decline around (unsuccessful) Doha summit
- Renewed increase since the 2015 Paris Agreement and the 2016 Trump election
- Opportunity and regulatory exposures resemble overall exposure

# Validation: time series pattern




- Lower average exposure
- High volatility
- No clear trend

# Validation: cross-sector pattern

| Panel A. *CCExposure* (x10^3) | | | | |
|---|---|---|---|---|
| Industry (SIC2) | Mean | Std.Dev. | Median | Obs. |
| Top-10 Industries | | | | |
| 49 Electric, Gas, & Sanitary Services | 6.565 | 5.985 | 4.996 | 2675 |
| 16 Heavy Construction, Except Building | 3.149 | 4.619 | 1.432 | 450 |
| 17 Construction | 1.930 | 2.982 | 0.863 | 167 |
| 12 Coal Mining | 1.826 | 1.396 | 1.441 | 285 |
| 36 Electronic & Other Electric Equipment | 1.787 | 3.676 | 0.480 | 5896 |
| 35 Industrial Machinery & Equipment | 1.776 | 4.036 | 0.615 | 2305 |
| 37 Transportation Equipment | 1.678 | 2.504 | 0.886 | 1401 |
| 29 Petroleum Refining | 1.558 | 2.072 | 0.926 | 685 |
| 34 Fabricated Metal Products | 1.492 | 2.561 | 0.613 | 925 |
| 87 Engineering & Management Services | 1.431 | 2.451 | 0.454 | 1216 |

- Top-10 industries are plausible
- Large standard deviation within each sector
- Within-sector variation seems to play an important role

# Firm-level: variance decomposition

| Panel A. Variance Decomposition of Climate Change Exposure Measures | | | | |
|---|---|---|---|---|
| Variable | $CCExposure$ | $CCExposure^{Opp}$ | $CCExposure^{Reg}$ | $CCExposure^{Phy}$ |
| | Incremental $R$-sq. | Incremental $R$-sq. | Incremental $R$-sq. | Incremental $R$-sq. |
| Time Fixed Effects | 0.6% | 0.6% | 0.2% | 0.0% |
| Sector Fixed Effects | 26.3% | 18.6% | 10.3% | 1.6% |
| Sector x Time Fixed Effects | 1.9% | 2.4% | 2.0% | 1.4% |
| Country Fixed Effects | 0.8% | 0.9% | 0.7% | 0.2% |
| "Firm Level" | 70.4% | 77.4% | 86.8% | 96.8% |
| Sum | 100.0% | 100.0% | 100.0% | 100.0% |
| | Fraction of variation | Fraction of variation | Fraction of variation | Fraction of variation |
| Permanent differences across firms within sector and countries (Firm Fixed Effects) | 51.8% | 56.3% | 41.1% | 48.3% |
| Variation over time in the identity of firms within sectors and countries most affected by climate change variable (Residual) | 48.3% | 43.8% | 58.9% | 51.7% |
| Sum | 100.0% | 100.0% | 100.0% | 100.0% |

# Alternative measures

Panel A. Carbon Intensity

| | $CCExposure$ | $CCExposure^{Opp}$ | $CCExposure^{Reg}$ | $CCExposure^{Phy}$ |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| *Carbon Intensity* (×100) | 0.133*** | 0.027*** | 0.026*** | -0.001 |
| | (7.47) | (3.87) | (5.69) | (-1.03) |
| Controls | Yes | Yes | Yes | Yes |
| Industry x Year Fixed Effects | Yes | Yes | Yes | Yes |
| Year Fixed Effects | Yes | Yes | Yes | Yes |
| Industry Fixed Effects | Yes | Yes | Yes | Yes |
| Country Fixed Effects | Yes | Yes | Yes | Yes |
| Obs. | 5404 | 5404 | 5404 | 5404 |
| adj. *R*-sq. | 0.505 | 0.369 | 0.254 | 0.026 |

