Climate Stress Testing

Robert Engle Hyeyoon Jung

NYU Stern

October 2020

Introduction

- We propose climate stress testing procedure to test the resilience of financial institutions to climate-related risks.
  - **Transition risks** arising from changes in policies
  - **Physical risks** arising from damage to property

Climate Stress Testing Methodology

Climate stress testing methodology involves three steps:

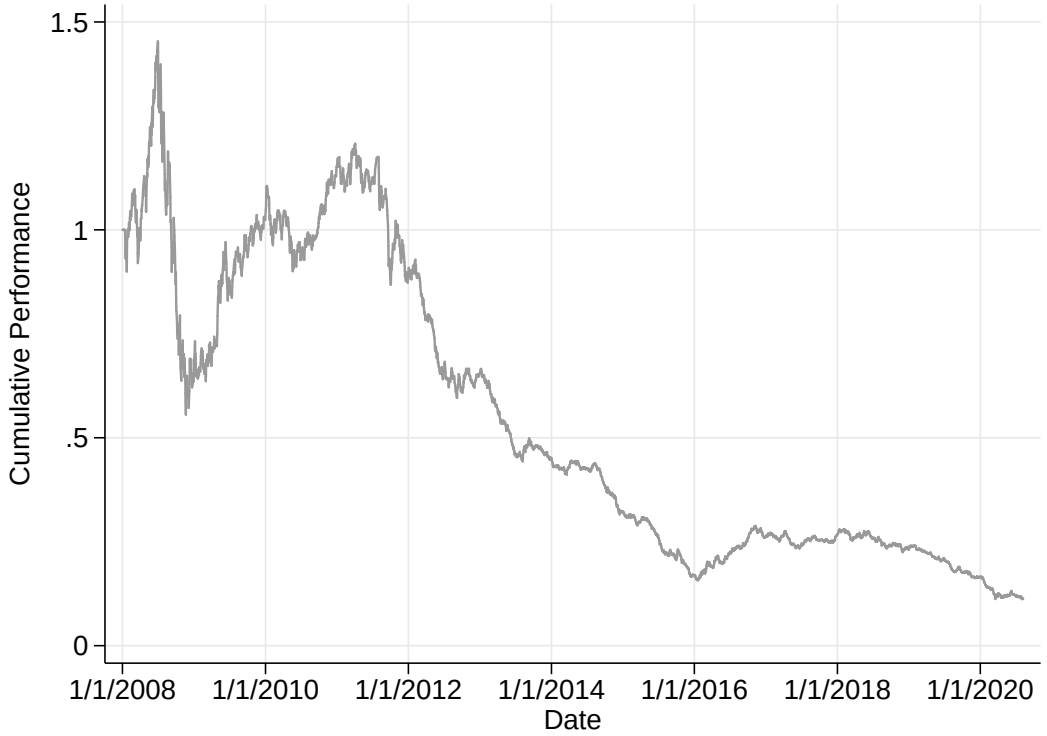
1. Measure the climate risk factor.
2. Estimate time-varying climate beta of banks.
   - Dynamic Conditional Beta (DCB) model
3. Compute systemic climate risk (CRISK).
   - CRISK: Capital shortfall of banks in a climate stress scenario

