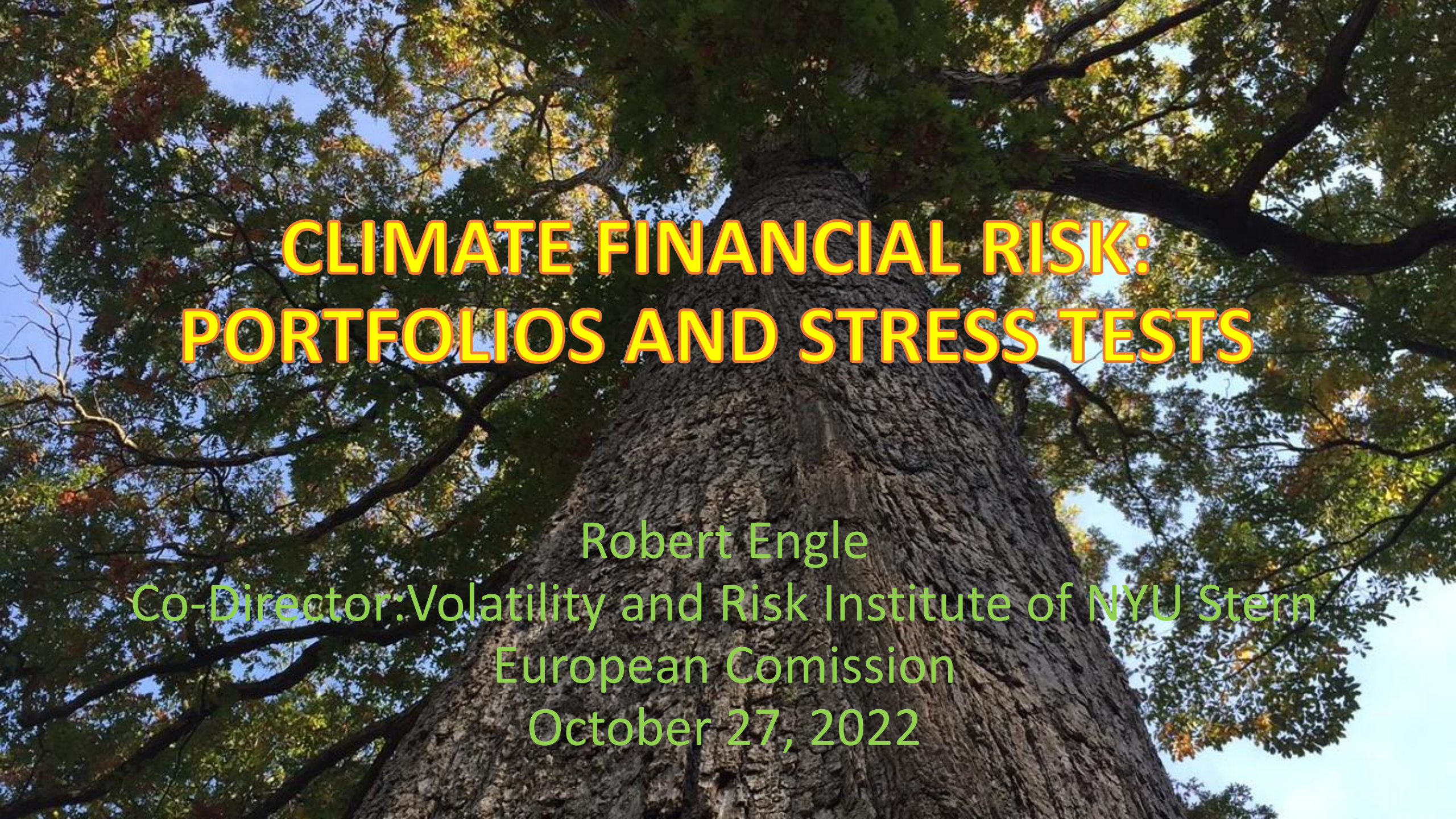


CLIMATE FINANCIAL RISK: PORTFOLIOS AND STRESS TESTS

Robert Engle
Co-Director:Volatility and Risk Institute of NYU Stern

European Comission
October 27, 2022

CLIMATE RISK

- Science says the world is warming and economics says that this will lead to lower productivity, population migration, stranded assets such as fossil fuels and more importantly stranded capital and land, global conflicts and reductions in the quality of life, and possibly the end of our species.
- But the worst effects of this are due to arrive many decades in the future if at all.
- Nevertheless we see signs of this today in asset prices as these reflect forecasts of long term cash flows and productivity. These asset price movements will guide capital and investment in the future and we are engaging today in an effort to understand what to expect and what to do about it.
- TSLA stock is selling for 75 times earnings and GM is less than 7. Forecasts matter.

ASSET PRICING FOR CLIMATE HEDGE PORTFOLIOS

- A climate hedge portfolio should overweight assets that will do well in climate change and underweight those that will not.
- Firms that are exposed to climate risk should be less desirable and therefore less expensive with higher expected returns. Bolton and Kazperczyk (2020). There is a risk premium for bearing climate risk.
- Climate hedge portfolios should have a negative risk premium as they are risk reducing.
- When there is news of increased climate risk, such portfolios should be repriced at a higher level. If climate change is ultimately worse than the market expects, hedge portfolios should outperform the market.

HOW TO BUILD HEDGE PORTFOLIOS

- FUNDAMENTAL ANALYSIS
  - ESG data is combined with financial data to form portfolios. There are many ways to do this and few ways to confirm the hedging ability
  - Specialized assets such as carbon emission certificates or wind farms.
- STATISTICAL ANALYSIS
  - Recognizing that climate news should move hedge portfolios suggests using statistical analysis to find portfolios that are maximally correlated with climate news holding everything else constant.
- V-LAB
  - We follow almost 200 publicly available funds with climate objectives.

Constructing climate hedge portfolios

TWO CLIMATE HEDGE PORTFOLIOS

- Stranded Asset Portfolio: SPY-.7*KOL-.3*XLE

- Climate Efficient Factor Mimicking Portfolio
- De Nard, Engle, Kelly(in draft)
  - Form dynamic, long only portfolios of publicly available climate funds
  - Minimize the variance of these portfolios
  - Maximize the correlation with climate news after taking out the effect of standard investment factors and Stranded Asset Portfolio
  - Hold the portfolio for one month and then recalculate.

