Climate Stress Testing

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October 5, 2021

Climate Change and Financial Stability

How could climate-related shocks impose systemic risk on financial sector?

- If banks systemically suffer substantial losses following abrupt increases in:
  - **Transition risks** arising from changes in policies
  - **Physical risks** arising from damage to property

How can we estimate banks' capital shortfall following a climate-related shock?

- We develop climate stress testing methodology to test the resilience of financial institutions to climate-related risks.

This Paper

- Climate stress testing methodology to test the resilience of financial institutions to climate-related risks.
- The methodology involves three steps:
  1. Measure the climate risk factor.
  2. Estimate time-varying climate beta of banks.
     - Dynamic Conditional Beta (DCB) model
  3. Compute systemic climate risk (CRISK).
     - CRISK: Expected capital shortfall of banks in a climate stress scenario
- Use the measure to study the climate-related risk exposure of large global banks

Key Findings

1. The climate beta and CRISK substantially increased during 2020.
   - Aggregate CRISK of top 4 US banks increased by $360 billion (40% relative to their market capitalization) during 2020.
2. The increase in CRISK during 2020 was primarily due to decrease in equity values of banks.
   - 75% due to equity deterioration
   - 23% due to debt deterioration
   - 2% due to increase in risk
3. CRISK is considerably higher than expected capital shortfall of banks under *zero* climate stress scenario.
   - Aggregate CRISK of top 4 US banks is higher than non-stressed CRISK by $245 billion.
4. Banks with higher exposure to gas & oil loans have higher climate beta and CRISK.

Step 1: Climate risk factor

- Litterman's stranded asset portfolio:
  a measure of transition risk

$$0.3XLE + 0.7KOL - SPY$$

Figure: Stranded Asset Portfolio Cumulative Return

Step 2: Time-varying climate beta

Estimate each bank i's $\beta_{it}^{Climate}$

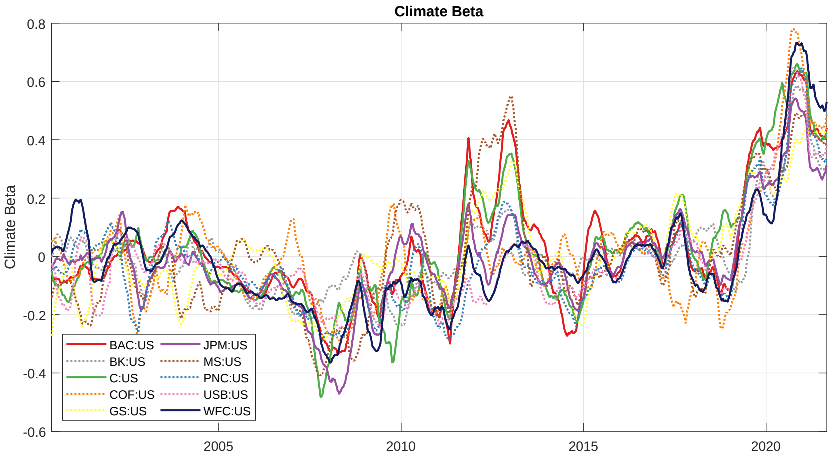
- Bank's stock return sensitivity to the climate factor
- Dynamic Conditional Beta Model[2]

$$r_{it} = \beta_{it}^{Mkt} MKT_t + \beta_{it}^{Climate} CF_t + \varepsilon_{it}$$

  - Allows volatility and correlation to be time-varying.
- Expect:
  - $\beta^{Climate} > 0$ for banks with large exposure to gas and oil loans
  - $\beta^{Climate} < 0$ for banks with large exposure to renewable energy, for example