Panel B. ISS Carbon Risk Rating

| | $CCExposure$ | $CCExposure^{Opp}$ | $CCExposure^{Reg}$ | $CCExposure^{Phy}$ |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| *ISS Carbon Risk Rating* | 1.142*** | 0.740*** | 0.020 | 0.005 |
| | (5.87) | (5.55) | (1.46) | (1.49) |
| Controls | Yes | Yes | Yes | Yes |
| Industry x Year Fixed Effects | Yes | Yes | Yes | Yes |
| Year Fixed Effects | Yes | Yes | Yes | Yes |
| Industry Fixed Effects | Yes | Yes | Yes | Yes |
| Country Fixed Effects | Yes | Yes | Yes | Yes |
| Obs. | 8747 | 8747 | 8747 | 8747 |
| adj. *R*-sq. | 0.414 | 0.337 | 0.155 | 0.001 |

- Exposure measures reflect some variation in carbon intensities and ISS carbon risk ratings
- Overlap is partial at best

# Regulation & extreme temperature

| Panel A. Climate Policy Regulation | | | | |
|---|---|---|---|---|
| | $CCExposure$ | $CCExposure^{Opp}$ | $CCExposure^{Reg}$ | $CCExposure^{Phy}$ |
| | (1) | (2) | (3) | (4) |
| *Climate Policy Regulation* | 0.012*** | 0.008*** | 0.001* | 0.000 |
| | (3.22) | (3.51) | (1.96) | (0.11) |
| Obs. | 61635 | 61635 | 61635 | 61635 |
| adj. $R$-sq. | 0.001 | 0.001 | 0.000 | -0.000 |
| Panel B. Extreme Temperatures | | | | |
| | $CCExposure$ | $CCExposure^{Opp}$ | $CCExposure^{Reg}$ | $CCExposure^{Phy}$ |
| | (1) | (2) | (3) | (4) |
| *Extreme Temperatures* | -0.028 | -0.024 | 0.000 | 0.001 |
| | (-0.87) | (-1.43) | (0.13) | (1.62) |
| Obs. | 70058 | 70058 | 70058 | 70058 |
| adj. $R$-sq. | 0.014 | 0.016 | 0.004 | 0.001 |

- Dependent variables are on country level
- Climate policy regulations:
  - subsidies for renewable energies
  - regulation to reduce carbon emissions
- The frequency of extreme temperature events in the prior year

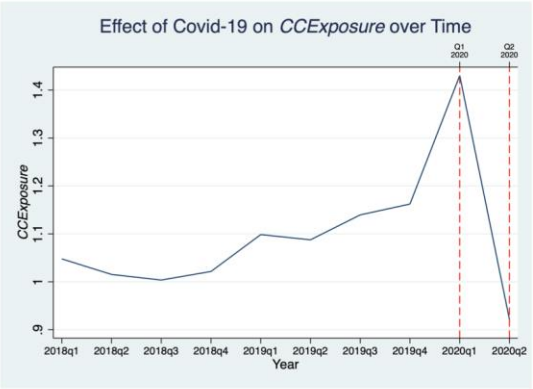
# Economic relations

- Time-series variation in media attention to climate change (Engle et al. 2020)
  - Positive association (higher exposure when more attention)
  - Firm-level exposures to regulatory and physical shocks
  - Not related to climate change opportunities
- Firm-level institutional ownership and climate change
  - Negative association (sell/underweight firms with high exposure)
  - Firm-level exposures to regulatory shocks and climate change opportunities
  - Institutions fail to differentiate between the sources of climate change exposure
- Mandatory ESG disclosure
  - Conference calls: voluntary information exchange