HOLDINGS OF CEP

Climate-Efficient FMP Weights on < Nov 2021 >

	Asset	Weight
1	Global X Lithium & Battery Tech ETF	0.37
2	VanEck Environmental Services ETF Fund	0.33
3	Brown Advisory Sustainable Growth Fund	0.18
4	KraneShares Global Carbon Strategy ETF	0.12

Climate-Efficient FMP Weights on < Oct 2022 >

	Asset	Weight
1	First Trust NASDAQ Clean Edge Green Energy Index Fund	0.57
2	First Trust EIP Carbon Impact ETF	0.43

Last updated: Tuesday, October 4th, 2022

LONG TERM BENCHMARK PERFORMANCE

Benchmark		Return	Volatility	Sharpe Ratio
iShares MSCI ACWI ETF	14.57 Years	5.48%	21.36%	0.06
SPDR S&P 500 ETF Trust	29.73 Years	9.58%	18.92%	0.27
Stranded Assets	23.84 Years	7.14%	22.79%	0.31
SPY:US - XLE:US	23.84 Years	-5.93%	21.78%	-0.27
Climate Efficient Factor Mimicking Portfolio	21.32 Years	12.72%	23.12%	0.36

CURRENT BENCHMARK PERFORMANCE

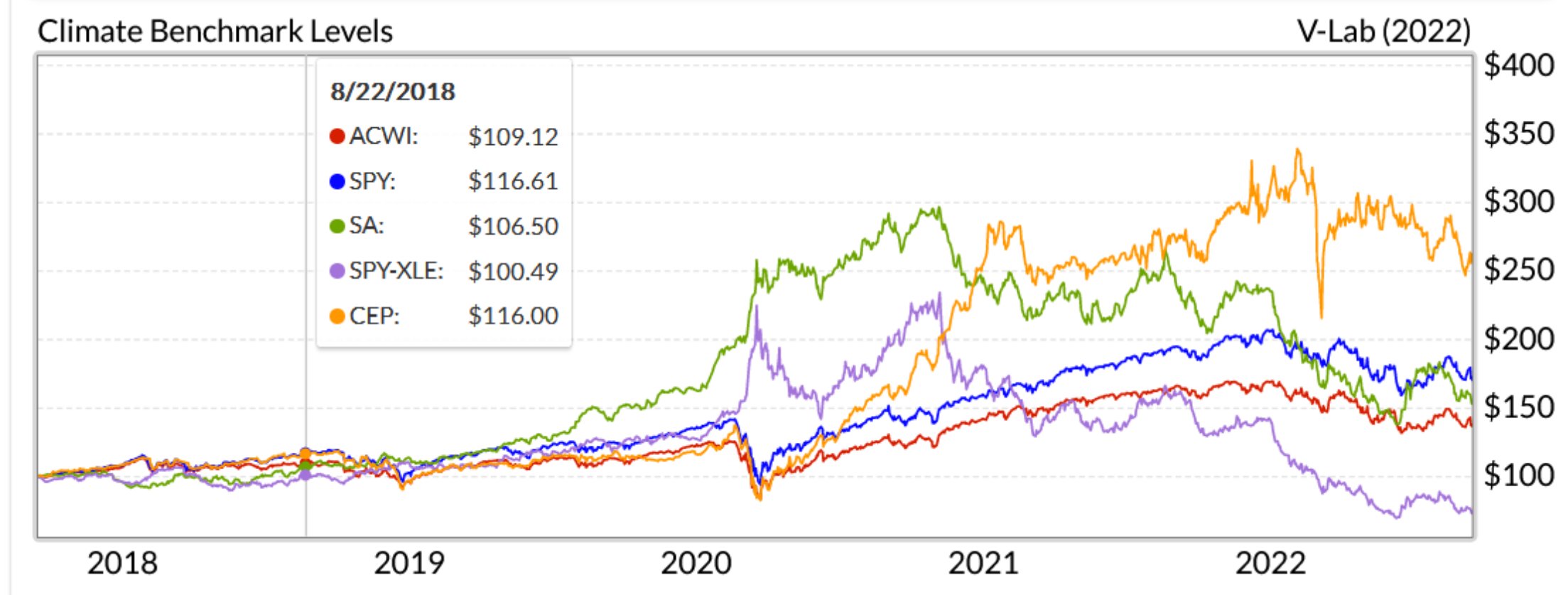
ONE YEAR

Benchmark	Return	Volatility	Sharpe Ratio
iShares MSCI ACWI ETF	-20.05%	21.49%	-1.15
SPDR S&P 500 ETF Trust	-14.22%	23.01%	-0.82
Stranded Assets	-28.16%	26.62%	-1.06
SPY:US - XLE:US	-49.44%	32.43%	-1.52
Climate Efficient Factor Mimicking Portfolio	-20.84%	40.59%	-0.63

FIVE YEAR

Benchmark	Return	Volatility	Sharpe Ratio
iShares MSCI ACWI ETF	5.45%	20.16%	0.06
SPDR S&P 500 ETF Trust	10.45%	21.22%	0.29
Stranded Assets	8.86%	20.29%	0.44
SPY:US - XLE:US	-8.04%	27.62%	-0.29
Climate Efficient Factor Mimicking Portfolio	16.94%	28.94%	0.44

BENCHMARK PLOT



FUND PERFORMANCE

One Year Regression Statistics

Category	α_{CAPM}
All (175)	-4.61
Fossil Fuel Free (47)	-6.72
Low Carbon (101)	-3.31
Low Environmental Risk (19)	-5.34
Sustainability Mandate (139)	-5.34
Sustainable Sector (32)	-11.82

Security	Return	Volatility	↓ Sharpe Ratio
First Trust EIP Carbon Impact ETF	14.45%	15.73%	0.67
KraneShares Global Carbon Strategy ETF	3.33%	42.85%	-0.01
First Trust NASDAQ Clean Edge Green Energy Index Fund	1.67%	46.57%	-0.05
SPDR S&P Kensho Clean Power ETF	1.86%	37.52%	-0.06
Invesco Solar ETF	1.02%	47.15%	-0.06

FUND FIVE YEAR PERFORMANCE

ALMOST ALL FUNDS HAVE POSITIVE SHARPE RATIOS

Five Year Regression Statistics

Category	α_{CAPM}
All (148)	-1.59
Fossil Fuel Free (40)	0.95
Low Carbon (91)	-2.43
Low Environmental Risk (19)	-4.94
Sustainability Mandate (116)	-0.97
Sustainable Sector (24)	3.74

Security	Return	Volatility	Sharpe Ratio ↓
First Trust NASDAQ Clean Edge Green Energy Index Fund	28.88%	37.48%	0.67
Invesco Solar ETF	31.34%	41.30%	0.67
iShares Global Clean Energy ETF	20.94%	30.39%	0.57
VanEck Low Carbon Energy ETF Fund	17.69%	29.41%	0.48
ClearBridge Sustainability Leaders Fund	13.73%	21.16%	0.48


USING CLIMATE FACTORS

WHAT CAN WE DO WITH THESE CLIMATE FACTOR MIMICKING PORTFOLIOS?

- Invest in them directly to achieve climate hedge performance.
- Invest in portfolios that have a high beta on these funds to achieve similar performance.
- Measure the risk and return of a hedge portfolio with GARCH.
- Examine the beta of banks to see how exposed they are to climate risk. Banks make loans to many sectors and if their loans are to firms with climate risk, then the banks will face climate risk.
- Stress test banks by examining the impact of rising climate risk.