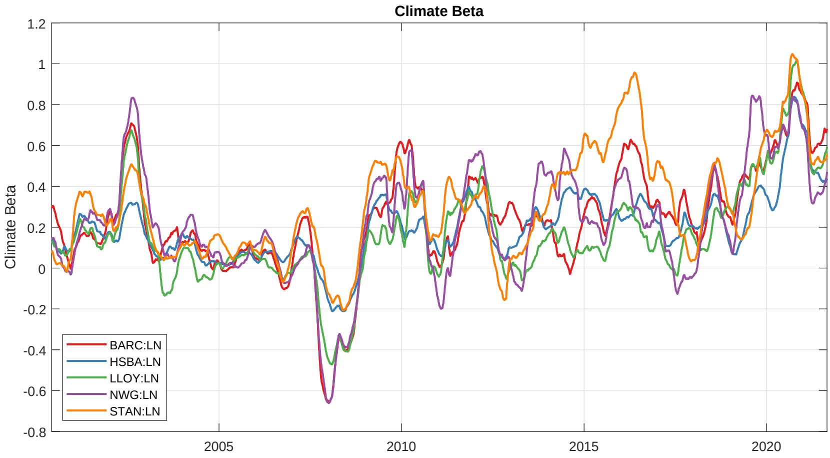
[2] Engle(2002), Engle(2009), Engle(2016)

Time-varying climate beta of U.S. Banks



Neg Beta | Events | CF Non-standardized | ACWI

Time-varying climate beta of U.K. Banks



Local

Step 3: CRISK

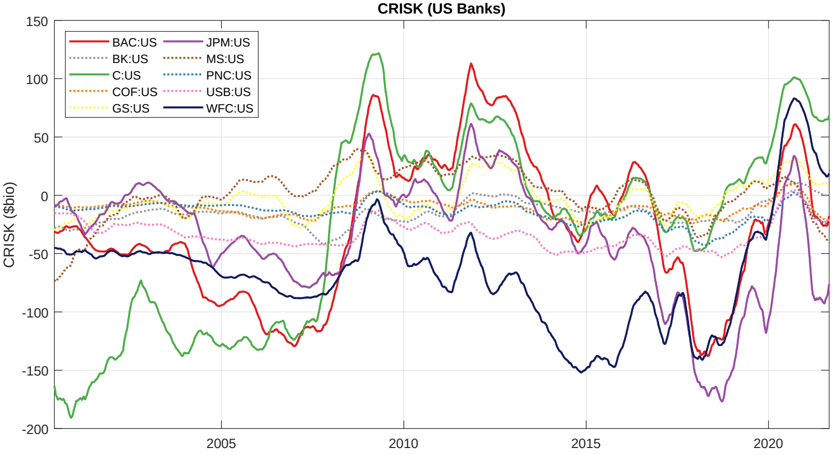
Follow the SRISK methodology[3]

$$\begin{aligned} CRISK_{it} &= E_t[\text{Capital Shortfall}_i \mid \text{Climate Stress}] \\ &= E_t\left[k(D_{it} + W_{it}) - W_{it} \mid \text{Climate Stress}\right] \\ &= kD_{it} - (1-k)\underbrace{(1 - LRMES_{it})}_{=\exp\left(\beta_{it}^{Climate}\log(1-\theta)\right)} W_{it} \end{aligned}$$

- D: Book value of debt
- W: Market capitalization
- LRMES: Expected equity loss conditional on the climate stress
- Prudential level of equity relative to assets $k = 0.08$ ($k = 0.055$ for Europe)
- Climate stress level $\theta = 0.5$
  - 1% quantile of 6 month return on the stranded asset portfolio

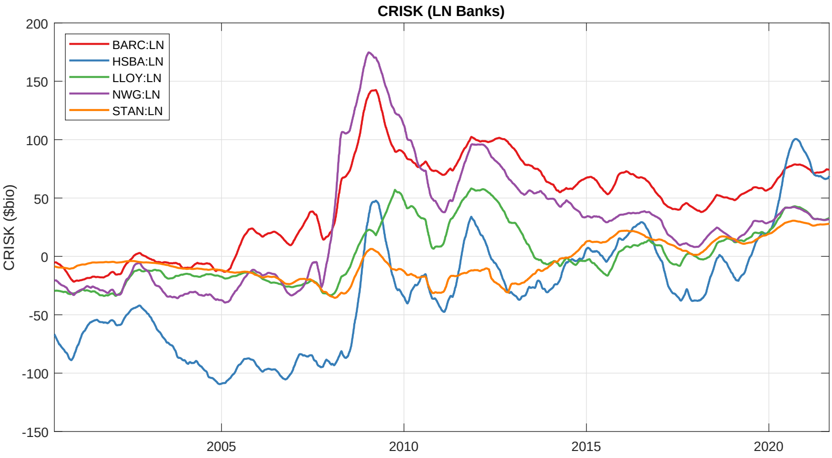
[3] Acharya et al (2011, 2012), Brownlees and Engle (2017)