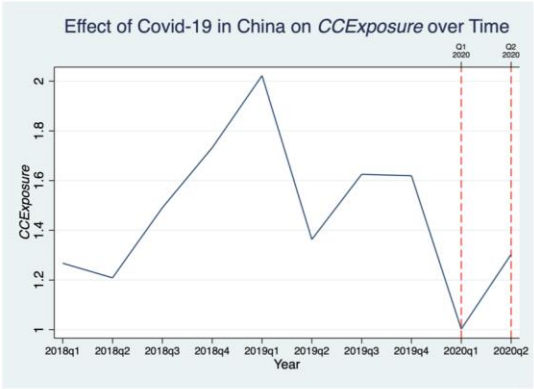
# Firm Value

| | $\Delta\ Tobin's\ Q$ After 2011 (1) | $\Delta\ Tobin's\ Q$ After 2011 (2) | $\Delta\ Tobin's\ Q$ After 2011 (3) | $\Delta\ Tobin's\ Q$ After 2011 (4) | $\Delta\ Tobin's\ Q$ Before 2011 (5) | $\Delta\ Tobin's\ Q$ Before 2011 (6) | $\Delta\ Tobin's\ Q$ Before 2011 (7) | $\Delta\ Tobin's\ Q$ Before 2011 (8) |
|---|---|---|---|---|---|---|---|---|
| $CCExposure^{Opp}$ | 0.007 | | | 0.020 | -0.012 | | | -0.014 |
| | (0.32) | | | (0.83) | (-0.44) | | | (-0.50) |
| $CCExposure^{Reg}$ | | -0.302** | | -0.323** | | 0.004 | | 0.020 |
| | | (-1.98) | | (-2.00) | | (0.03) | | (0.15) |
| $CCExposure^{Phy}$ | | | -0.132 | -0.098 | | | 0.104 | 0.114 |
| | | | (-0.60) | (-0.45) | | | (0.35) | (0.40) |
| Industry x Year Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Industry Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Country Fixed Effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Obs. | 25107 | 25107 | 25107 | 25107 | 28694 | 28694 | 28694 | 28694 |
| Adj. $R$-sq | 0.039 | 0.039 | 0.039 | 0.039 | 0.058 | 0.058 | 0.058 | |

# Climate change and Covid-19




(a)

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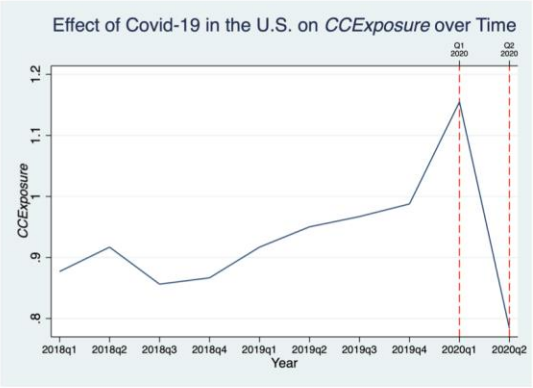
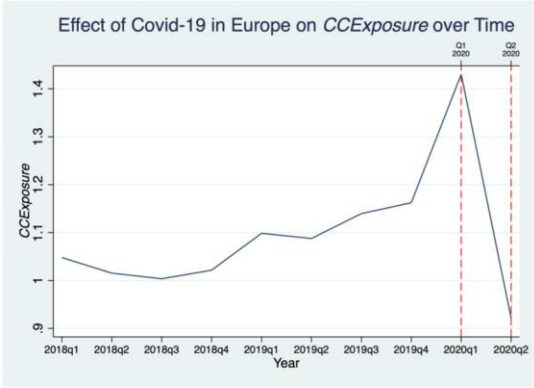



(c)




(d)

- Limited attention of market participants
- Distracted by Covid-19

# Take away

- Make progress in addressing a key challenge for investors, firms, regulators: quantification of firm-level exposure to climate change
- Firm-level climate change exposure
  - Combined views of key stakeholders
  - Opportunity, physical, and regulatory shocks
  - Broad coverage
- Make data publicly available

# My perspectives on “climate finance”

- An area that really matters
- Climate change affects finance & finance affects climate change
- Much more work to be done
  - But “low-hanging” fruits may have been picked soon
- Potential areas
  - Measurement of climate change exposure / risks
  - Effects on risk and returns
  - Climate risk disclosure: what, how
  - Hedging
  - How to encourage capital reallocations?
  - Role for monetary policy (cf. ECB)