1 YEAR PERFORMANCE: TWO FLAVORS OF GREEN

Security	Return	Volatility	↓ Sharpe Ratio	Cos Sim	Tag Index	α_{CAPM}	β_{SA}	β_{CEP}
First Trust EIP Carbon Impact ETF	3.38%	17.79%	-0.07	-0.118	0.108	13.07 (1.08)	-0.03 (-1.00)	0.01 (0.33)
KraneShares Global Carbon Strategy ETF	1.32%	42.76%	-0.08	-0.223	0.094	17.30 (0.53)	-0.02 (-0.29)	0.98 (34.58)
ALPS Clean Energy ETF	-8.37%	44.67%	-0.29	0.171	-0.154	-0.25 (-0.01)	-0.13 (-1.16)	0.01 (0.18)
VanEck Uranium + Nuclear Energy ETF Fund	-4.48%	20.73%	-0.44	-0.055	-0.010	8.08 (0.83)	-0.08 (-2.24)	0.03 (0.97)
WisdomTree U.S. Quality Dividend Growth Fund	-3.79%	18.05%	-0.47	0.061	0.008	8.97 (1.84)	0.06 (5.17)	-0.01 (-1.00)
First Trust NASDAQ Clean Edge Green Energy Index Fund	-22.97%	48.10%	-0.57	0.104	-0.141	12.39 (0.41)	-0.22 (-2.14)	0.06 (1.38)
Invesco Solar ETF	-25.29%	47.41%	-0.63	0.013	-0.172	2.53 (0.06)	-0.25 (-1.54)	0.03 (0.50)
SPDR S&P Kensho Clean Power ETF	-20.41%	38.73%	-0.65	0.079	-0.116	3.68 (0.11)	-0.13 (-1.29)	0.05 (1.01)
VanEck Environmental Services ETF Fund	-10.41%	23.15%	-0.65	-0.054	0.029	5.28 (0.38)	-0.06 (-2.01)	-0.01 (-0.17)
Direxion Daily Global Clean Energy Bull 2x Shares	-48.34%	72.97%	-0.73	-0.032	-0.138	-4.60 (-0.08)	-0.24 (-0.91)	0.11 (1.25)

CLIMATE STRESS TESTS FOR BANKS JUNG, ENGLE AND BERNER

- Why should central banks do this?
  - Banks may have climate sensitive assets that have more risk than they think.
  - If many banks are exposed, then there is potential for systemic risk and another financial crisis.
  - Policies that mitigate climate change will impact the fossil fuel sector. If mitigation induces a financial crisis, policy makers and regulators should know.
- How much would bank stock prices fall if climate risk increases?
  - *Dynamic climate beta*.
- Would these banks need new capital in order to continue to function?
  - *CRISK calculated the same as SRISK*

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.
  - When bank stocks are traded in other time zones, both a contemporaneous DCB and a lagged factor DCB model are estimated. The beta is the sum of these two. This is appropriate if the factors are serially uncorrelated.

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

HOW MUCH STRESS?

- Consider the stranded asset risk portfolio. (the negative of SA which is therefore long fossil fuel sector and short SPY)
- Look at all the six monthly returns for the last 20 years.
- Find the 1% quantile of this distribution. This is a 50% decline. We will use this. This is the default in VLAB CRISK.
- We used the same criterion for market declines and found 40% decline which is what is used as a default in VLAB for SRISK.

CRISK AND MARGINAL CRISK

- CRISK is the expected capital shortfall of a bank under climate stress
- CS=k(D+W)-W where k is a prudential capital ratio set to 8% here, D is balance sheet liabilities and W is the market value of equity.
- CRISK=E(CS conditional on climate stress)
- Marginal CRISK = CRISK-CS , i.e. the difference between stressed capital shortfall and unstressed capital shortfall.
- CRISK is a measure of capital adequacy
- Marginal CRISK is a measure of exposure.

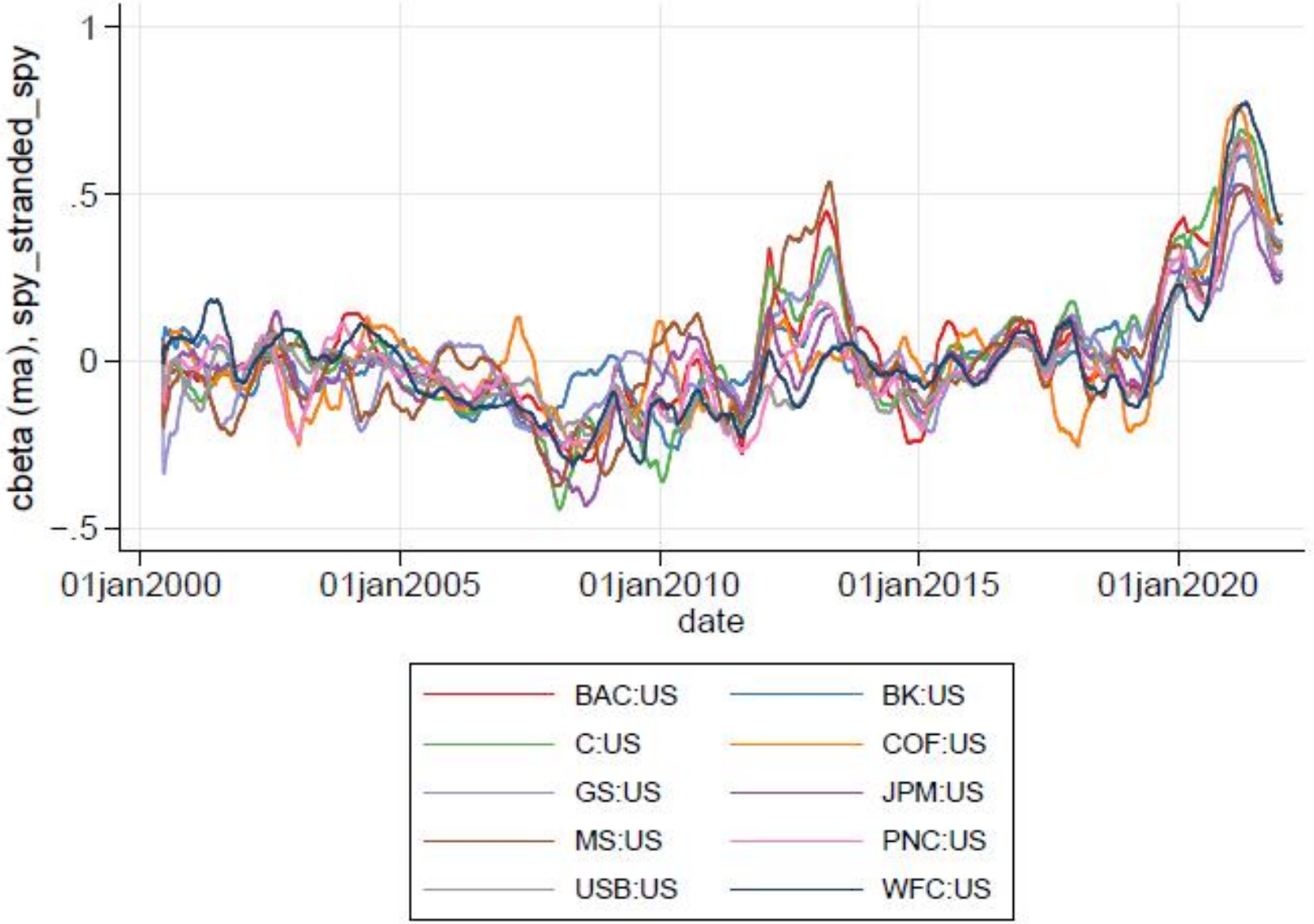


Figure 2: Climate Beta of U.S. Banks Climate beta estimates from June 2000 to Dec 2021.