CRISK of U.S. Banks



ACWI CF Non-standardized

CRISK of U.K. Banks



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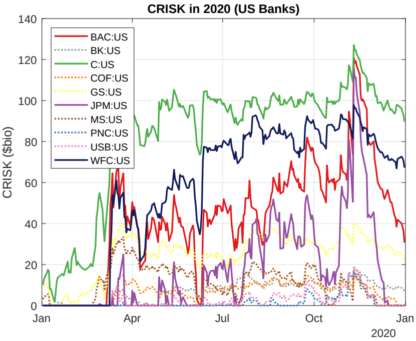
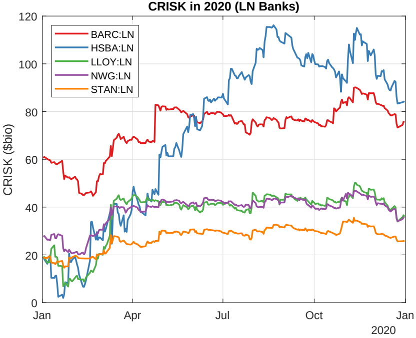
CRISK of U.S. Banks in 2020



Loan Exposure to Gas & Oil Industry

No	Name	Ticker	LoanAmt
1	Wells Fargo	WFC	46,939
2	JP Morgan	JPM	38,792
3	BofA	BAC	29,720
4	Citi	C	28,072
5	US Bancorp	USB	12,091
6	PNC Bank	PNC	11,818
7	Goldman Sachs	GS	11,597
8	Morgan Stanley	MS	10,024
9	Capital One Financial Corp	COF	9,621
10	Bank of New York Mellon	BK	1,289

CRISK of U.K. Banks in 2020



Loan Exposure to Gas & Oil Industry

No	Name	Ticker	LoanAmt
1	Barclays	BARC	19,893
2	HSBC Banking Group	HSBC	7,546
3	Standard Chartered Bank	STAN	3,945
4	Natwest	NWG	1,361
5	Lloyds Banking Group	LLOY	869

CRISK Decomposition

$$dCRISK = \underbrace{k \cdot \Delta DEBT}_{dDEBT} \underbrace{-(1-k)(1-LRMES) \cdot \Delta EQUITY}_{dEQUITY}$$
$$+ \underbrace{(1-k) \cdot EQUITY \cdot \Delta LRMES}_{dRISK}$$

- *dDEBT*: debt $\uparrow \Rightarrow$ CRISK $\uparrow$
- *dEQUITY*: market cap $\downarrow \Rightarrow$ CRISK $\uparrow$
- *dRISK*: effect of higher volatility or correlation