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 $\beta_{it}^{Climate}$

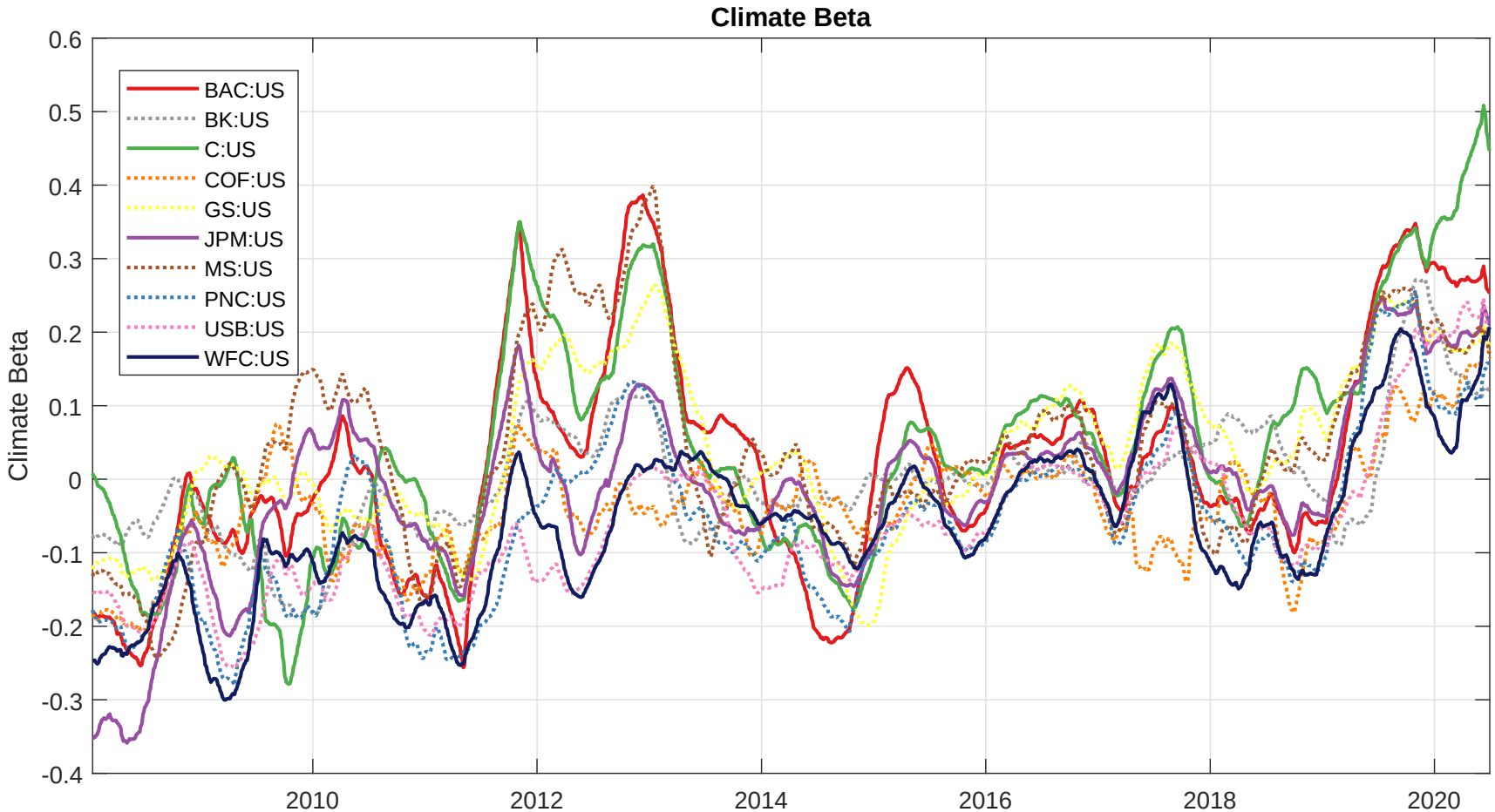
- Bank's stock return sensitivity to the climate factor
- Dynamic Conditional Beta Model[1]