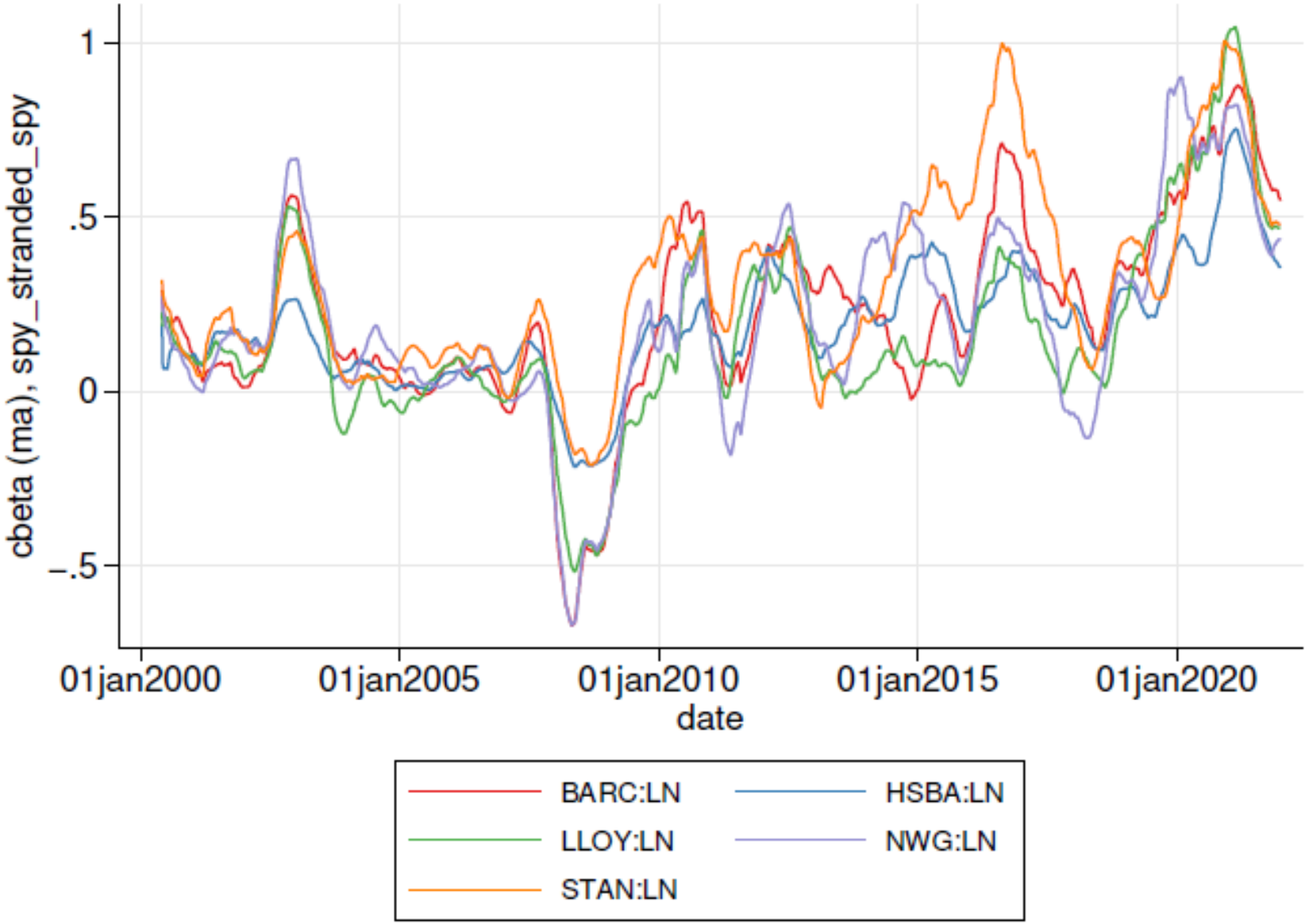


Figure 3: Climate Beta of U.K. Banks Climate beta estimates from June 2000 to Dec 2021.