CRISK Decomposition: U.S. Banks in 2020

- CRISK(t-1): CRISK as of Dec 31, 2019
- CRISK(t): CRISK as of Dec 31, 2020

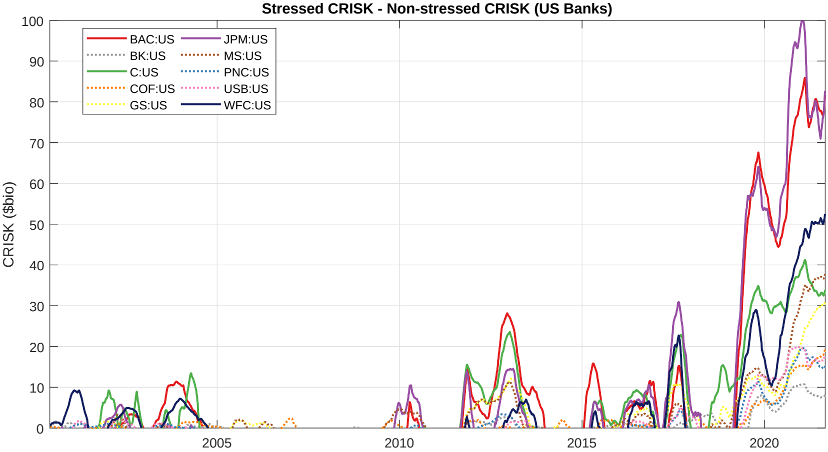
Ticker	CRISK(t-1)	CRISK(t)	dCRISK	dDEBT	dEQUITY	dRISK
WFC:US	−48.78	62.82	111.6	−0.84	106.57	5.03
JPM:US	−148.31	−47.99	100.32	38.42	74.39	−14.65
C:US	5.39	82.05	76.67	17.49	42.59	15.42
BAC:US	−60.61	15.19	75.79	24.63	55.2	−4.46
USB:US	−40.06	−10.86	29.2	4.13	23.41	1.3
PNC:US	−28.31	−12.57	15.74	3.8	13.75	−1.56
BK:US	−8.64	4.75	13.39	4.11	9.93	−0.83
COF:US	−11.62	−3.38	8.24	3.25	6.36	−0.79
GS:US	8.92	12.73	3.81	9.9	−1	−5.29
MS:US	2.05	−21.55	−23.6	3.65	−23.76	−3.85
Top 4			364.38	79.7	278.75	1.35

CRISK Decomposition: U.K. Banks in 2020

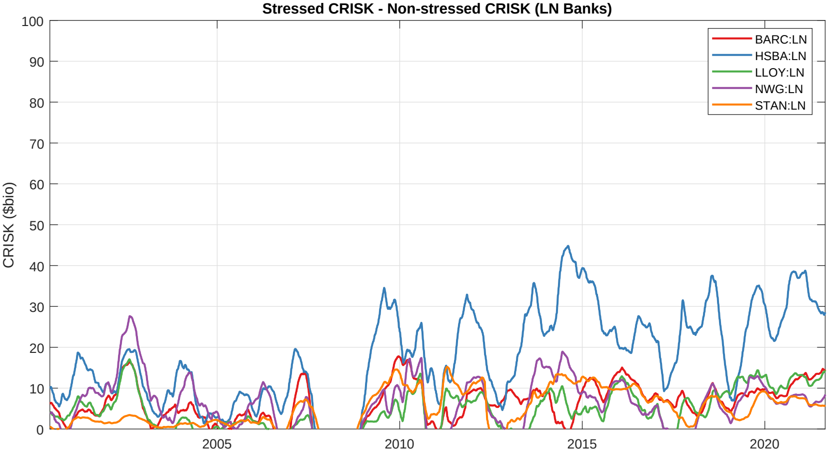
- CRISK(t-1): CRISK as of Dec 31, 2019
- CRISK(t): CRISK as of Dec 31, 2020

Ticker	CRISK(t-1)	CRISK(t)	dCRISK	dDEBT	dEQUITY	dRISK
HSBA:LN	19.17	85.87	66.69	19.48	50.88	−2.85
LLOY:LN	19.27	41.8	22.53	3.14	21.2	−2.22
BARC:LN	60.59	79.61	19.02	11.08	11.71	−3.7
NWG:LN	27.64	42.7	15.05	3.12	13.15	−1.19
STAN:LN	18.94	29.86	10.92	4.17	8.77	−2.09
Total			134.22	40.99	105.71	−12.04