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

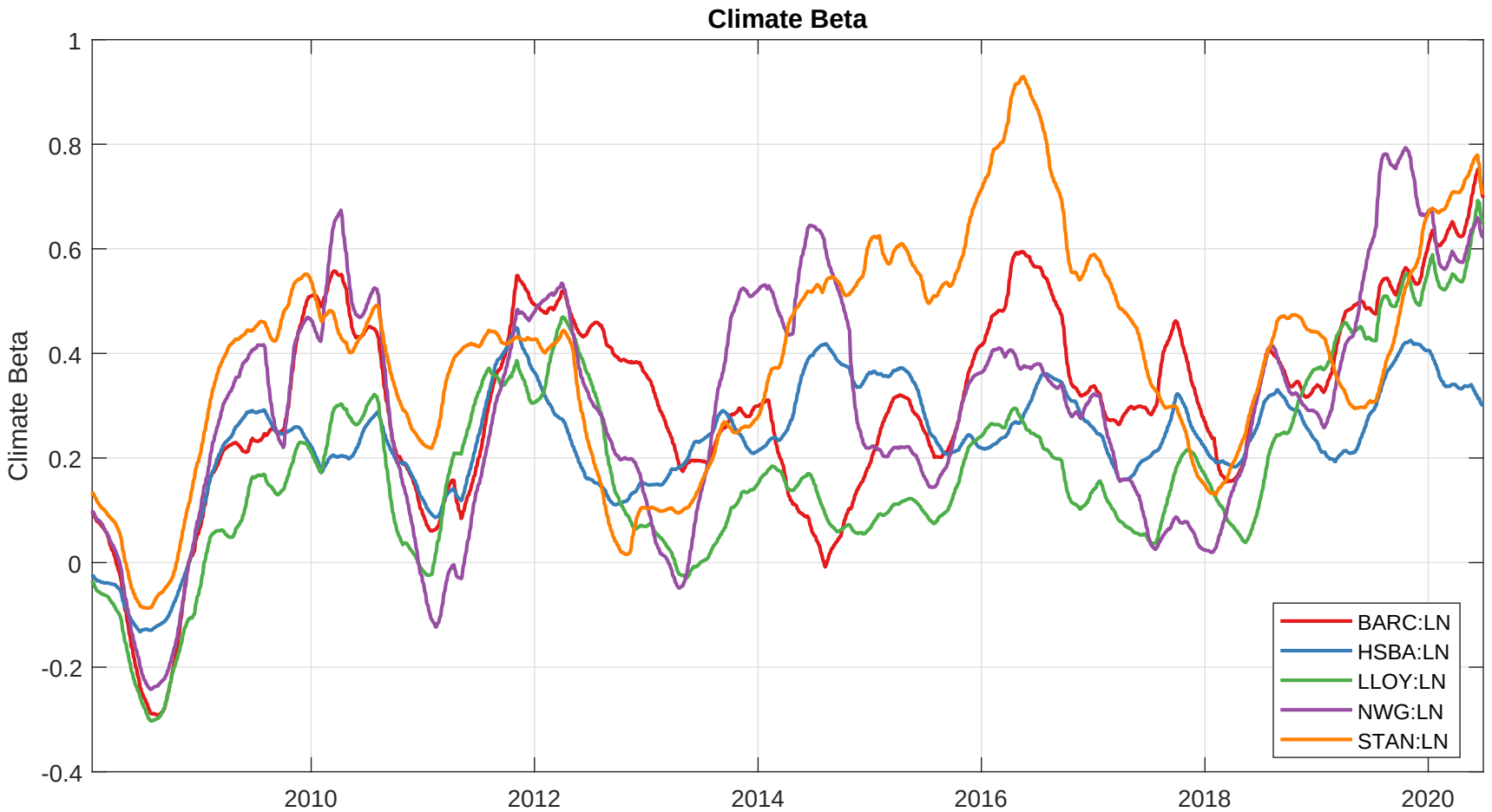
  - Allows volatility and correlation to be time-varying.
- Expect:
  - $\beta^{Climate} > 0$ for banks with large exposure to oil and gas loans
  - $\beta^{Climate} < 0$ for banks with large exposure to renewable energy, for example