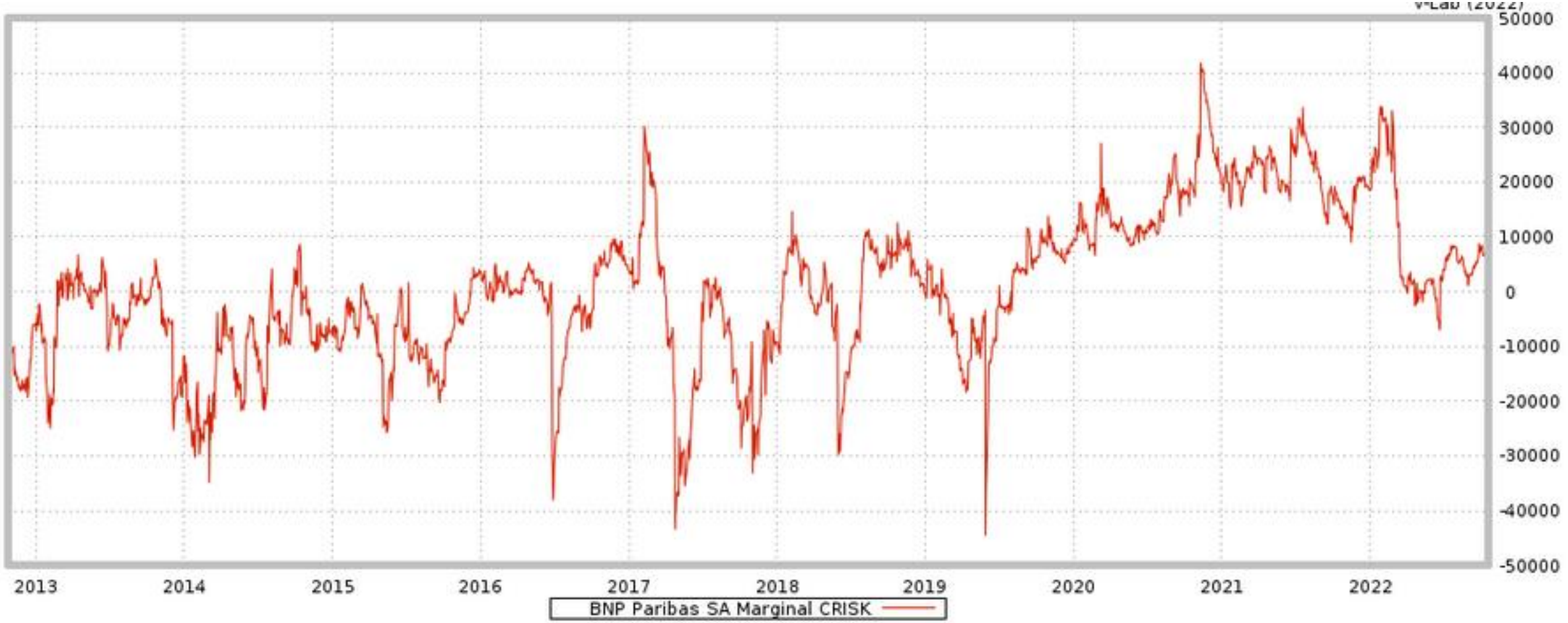
VLAB.STERN.NYU.EDU OCT 26, 2022

Climate Risk Rankings for < Oct 2022 > View changes

Institution	CRISK %	↓ CRISK ($ m)	Marginal CRISK	LRMES	Climate β	Cor	Vol	Lvg
BNP Paribas SA	10.45	110923.3	4080.77	7.72	0.12	-0.01	36.05	52.90
Credit Agricole SA*	9.09	96480.0	1765.88	7.06	0.11	0.01	33.32	83.26
Barclays PLC	7.69	81606.3	4331.94	17.74	0.28	0.02	46.80	72.56
HSBC Holdings PLC	6.75	71693.2	18552.94	18.51	0.30	0.09	35.77	27.29
Societe Generale SA	6.55	69493.3	2665.66	14.95	0.23	0.05	36.32	82.57
Deutsche Bank AG	5.91	62746.3	3815.40	22.39	0.37	0.06	44.34	77.60
Banco Santander SA	5.38	57138.5	4815.16	11.64	0.18	-0.00	36.33	39.91
Natwest Group PLC	3.53	37493.1	10140.47	42.14	0.79	0.15	54.35	37.71
Lloyds Banking Group PLC	3.36	35640.9	9342.63	31.17	0.54	0.08	56.12	33.26
UniCredit SpA	3.00	31808.8	1972.82	9.36	0.14	0.04	35.43	42.50

BNP PARIBAS: CLIMATE BETA OCT 26,2022

BNP PARIBAS: MARGINAL CRISK OCT 26,2022



BNP PARIBAS: CRISK OCT. 26,2022

THREE YEAR CHANGE IN EUROPEAN CRISK

Climate Risk Rankings for Oct 2022 View changes since Sep 2019

Institution	↓ CRISK (t)	CRISK (t - 1)	Δ CRISK	Δ DEBT	Δ EQUITY	Δ RISK
BNP Paribas SA	110923.3	70019.1	40904.2	37539.4	4244.7	-879.9
Credit Agricole SA*	96480.0	76759.4	19720.5	16500.0	7002.1	-3781.7
Barclays PLC	81606.3	55497.3	26109.0	20414.0	4881.1	813.8
HSBC Holdings PLC	71693.2	1942.6	69750.6	23477.6	39661.7	6611.3
Societe Generale SA	69493.3	63036.8	6456.5	1295.0	3779.1	1382.4
Deutsche Bank AG	62746.3	74730.6	-11984.3	-10184.0	-1875.6	75.4
Banco Santander SA	57138.5	31762.3	25376.1	5871.5	19881.5	-376.9
Natwest Group PLC	37493.1	26921.3	10571.8	3582.3	3346.9	3642.6
Lloyds Banking Group PLC	35640.9	15921.3	19719.6	2148.1	11002.5	6569.0
UniCredit SpA	31808.8	26627.0	5181.8	1985.3	3441.2	-244.7

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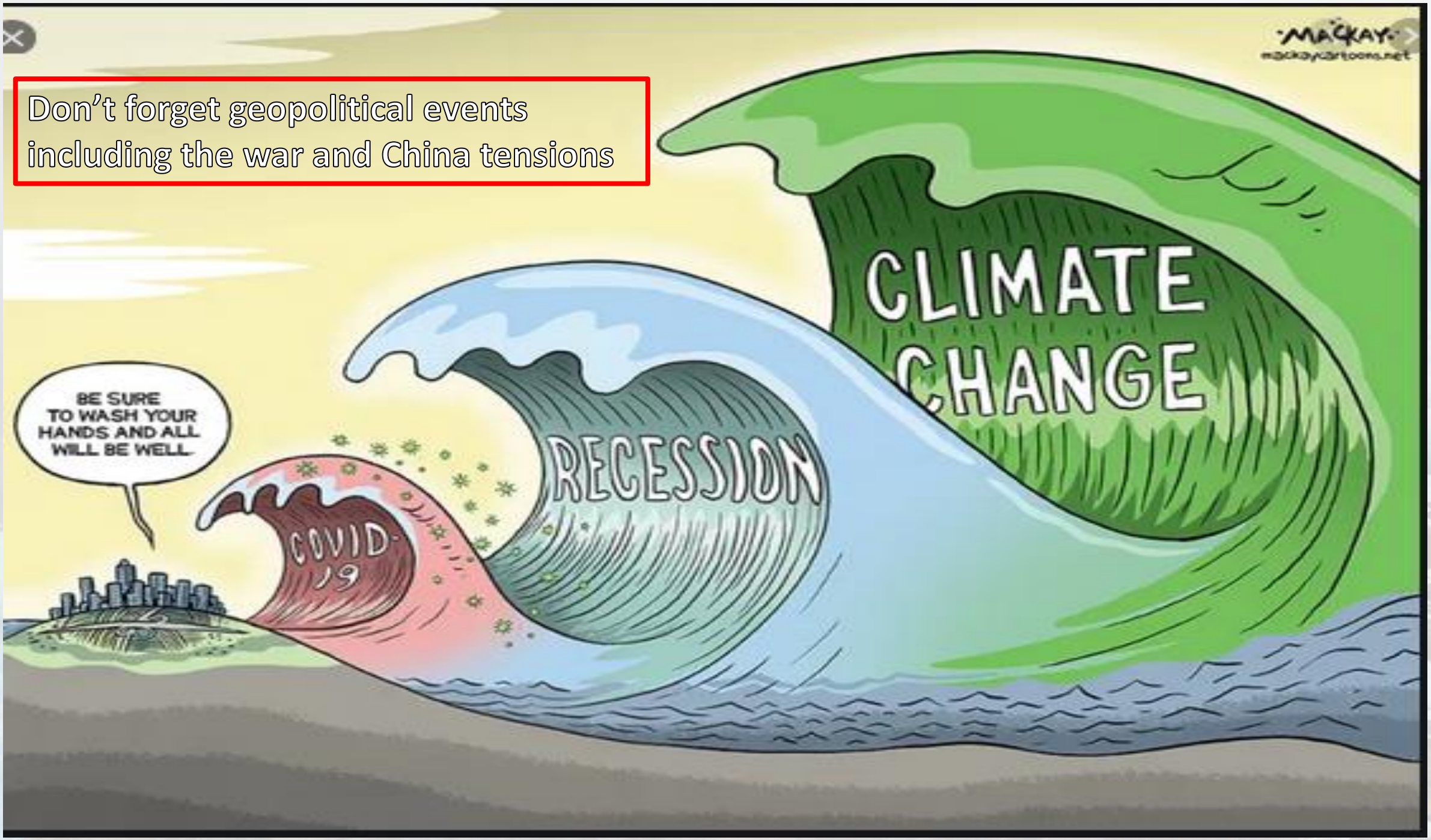
COMPOUND RISKS

- At the VRI we study many different kinds of risks. Geopolitical, Climate, Pandemic, Cyber, Financial and Macroeconomic.
- However, these do not just happen one at a time. Often more than one risk arises and they often exacerbate each other.
- Such compound risks are what we see today. Geopolitical risk is creating macro risk and Climate risk is contributing to both geopolitical and macro risk. Pandemic risk is also creating macro risk.

- When the SA climate index fell by 50%, the SPY also fell as the great financial crisis approached. These are likely to occur together.