CRISK vs. Non-stressed CRISK: U.S. Banks

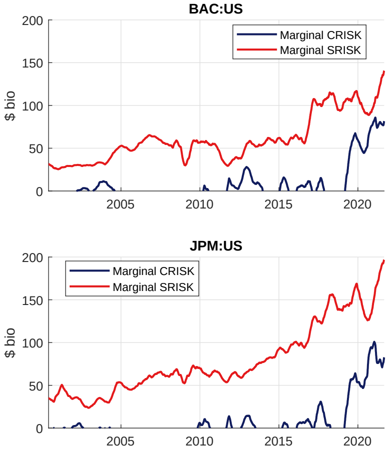


CRISK vs. Non-stressed CRISK: U.K. Banks

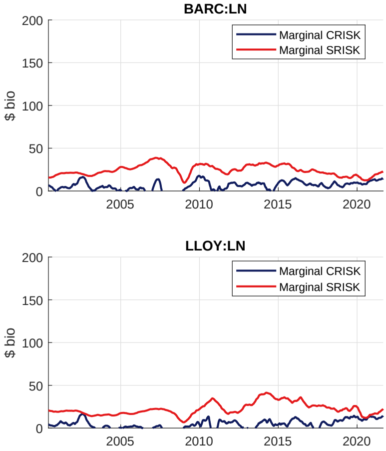


Canada Japan France

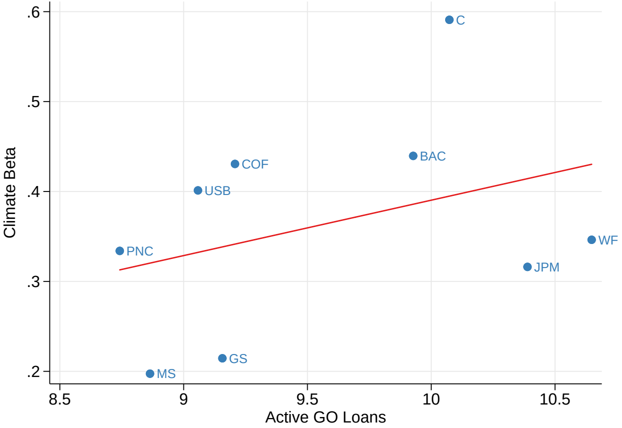
Marginal CRISK vs. Marginal SRISK: U.S. Banks



Marginal CRISK vs. Marginal SRISK: U.K. Banks



Climate Beta and Gas & Oil Loan Exposure



Banks with higher exposure to gas & oil loans have higher climate beta.

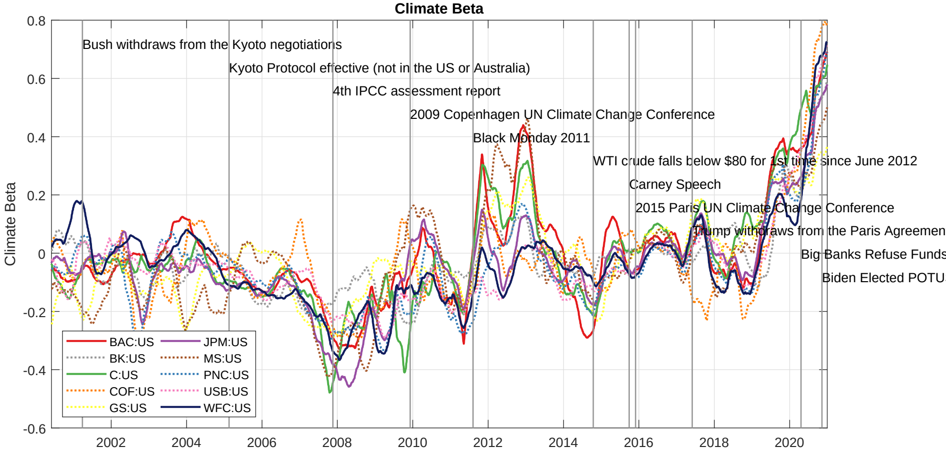
Regression

Conclusion

- We introduce a measure called CRISK, systemic climate risk, which is the expected capital shortfall of a financial institution in a climate stress scenario.
- The climate beta and CRISK substantially increased during 2020.
- The increase in CRISK during 2020 was primarily due to decrease in equity values of banks.
- CRISK is considerably higher than expected capital shortfall of banks under *zero* climate stress scenario.
- Banks with higher exposure to gas & oil loans have higher climate beta and CRISK.