# Thank you!

# CC Exposure and Firm Characteristics

| | $CCExposure$ | $CCExposure^{Opp}$ | $CCExposure^{Reg}$ | $CCExposure^{Phy}$ |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| *Sales Growth* | -0.001 | -0.001 | 0.000 | -0.000 |
| | (-0.62) | (-1.22) | (0.03) | (-0.88) |
| *Log(Assets)* | -0.011 | -0.009* | 0.002** | -0.001** |
| | (-1.29) | (-1.89) | (2.52) | (-2.25) |
| *Debt/Assets* | 0.018*** | 0.008*** | -0.001*** | 0.000 |
| | (3.22) | (2.73) | (-2.83) | (0.55) |
| *Cash/Assets* | 0.027*** | 0.013** | 0.002*** | -0.001* |
| | (2.89) | (2.43) | (2.68) | (-1.74) |
| *PPE/Assets* | 0.009 | 0.002 | 0.000 | 0.001 |
| | (1.22) | (0.37) | (0.33) | (1.50) |
| *EBIT/Assets* | -0.118*** | -0.052*** | -0.006*** | -0.001 |
| | (-6.55) | (-4.65) | (-4.41) | (-1.53) |
| *Capex/Assets* | 0.092** | 0.037 | 0.003 | 0.001 |
| | (1.97) | (1.33) | (0.85) | (0.58) |
| *R&D/Assets* | -0.444*** | -0.220*** | -0.003 | -0.004 |
| | (-5.63) | (-5.01) | (-0.25) | (-0.97) |
| Industry x Year Fixed Effects | Yes | Yes | Yes | Yes |
| Year Fixed Effects | Yes | Yes | Yes | Yes |
| Industry Fixed Effects | Yes | Yes | Yes | Yes |
| Country Fixed Effects | Yes | Yes | Yes | Yes |
| Obs. | 65932 | 65932 | 65932 | 65932 |
| adj. $R$-sq. | 0.284 | 0.211 | 0.114 | 0.014 |

- Mostly consistent with Shive and Forster (2020)
- Puzzling R&D

# Alternative measures

| Panel B. Variance Decomposition of Carbon Intensities and ISS Carbon Risk Measures | | |
|---|---|---|
| Variable | *Carbon Intensity* | *ISS Carbon Risk Rating* |
| | Incremental $R$-sq. | Incremental $R$-sq. |
| Year Fixed Effects | 0.3% | 1.0% |
| Sector Fixed Effects | 38.4% | 17.3% |
| Sector x Year Fixed Effects | 1.2% | 1.7% |
| Country Fixed Effects | 3.5% | 7.1% |
| "Firm Level" | 56.6% | 73.0% |
| Sum | 100.0% | 100.0% |
| | Fraction of variation | Fraction of variation |
| Permanent differences across firms within sectors and countries (Firm Fixed Effects) | 53.2% | 66.9% |
| Variation over time in the identity of firms within sectors and countries most affected by climate change variable (Residual) | 46.8% | 33.2% |
| Sum | 100.0% | 100.0% |

# Alternative measures

| | | *Carbon Intensity* | | | *ISS Carbon Risk Rating* | | |
|---|---|---|---|---|---|---|---|
| | | Missing | Nonmissing | Obs | Missing | Nonmissing | Obs. |
| *CCExposure* | Zero | 18303 | 698 | 19001 | 17189 | 1812 | 19001 |
| | | (22.8%) | (0.9%) | (23.7%) | (21.4%) | (2.3%) | (23.7%) |
| | Nonzero | 55909 | 5311 | 61220 | 53037 | 8183 | 61220 |
| | | (69.7%) | (6.6%) | (76.3%) | (66.1%) | (10.2%) | (76.3%) |
| | Obs. | 74212 | 6009 | 80221 | 70226 | 9995 | 80221 |
| | | (92.5%) | (7.5%) | (100%) | (87.5%) | (12.5%) | (100%) |

- Carbon intensity (CDP database)
- ISS carbon risk rating
- 7.5%-12.5% coverage of CC exposure measure
- 66%-70% missing values have non-zero CC exposure