Don’t forget geopolitical events including the war and China tensions



STRESS TESTING FOR COMPOUND RISKS

- For the two factor stress test reported, the stresses can be combined. Suppose a climate disaster is typically combined with a market collapse. Then the stress would be a combination of SPY decline and SA decline.
- Letting p be the bank market cap and x and y be the factors driving returns, then the six month change in market cap if x falls by 50% of todays value and y falls 40%, would be given by

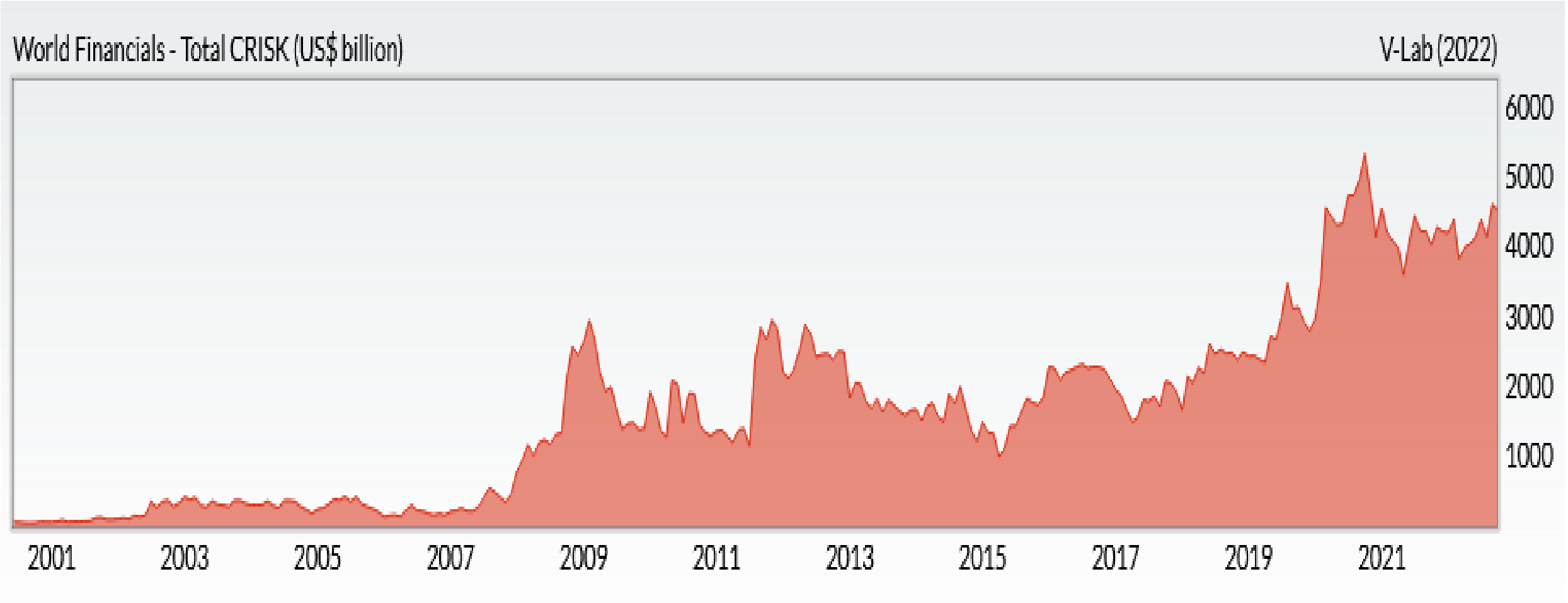
$$\log\left(\frac{p_{t+h}}{p_t}\right) = \beta_x \log\left(\frac{x_{t+h}}{x_t}\right) + \beta_y \log\left(\frac{y_{t+h}}{y_t}\right), \ \textit{then}$$

$$p_{t+h} = p_t \exp\left\{\beta_x \log(.5) + \beta_y \log(.6)\right\}$$

HOW BIG IS EUROPEAN CLIMATE RISK

- TOP 10 EUROPEAN BANKS BY CRISK: TOTAL CRISK = $655 BIL
- SAME BANKS: TOTAL MARGINAL CRISK=$61 BIL
- SAME BANKS: THREE YEAR CHANGE IN CRISK=$211 BIL
- SAME BANKS: COMPOUND RISK: C&SRISK=$776 BIL, MARGINAL C&SRISK=$183 BIL

WORLD CRISK 10/26/22



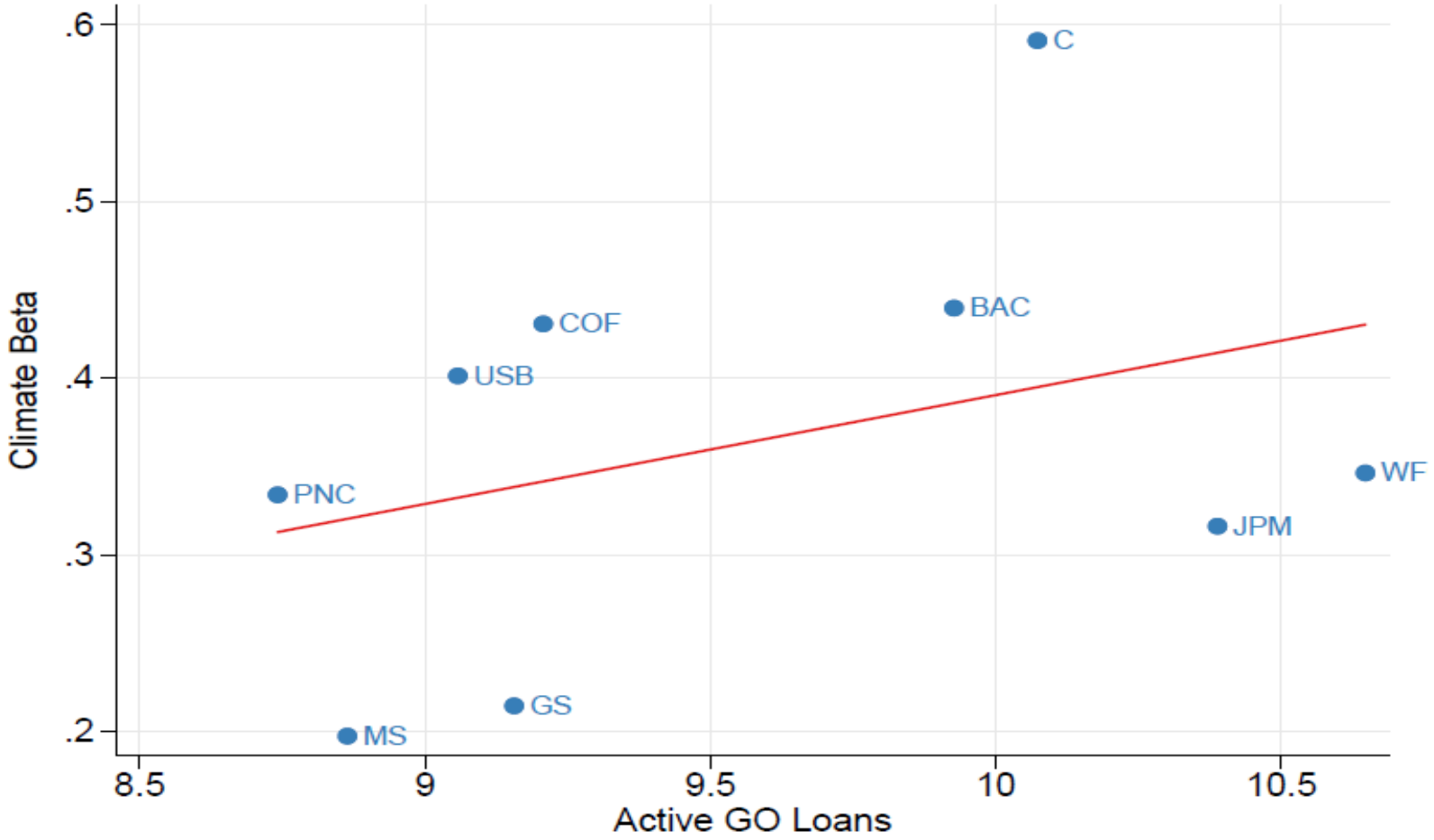
HOW ROBUST ARE THESE BETAS?