Appendix

Time-varying climate beta of U.S. Banks



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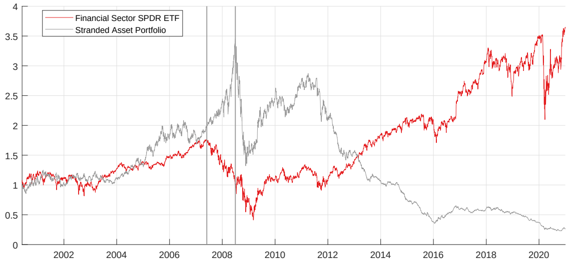
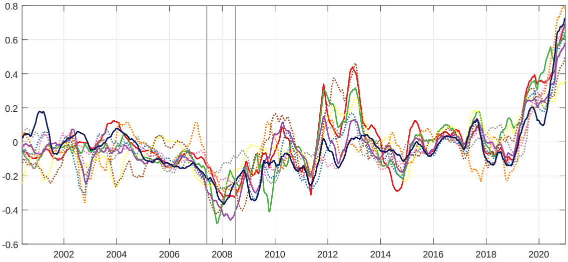
Negative Climate Beta





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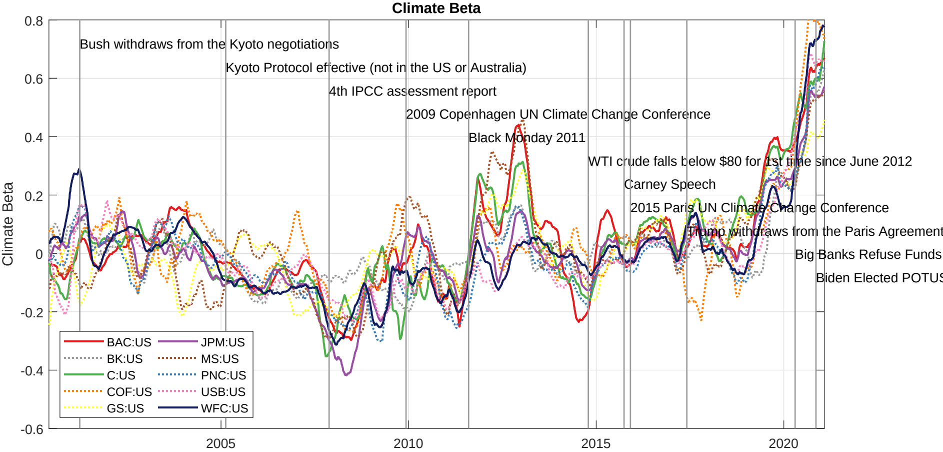
Time-varying climate beta of U.S. Banks

Climate factor 0.3 XLE + 0.7 KOL



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Climate Beta and Gas & Oil Loan Exposure

	(1) $\Delta\beta^{Climate}$	(2) $\Delta\beta^{Climate}$	(3) $\Delta\beta^{Climate}$	(4) $\Delta\beta^{Climate}$
GO Loans	0.00607**	0.00622*	0.0111***	0.00904*
	(2.91)	(2.26)	(3.61)	(2.08)
Constant	0.00102	0.00496	-0.00920**	-0.0281
	(0.45)	(0.09)	(-2.48)	(-1.10)
Bank Controls	N	Y	N	N
Bank FE	N	N	Y	Y
Year FE	N	N	N	Y
N	462	462	462	462
RSqr	0.00611	0.00612	0.0140	0.176

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

- $\beta_{it}^{Climate}$ is bank i's time-averaged daily climate beta during quarter t
- $GOLoans_{it}$ is bank i's new syndicated loans to the gas and oil industry (in log) in quarter t

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Coal Futures vs. KOL ETF