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

Time-varying climate beta of U.S. Banks



Time-varying climate beta of U.K. Banks



Step 3: CRISK

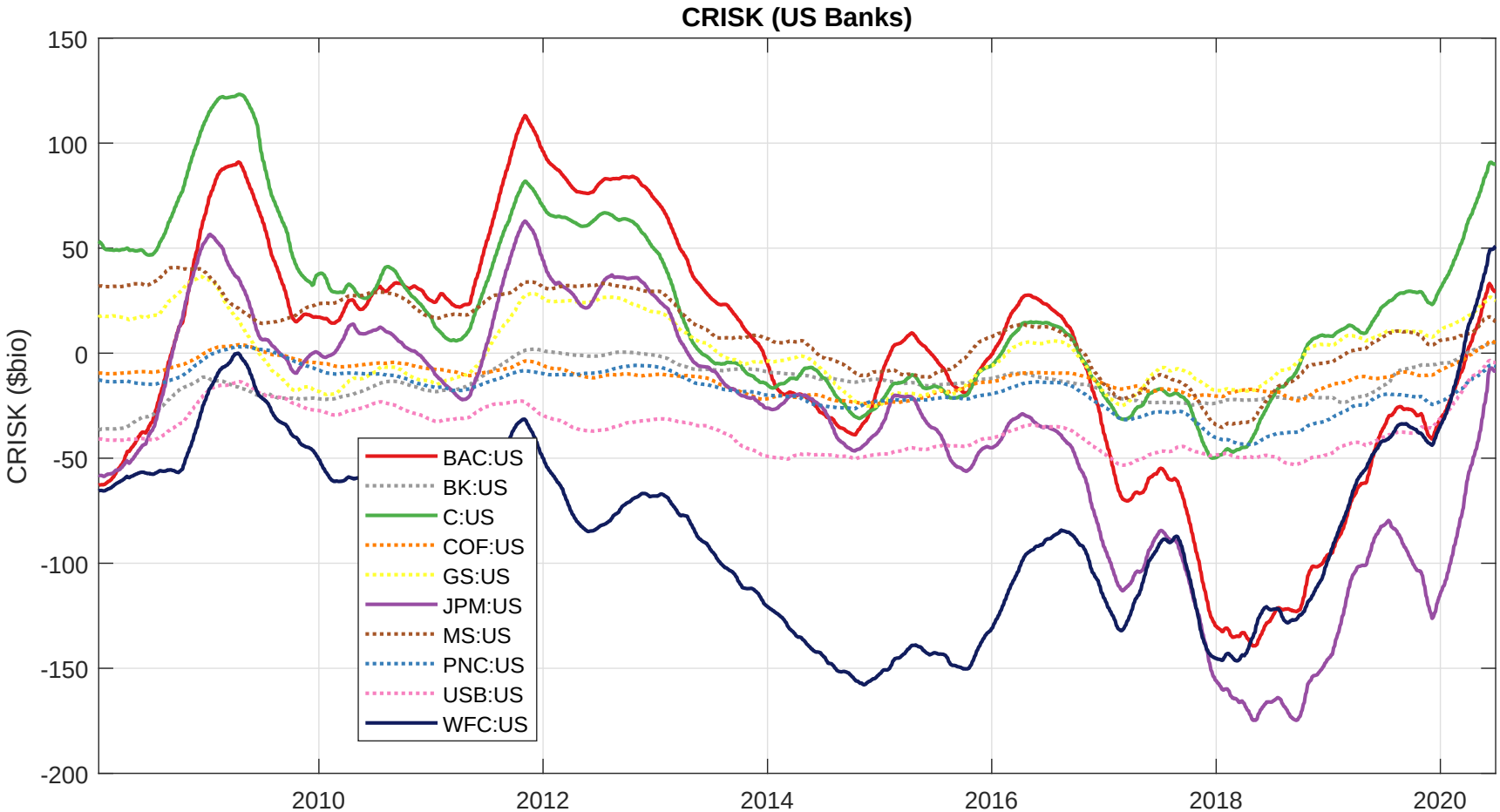
Follow the SRISK methodology[2]