- OMITED FACTORS:
  - Introduce interest rate, bank performance measures and term structure factors as well as returns on mortgage backed securities in a first step. Then do the same DCB on the residuals.
  - Results were very similar.
- OTHER TRANSITION RISK MEASURES
  - Emissions factor is the return on a portfolio of stocks in the 30 sectors with the highest scope 1 and scope 2 emissions. A carbon tax transition scenario.
  - Emission factor less return on green energy : A transition scenario of clean energy subsidies and/or taxes.
  - Climate Efficient Factor Mimicking Portfolio. Second climate factor is the transition.
  - Coefficients were bigger for emissions portfolio and much smaller for CEP and brown-green returns.

ROBUSTNESS 2

- Is the econometrics doing what it is expected to do?
  - 1 year rolling regressions gives similar patterns.
  - Constraining some of the dynamic parameters to be the same within a country makes little difference.
  - The correction for asynchronous returns makes the betas only slightly bigger.
- Does this work in other countries?
  - Yes in the manuscript we do 5 countries, US, UK, Canada, Japan, France
  - In an implementation in VLAB we will have I believe 74 countries just as for SRISK and 1000 financial institutions.
- Can we implement more granular data on holdings?
  - Yes we now have Y-14 data for US banks and have a panel model explaining the dynamic betas in terms of the holdings and pd of the holdings.

Climate Beta and Gas & Oil Loan Exposure



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

PANEL REGRESSION OF US CLIMATE BETAS ON BANK CHARACTERISTICS.

	(1) Climate Beta	(2) Climate Beta	(3) Climate Beta	(4) Climate Beta
Brown Loan Share (Emiss)	2.448***	1.862***	2.299**	0.869**
	(3.16)	(2.89)	(2.45)	(2.58)
Log Assets		0.0140	0.478***	0.0501
		(0.89)	(5.44)	(0.67)
Leverage		3.612***	-1.314	-2.274*
		(4.26)	(-0.83)	(-2.00)
ROA		6.623***	3.039*	1.631
		(3.12)	(1.87)	(1.52)
Loans/Assets		-0.0646	-0.948**	-0.577**
		(-0.76)	(-2.29)	(-2.49)
Deposits/Assets		0.527***	0.956**	-0.182
		(3.83)	(2.39)	(-0.75)
Book/Market		0.235***	0.237***	0.00956
		(4.42)	(5.95)	(0.27)
Loan Loss Reserves/Loans		4.001*	7.216***	3.151*
		(1.93)	(4.96)	(1.82)
Non-interest Income/Net Income		0.00134***	0.00123***	0.00109***
		(3.93)	(5.90)	(5.68)
Market Beta		0.177***	0.0840***	0.00808
		(4.90)	(3.22)	(0.42)
N	715	715	715	715
Bank Controls	N	Y	Y	Y
Bank FE	N	N	Y	Y
Year FE	N	N	N	Y
Adj R2	0.0557	0.292	0.518	0.677

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 5: Climate Beta and Brown Loan Share The dependent variable, $\beta_{it}^{Climate}$ is bank i's time-averaged daily climate beta during quarter-end month. *Brown Loan Share*$_{it}$ is bank i's loan exposure to the top 30 industries with highest emissions in quarter t. Bank control variables include log assets, leverage, ROA, loans/assets, deposits/assets, book/market, loan loss reserves/loans, non-interest income/net income, market beta. Standard errors are clustered at bank level. The sample period is from 2012:Q2 to 2021:Q4.

VLAB
VOLATILITY MAP
OCTOBER 26,2022

WHAT DO WE SEE TODAY?

EXPLANATION OF FINDINGS

- Most Sustainable funds are underperforming the market.
- This is not surprising because they are underweighting fossil energy which has strikingly outperformed the market.
- But why has energy done so well? Because of the private sector approach to decarbonization. The long run risk of stranded assets, has lead to under investment in fossil energy and reduced supply. This generates price increases and profit increases in fossil energy as demand recovers.
- This profitability has only a small impact on supply as any new investment is potentially going to be stranded.

IMPACTS ON COUNTRIES

- We see inflation higher than in we have seen in decades and energy prices are a part of this.

- Another cause is the supply chain collapse which is partly due to high costs of transportation, partly due to pandemic issues and partly due to deteriorating relations with China.

- Interest rate hikes will slow the global economy. Can we increase energy supply and fix the supply chain instead?

