Carbon Tail Risk

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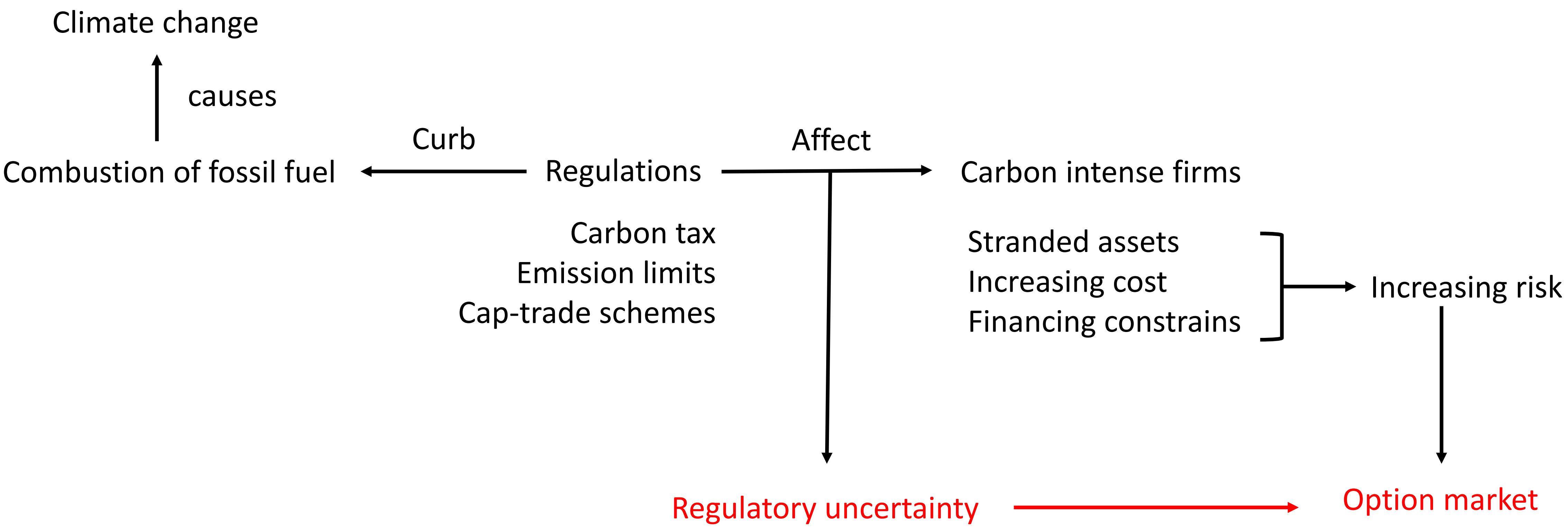
Intro


Climate change
causes
Combustion of fossil fuel
Curb
Regulations
Affect
Carbon intense firms
Carbon tax
Emission limits
Cap-trade schemes
Stranded assets
Increasing cost
Financing constrains
Increasing risk
Regulatory uncertainty
Option market

Intro

To what extent carbon-intense firms will be affected by regulation uncertainty?

↓

Whether climate political/ regulatory uncertainty is priced in option market?

↓

Whether the cost of option protection against downside tail risks is larger for firms with more carbon-intense business models.

Hypothesises

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

HYPOTHESIS 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.

HYPOTHESIS 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.

Data

Option market measures

- Implied volatility slope (*SlopeD*)
- Model-free implied skewness (MFIS)
- Variance risk premium (VRP)

Carbon emission measurement

- Carbon intensity

Option market measures

1, Implied volatility slope (*SlopeD*)

The implied volatility slope measures the steepness of the function that relates implied volatility to moneyness, as measured by the option's Black-Scholes delta. Specifically, SlopeD is the slope coefficient from regressing implied volatilities of OTM puts on the corresponding deltas and a constant.

A more positive value of SlopeD indicates that deeper OTM puts are relatively more expensive, suggesting a relatively higher cost of protection against downside tail risks.

Option market measures

2, Model-free implied skewness (MFIS)

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

MFIS captures the distribution of the probability mass in the left versus the right tail of the risk-neutral distribution, it can be interpreted as the cost of protection against left tail events relative to the cost of gaining positive realizations on the right tail.

Option market measures

3, Variance risk premium (VRP)

$$VRP_{t,m} = IV^2_{t,m} - RV^2_{t,m},$$

VRP is computed as the difference between the risk-neutral expected and the realized variance.

In short…

SlopeD capture the cost of protection against left tail risk relative to “normal” risks.

VRP captures the cost of protection against general uncertainty-related volatility changes in down and up directions.

MFIS capture the cost of protection against left tail risk relative the right tail.

Carbon emission measurement

Firm carbon intensity

Carbon Intensity = Scope 1/MV industry

As firm-level variation in carbon intensity is largely subsumed by industry-level variation, a firm’s industry carbon intensity can be captured by total Scope 1 carbon emissions (in metric tons of CO_2) of all reporting firms in the industry divided by the total market capitalization of all reporting firms in the industry (in millions $)