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

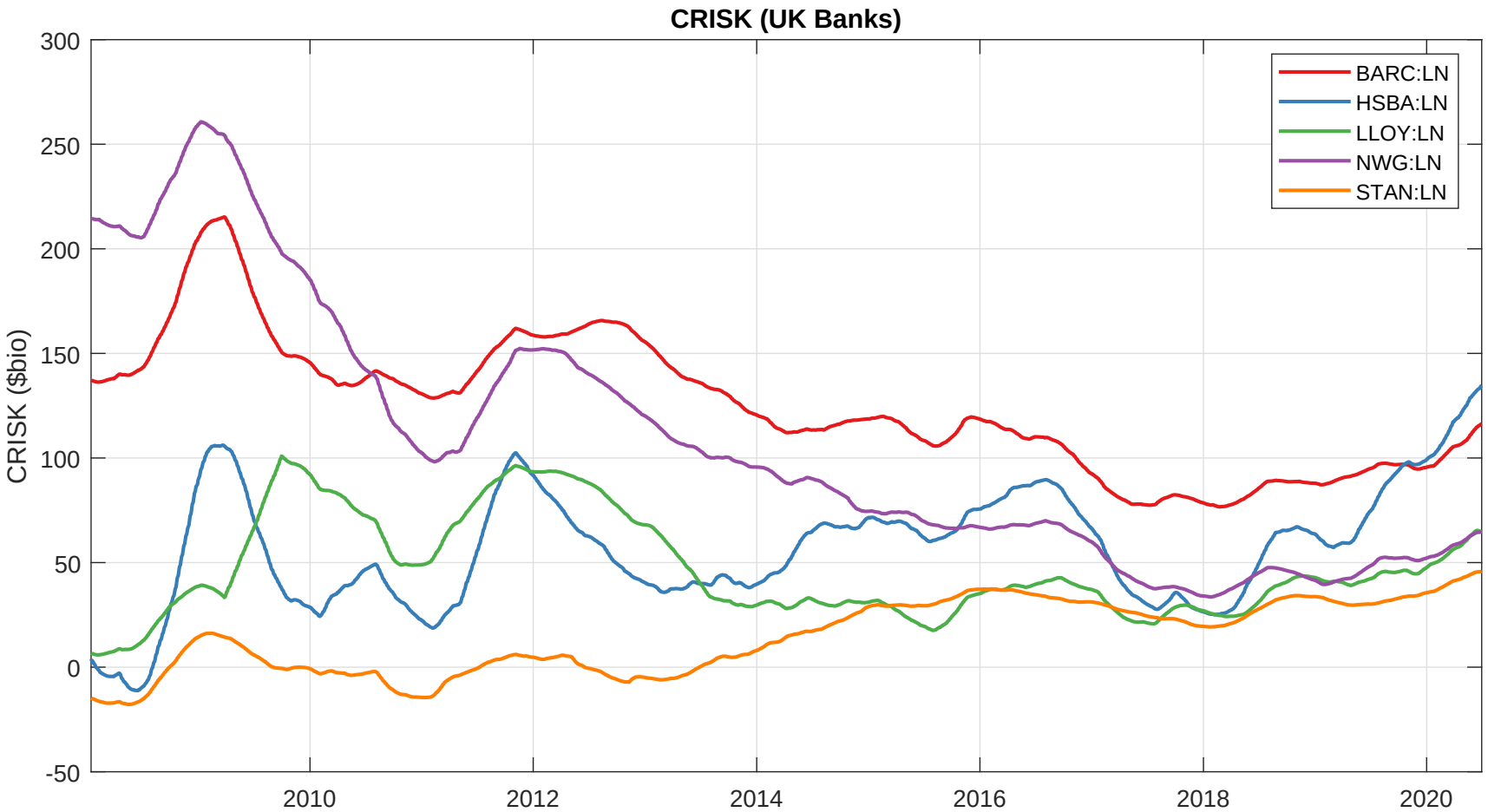
- D: Book value of debt
- W: Market capitalization
- LRMES: Expected equity loss conditional on the climate stress
- Prudential level of equity relative to assets $k = 0.08$
- Climate stress level $\theta = 0.5$
  - 1% quantile of 6 month return on the stranded asset portfolio

