Carbon Tail Risk

Ilhan et al. (2021)

Env Climate discussion group S18

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Research questions

Whether climate policy uncertainty is priced in the option market:
larger cost of option protection against downside tail risks for more carbon-intensive firms?

1. whether the effect of carbon intensities on downside tail risk is amplified at times when public attention to climate change is high
2. election of Trump as a shock (unexpected change in policy uncertainty)

Hypotheses

1. The cost of option protection against downside tail and variance risks associated with climate policy uncertainty is higher at carbon-intense firms.

   uncertainty: whether, how and when to have regulations (which ones) implemented? affect firm profitability and how? effectiveness and future expectations?

2. The cost of option protection against downside tail risks associated with climate policy uncertainty increases at times when public attention to climate change is higher.

   high public attention = higher changes of pro-climate policies and their adoption

3. The cost of option protection against downside tail risks associated with climate policy uncertainty declined after the election of President Trump in 2016 at carbon-intense firms.

   two candidates with opposing views on climate change → his unexpected election reduce uncertainty about which climate policies will be adopted

Carbon emissions

- CDP, 2009 - 2016, S&P500, scope 1
- measure: carbon intensity = scope 1 / equity market cap
  - a firm's industry carbon intensity = $\frac{\sum scope1}{\sum Marketcap}$ of all the reporting firms in the industry
  (firm-level variation in carbon intensity is largely subsumed by industry-level variation)

Option market measures

Why options? Options-based measures reflect expectations about all possible future events, even the rarest ones.

- Surface File of Ivy DB OptionMetrics:
  - daily Black-Scholes implied volatilities for standard maturities and delta points
  - The implied volatilities are created from closing options prices through interand extrapolation in the time and delta dimensions
- CRSP: return and market capitalization data
- the underlying asset = State Street Global Advisors' ETFs (SPDR ETFs)
- OTM calls and puts with absolute deltas smaller than 0.5

Getting smaller grids: interpolate the observed implied volatilities as a function of moneyness ($\frac{strike}{spot}$) within the available data range using monotonic cubic splines, then fill in the implied volatilities beyond the observed moneyness bounds with the volatilities on the bounds. $\Longrightarrow$ 1001 data points over the moneyness range from 1/3 to 3

Implied volatility slope : Slope D

- the slope coefficient from regressing implied volatilities of OTM puts (deltas between -0.5 and -0.1) on the corresponding deltas and a constant
- A more positive value of SlopeD indicates that deeper OTM puts are relatively more expensive (= higher cost of option protection)
- directly captures the relative cost of protection against downside tail risk

Additional measures

- Model-free implied skewness (MFIS): the third central moment of the risk-neutral distribution, normalized by the risk-neutral variance
  - captures the distribution of the probability mass in the left versus the right tail of the risk-neutral distribution
  - the cost of protection against left tail events relative to the cost of gaining positive realizations on the left tail

$$MFIS(t,\tau)=\frac{e^{r\tau}W(t,\tau)-3\mu(t,\tau)e^{r\tau}V(t,\tau)+2\mu(t,\tau)^3}{[e^{r\tau}V(t,\tau)-\mu(t,\tau)^2]^{3/2}}$$

- variance risk premium (VRP): the difference between the risk-neutral expected and the realized variance
  - the cost of protection against general uncertainty-related volatility changes in down and up directions

Selection Model

$$OMM_{i,m,t+1} = \beta_0 + \beta_1 Log(Scope1/MV\ industry)_{i,t} + \boldsymbol{x_{i,t}}\boldsymbol{\beta} + u_{i,m,t+1}, \quad (1)$$

$$CDP\ disclosure_{i,t} = \gamma_0 + \gamma_1 Industry\ CDP\ disclosure_{i,t} + \boldsymbol{x_{i,t}}\boldsymbol{\gamma} + v_{i,t}, \quad (2)$$

+ full-information maximum likelihood (FIML)

See Table 3: the importance of accounting for selection bias.

Main Results

Table 4
Carbon intensities and option market variables: Main results

A. Firm-level regressions

Dependent variable:	*SlopeD* (1)	*MFIS* (2)	*VRP* (3)
log(Scope 1/MV industry)	0.006***	−0.002	0.001***
	(3.85)	(−0.70)	(3.79)

Table 4
(Continued)

B. Sector-level regressions

Dependent variable:	*SlopeD* (1)	*MFIS* (2)	*VRP* (3)
log(Scope 1/MV sector)	0.037***	−0.067*	0.003
	(2.80)	(−1.92)	(1.46)
Model	OLS	OLS	OLS
Sector fixed effects	Yes	Yes	Yes
Level	Sector	Sector	Sector
Frequency	Monthly	Monthly	Monthly
Obs.	774	774	774
Adj. R^2	.138	.366	.005

Main Results: Reltaive importance

whether firms with carbon intensities that are lower (higher) than those of their industry peers exhibit less (more) downside tail risk once we account for industry effects:

Table 5
Firm versus industry carbon intensities: Relative importance

Dependent variable:	*SlopeD* (1)	*SlopeD* (2)	*SlopeD* (3)
log(Scope 1/MV firm)	0.006***		
	(3.39)		
Residual log(Scope 1/MV firm)		0.003	0.005
		(0.81)	(1.06)
log(Scope 1/MV industry)			0.006***
			(3.76)
Model	Heckman	Heckman	Heckman
Controls	Yes	Yes	Yes
Year-by-quarter fixed effects	Yes	Yes	Yes
Level	Firm	Firm	Firm
Frequency	Monthly	Monthly	Monthly
Obs.	18,664	18,664	18,664
Adj. R^2	n/a	n/a	n/a

Main Results: Attention

- allow the effect of carbon intensities to vary with two proxies for public attention to climate change.
- Measure 1: an index developed by Engle et al. (2020) which captures the share of news articles in outlays, such as Wall Street Journal, The New York Times, or Yahoo News, that are about "climate change" and have been assigned to a "negative sentiment" category
- Measure 2: use Google's search volume index (SVI) for the search topic "climate change" $\rightarrow$ the dummy variable Climate change SVI high, which equals one if the search index is above the median, and zero otherwise

interact each of these two variables with log(Scope 1/MV industry)

Main Results: attention

Table 6
Carbon intensities and option market variables: Effects of public attention to climate change

Dependent variable:	*SlopeD* (1)	*SlopeD* (2)
log(Scope 1/MV industry) x Negative climate change news high	0.002*	
	(1.67)	
log(Scope 1/MV industry) x Climate change SVI high		0.001
		(0.45)
log(Scope 1/MV industry)	0.005***	0.006***
	(3.47)	(3.61)
Negative climate change news high	−0.003	
	(−0.82)	
Climate change SVI high		−0.005
		(−1.01)
Estimated slope if *Negative climate change news high* = 1	0.007***	
Estimated slope if *Climate change SVI high* = 1		0.007***
Model	Heckman	Heckman
Controls	Yes	Yes
Year-by-quarter fixed effects	Yes	Yes
Level	Firm	Firm
Frequency	Monthly	Monthly
Obs.	18,664	18,664
Adj. R^2	n/a	n/a

Main Results: Trump election DiD [-250, +250]

$$OMM_{i,t} = \gamma_0 + \gamma_1 Post\ Trump\ election_t \times Scope\ 1/MV\ industry\ high_i + \gamma_2 Scope\ 1/MV\ industry\ high_i + \gamma_3 Post\ Trump\ election_t + \mathbf{x}_{i,t-1}\boldsymbol{\gamma} + \epsilon_{i,t} \quad (3)$$

Table 7
Effect of the election of President Trump in 2016 on option market variables

Dependent variable:	*SlopeD*	*SlopeD*	*SlopeD*	*SlopeD*	*SlopeD*	*SlopeD*
Event window:	[−250; +250]	[−250; +250]	[−250; +250]	[−250; +250]	[−250; +250], excl. [−50; +50]	[−250; +250], excl. [−50; +50], excl. Healthcare
	(1)	(2)	(3)	(4)	(5)	(6)
Post-Trump election x Scope 1/MV industry high	−0.025**	−0.029**	−0.025***	−0.020**	−0.037***	−0.035**
	(−2.18)	(−2.43)	(−2.88)	(−2.20)	(−2.63)	(−2.45)
Scope 1/MV industry high	0.041*	0.043*			0.046*	0.043*
	(1.67)	(1.77)			(1.88)	(1.72)
Post-Trump election	−0.025***			−0.022***	−0.036***	−0.041***
	(−4.63)			(−4.33)	(−5.97)	(−6.13)
Model	DiD	DiD	DiD	DiD	DiD	DiD
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Day fixed effects	No	Yes	Yes	No	No	No
Firm fixed effects	No	No	Yes	No	No	No
Industry fixed effects	No	No	No	Yes	No	Yes
Level	Firm	Firm	Firm	Firm	Firm	Firm
Frequency	Daily	Daily	Daily	Daily	Daily	Daily
Obs.	200,897	200,897	200,897	200,897	159,041	139,635
Adj. R^2	.062	.091	.294	.184	.061	.060

Conclusions

- strong evidence that climate policy uncertainty is priced in the option market
- Evidence for the two other measures is more mixed, but it complements the picture presented by SlopeD.
- The results for all three measures combined indicate that higher climate policy uncertainty increases at the firm level the likelihood of left and right tail events, and it has some effect on firm-level uncertainty as measured by VRP.
- While they find that the effect of carbon intensities on SlopeD is aggravated when there is more negative climate change news, they cannot detect a corresponding effect for Google search data
- Supporting Hypothesis 3, SlopeD for highly carbon-intense firms decreased by 0.025 after President Trump's election, relative to less carbon-intense firms, a decline equal to 12% of the variable's standard deviation during the event window.

The end!