	A. Determinants of carbon intensities or carbon emissions			
Dependent variable:	*log(Scope 1/MV firm)*		*log(Scope 1 firm)*	
	(1)	(2)	(3)	(4)
log(Scope 1/MV industry)	0.969***	0.940***		
	(180.20)	(87.06)		
log(Scope 1 industry)			1.015***	0.927***
			(148.91)	(50.36)
Industry CDP disclosure				
log(Assets)		0.015		0.342***
		(0.89)		(8.77)
Dividends/net income		0.056*		0.125**
		(1.78)		(2.44)
Debt/assets		0.561***		1.123***
		(3.80)		(4.19)
EBIT/assets		0.073		2.334***
		(0.23)		(3.85)
CapEx/assets		1.807**		5.812***
		(2.27)		(3.98)
Book-to-market		0.365***		0.142
		(3.82)		(0.93)
Returns		0.013		0.059
		(0.16)		(0.33)
Institutional ownership		0.212		0.022
		(1.26)		(0.09)
CAPM beta		0.093***		0.168**
		(2.98)		(2.57)
Volatility		-2.444***		-8.362***
		(-3.05)		(-4.45)
Oil beta		-0.096		-0.341*
		(-1.13)		(-1.86)
Time trend		-0.006		-0.029
		(-0.70)		(-1.37)

Test of hypothesises

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

A Heckman selection model

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

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

Results

A. Firm-level regressions			
Dependent variable:	*SlopeD*	*MFIS*	*VRP*
	(1)	(2)	(3)
log(Scope 1/MV industry)	0.006***	-0.002	0.001***
	(3.85)	(-0.70)	(3.79)
log(Assets)	-0.029***	-0.043***	-0.005***
	(-9.22)	(-8.04)	(-7.10)
Dividends/net income	0.009	-0.014	-0.000
	(1.54)	(-1.26)	(-0.00)
Debt/assets	0.038**	0.062**	0.003
	(2.28)	(2.00)	(0.71)
EBIT/assets	-0.187***	-0.078	-0.018
	(-4.59)	(-1.02)	(-1.60)
CapEx/assets	-0.374***	0.216*	-0.060**
	(-5.13)	(1.75)	(-2.35)
Book-to-market	0.077***	0.122***	0.016***
	(8.10)	(5.21)	(4.30)
Returns	-0.018**	-0.054***	-0.010*
	(-2.13)	(-2.95)	(-1.93)
Institutional ownership	-0.045*	-0.085	-0.008
	(-1.75)	(-1.59)	(-1.20)
CAPM beta	0.010	-0.033***	-0.001
	(1.42)	(-3.18)	(-0.44)
Volatility	-0.687***	1.926***	
	(-6.48)	(8.27)	
Oil beta	-0.008	-0.003	-0.020***
	(-0.50)	(-0.10)	(-2.73)
Time trend	-0.000	0.033***	-0.001*
	(-0.29)	(9.93)	(-1.67)

Results

B. Sector-level regressions			
Dependent variable:	*SlopeD*	*MFIS*	*VRP*
	(1)	(2)	(3)
log(Scope 1/MV sector)	0.037***	-0.067*	0.003
	(2.80)	(-1.92)	(1.46)
Model	OLS	OLS	OLS

Results

Taken together, the results indicate that higher climate policy uncertainty increases the firm-level likelihood of left and right tail events, and it has some effect on firm-level VRP. On the sector level, where firm-specific risks are diversified away, we observe an effect that is more systematic and concentrated in the left tail. (One other reason sector-level results may differ from those at the firm level is that sector carbon intensities are noisier as we do not have carbon emissions for all firms in a given sector; this may introduce measurement error.)

Test of hypothesises

HYPOTHESIS 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.

Two proxies (dummy variables)

Negative climate change news high = 1 if Engle et al. (2020) index is above the median;
Negative climate change news high = 0 otherwise.

Climate change SVI high = 1 if the search index is above the median;
Climate change SVI high = 0 otherwise.

Results

Dependent variable:	*SlopeD*	*SlopeD*
	(1)	(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)

Test of hypothesises

HYPOTHESIS 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.

A difference-in-differences (DiD) model

$$OMM_{i,t} = \gamma_0 + \gamma_1 Post\ Trump\ election_t \text{ x } Scope\ 1/MV\ industry\ high_i$$

$$+\ \gamma_2\ Scope\ 1/MV\ industry\ high_i +\ \gamma_3 Post\ Trump\ election_t +\ \boldsymbol{x_{i,t-1}\gamma}$$

$$+\ \epsilon_{i,t}$$

Post-Trump election = 1 for observations after Election Day
Post-Trump election = 0 for observations before Election Day

Scope 1/MV industry high = 1 for the ten industries with the highest carbon intensities
Scope 1/MV industry high = 0 otherwise

Results

Dependent variable:	*SlopeD*	*SlopeD*	*SlopeD*	*SlopeD*	*SlopeD*
Event window:	[-250; +250]	[-250; +250]	[-250; +250]	[-250; +250]	[-250; +250], excl. [-50; +50]
	(1)	(2)	(3)	(4)	(5)
Post-Trump election x Scope 1/MV industry high	-0.025**	-0.029**	-0.025***	-0.020**	-0.037***
	(-2.18)	(-2.43)	(-2.88)	(-2.20)	(-2.63)
Scope 1/MV industry high	0.041*	0.043*			0.046*
	(1.67)	(1.77)			(1.88)
Post-Trump election	-0.025***			-0.022***	-0.036***
	(-4.63)			(-4.33)	(-5.97)

Conclusion

- Climate policy uncertainty is priced in the option market. Specifically, the cost of option protection against downside tail risk is larger for more carbon-intense firms.
- The cost of downward option protection is magnified when public attention to climate change spikes.
- The cost of downward option protection has significantly decreased at highly carbon-intense firms after President Trump’s election in 2016, relative to other firms.

limitation

- Observation of CDP carbon emission is limited

Cheerio!