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

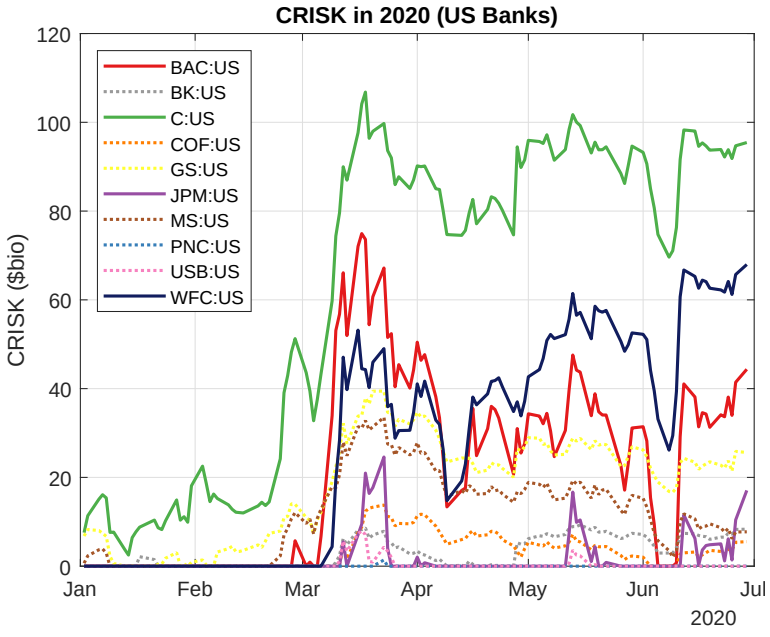
CRISK of U.S. Banks



CRISK of U.K. Banks



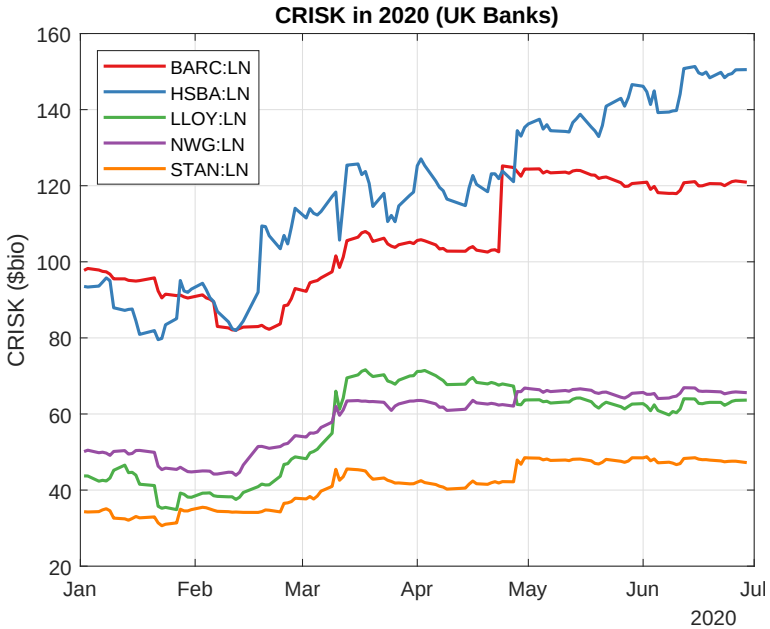
CRISK of U.S. Banks in 2020



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	Royal Bank of Scotland	RBS	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 Jun 30, 2020

Bank	CRISK(t-1)	CRISK(t)	dCRISK	dDEBT	dEQUITY	dRISK
BAC:US	-62.8782	44.3566	107.2347	15.3599	84.3207	4.3684
BK:US	-10.0837	8.3294	18.4132	7.6062	11.3722	-1.0834
C:US	7.5527	95.4446	87.8919	16.487	49.8091	19.1819
COF:US	-12.9993	5.5241	18.5234	1.3902	14.8636	1.978
GS:US	6.7912	25.6111	18.8199	6.5776	13.8314	-2.9448
JPM:US	-154.7662	17.0675	171.8337	30.1494	126.2404	10.8338
MS:US	0.66584	7.7376	7.0718	3.2242	6.7423	-4.0878
PNC:US	-29.4485	-1.5319	27.9166	2.8522	22.1912	2.6078
USB:US	-42.6356	-1.9258	40.7098	4.4132	30.5586	5.6696
WFC:US	-50.0227	67.9625	117.9852	3.8769	112.4639	1.2714

CRISK Decomposition: U.K. Banks in 2020

- CRISK(t-1): CRISK as of Dec 31, 2019
- CRISK(t): CRISK as of Jun 30, 2020

Bank	CRISK(t-1)	CRISK(t)	dCRISK	dDEBT	dEQUITY	dRISK
BARC:LN	97.7511	120.9177	23.1666	16.1093	10.3793	-3.6902
HSBA:LN	93.5244	150.5221	56.9977	14.0741	47.4316	-4.306
LLOY:LN	43.7237	63.6475	19.9238	1.5111	20.3236	-2.6533
NWG:LN	50.124	65.6033	15.4794	4.5435	12.5412	-1.8796
STAN:LN	34.317	47.2166	12.8996	6.0664	7.9461	-1.2523