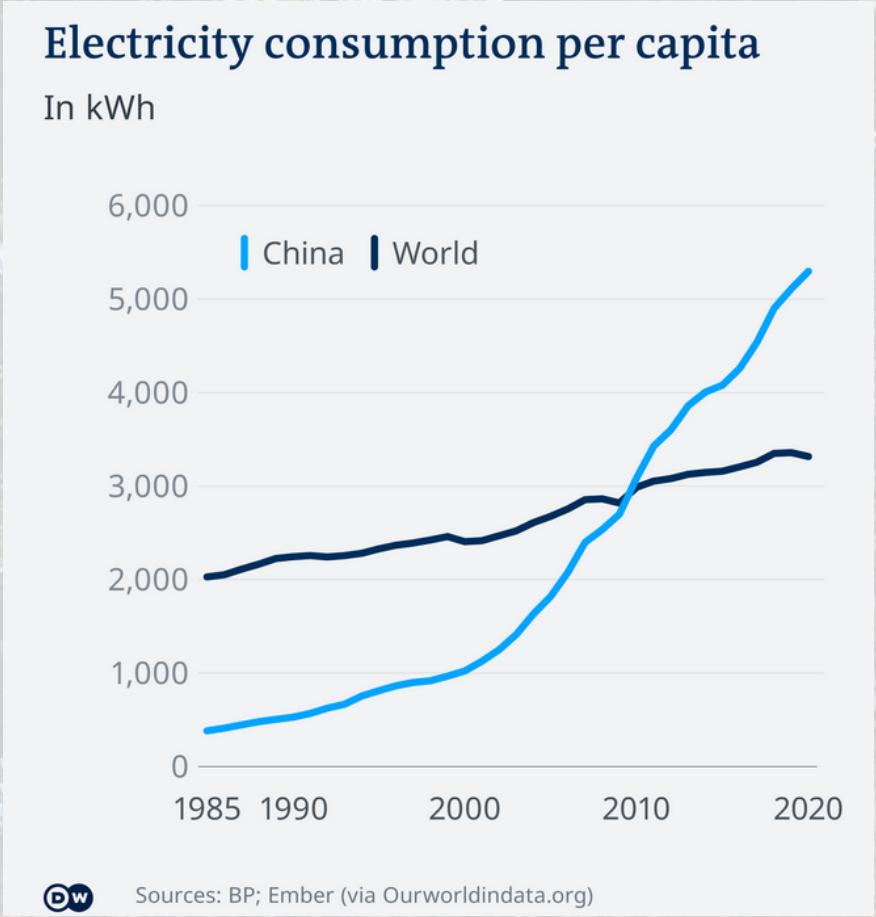
RUSSIA

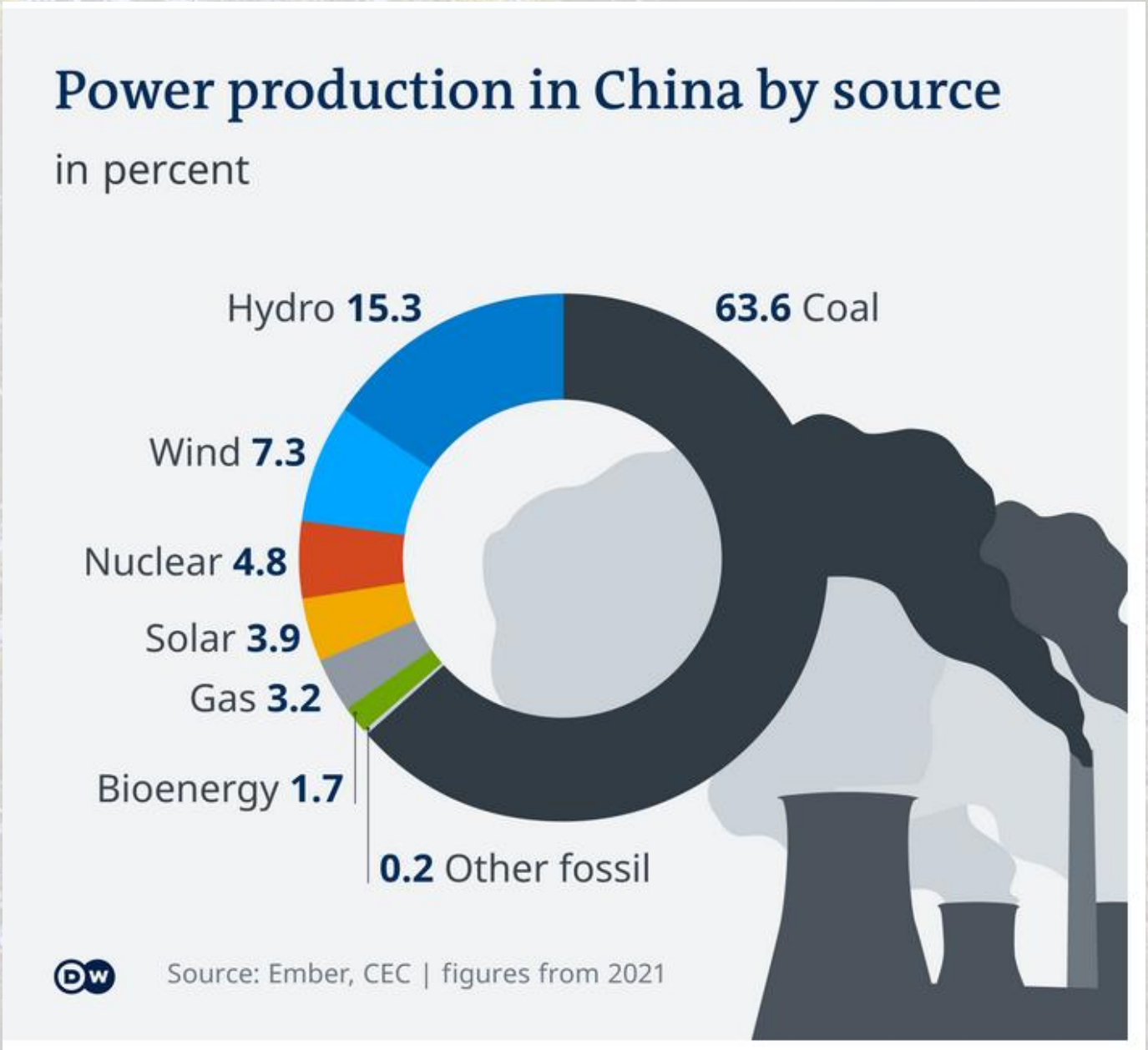
- A major reduction of energy supply is due to the Russian invasion of Ukraine.
- Putin is a climate activist.
- He has reduced supply and is trying to diversify his economy with a catastrophic war. He knows his resources will be worth less in 10 years and the demand curve will be more elastic because of European renewable energy.
- He is still selling fossil energy at elevated prices and the ruble has more than recovered

CHINA NEWS

- Last year, **China suffered its most severe energy crisis in decades**, with more than half its 31 provincial-level jurisdictions imposing electricity rationing. Aug 27, 2022
- China is facing, like many other countries worldwide, an energy crisis. Since September, **high coal costs and inflexible electricity prices have caused shortages that forced local governments to implement rolling blackouts for energy-intensive industries**.
- A severe drought and sweltering heat have led to low water levels and a drop in hydroelectric power generation in China in recent weeks, causing power shortages and forcing the government to ration electricity in some provinces.
- China relies heavily on hydroelectric power to meet its electricity needs, with the source accounting for about 15% of its overall energy mix. In places like Sichuan, which has been the worst affected, the figure is as high as 80%.

DEMAND FOR ELECTRICITY IS RISING RAPIDLY





Is some of the energy shortfall due to decarbonization or forecasts of decarbonization?

CLIMATE MITIGATION EFFECTS

- It has always been clear that decarbonization would require consumers and businesses shifting from high emitting products to low emitting products. High fossil energy prices are part of this process and therefore the high prices are consistent with climate goals. As consumers add insulation, buy electric cars and reduce driving, they are helping to mitigate climate change.
- Conveniently we can blame Putin for inflation rather than radical climate activists.
- Insofar as fossil energy supply is increased, this may delay decarbonization. A better solution from the climate perspective is investment in renewables.
- Other considerations are energy security and inexpensive energy. Arguably these are also enhanced by domestic investment in renewables.

What would be different with a carbon tax?

- If instead, the government set a carbon price, then the profits would flow to the government rather than the fossil energy companies, and the stock market would punish rather than reward these companies.
- The fossil energy prices would still rise but revenue could be used to reduce other taxes and achieve better climate justice.
- Climate hedge portfolios such as the Stranded Asset Portfolio would be performing well.
- Inflation would be lower if the revenue were directed at either subsidizing renewable energy or from a monetarist perspective, reducing the deficit.

FUTURE PERFORMANCE OF HEDGE PORTFOLIOS?

- In the model, ultimately fossil energy stocks go to zero.
- Hedge portfolios are likely to out-perform if decarbonization continues.
- Putin has accelerated decarbonization. So has the Biden climate bill. So has the EU Green Deal.

- Maybe this will end up moving us in a climate friendly direction.


What kind of world will we inherit?


But if we can tell them that we have it solved, ...