Virtual Seminar on Climate Economics

Federal Reserve Bank of San Francisco

Organizing Committee:

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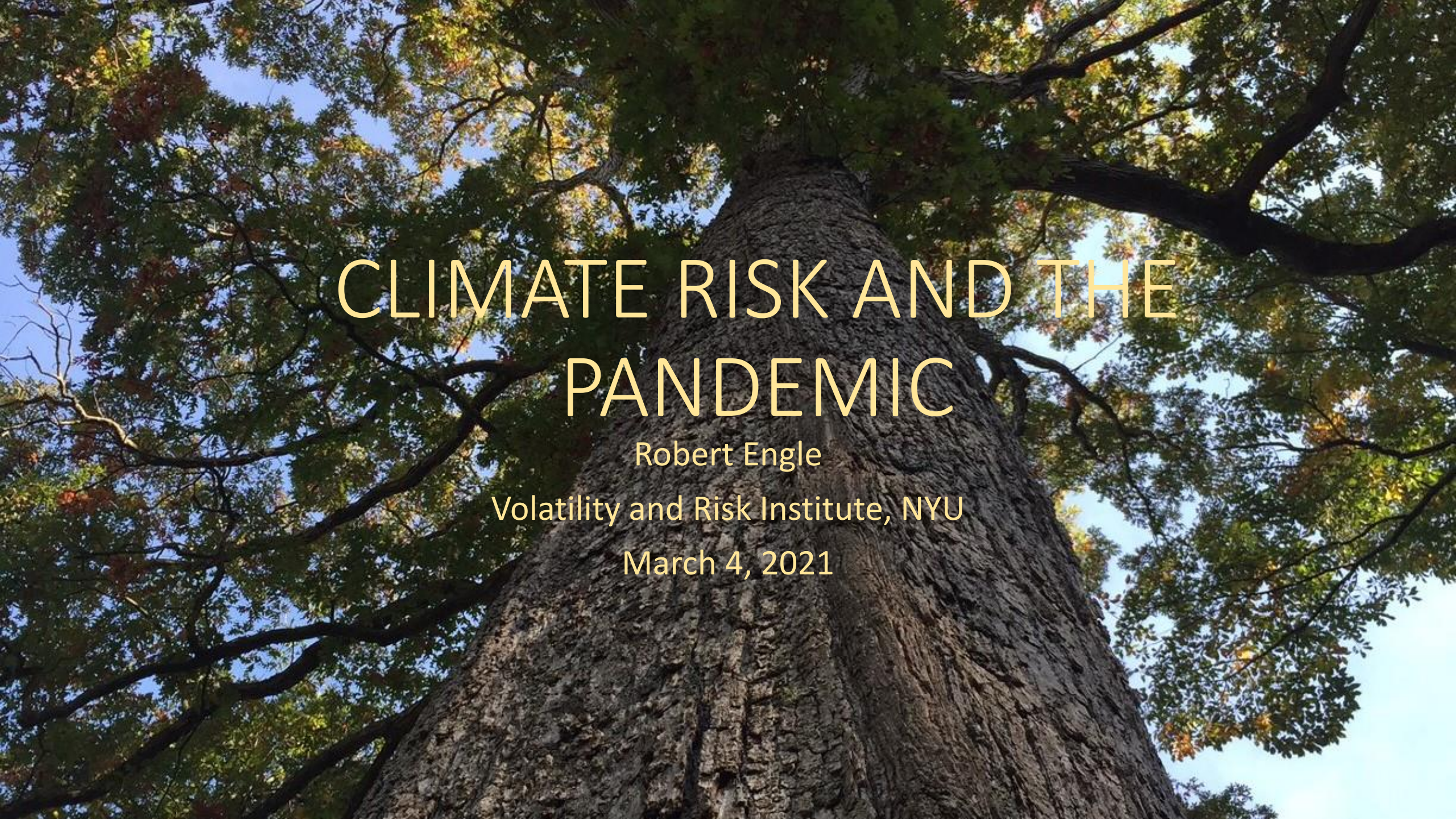


CLIMATE RISK AND THE PANDEMIC

Robert Engle

Volatility and Risk Institute, NYU

March 4, 2021

TWO CLIMATE RISKS

- Physical Risk
  - Damages due to warmer temperatures, rising sea level, droughts, floods and storms
- Transition Risk
  - Costs associated with the transition to a low carbon economy
  - Depend upon government policy including pricing, regulating and timing emissions.
- These risks sometimes reinforce each other and sometimes go in the opposite direction. For example, withdrawing from the Paris accord reduces transition risk but increases physical risk. And rejoining the Paris agreement increases transition risk and reduce physical risk. Scientific discoveries such as the fracturing of the Greenland ice sheet increase both risks.

TWO SOLUTIONS

- ADAPTATION
  - Firms and governments and individuals adapt to reduce as much as possible, the damage due to climate change.
  - Sometimes adaptation creates additional emissions such as air conditioning, and sometimes it is reduces them such as insulating buildings.

- MITIGATION
  - Firms and governments and individuals take actions to reduce emissions and thereby reduce damages. Effective mitigation will reduce the need for adaptation.

CLIMATE RISK IS INVESTMENT RISK

- How should investors choose optimal portfolios to adjust for these risks?
- Because these risks impact almost all assets, these are pervasive risks which cannot be fully diversified away and therefore should be priced. This is a risk premium.
- If the risk increases, then the market should fall as investors will require higher expected returns to hold the market.
- If the market view of climate risk is less severe than science, then news of scientific validation should lead to higher risk premia and a decline in market values.
- Policy that reduces the risk should have a positive effect on market prices.

STRATEGIES for INVESTORS

- INVEST for IMPACT
- INVEST for CHARITABLE PLANETARY GOALS
- INVEST to HEDGE CLIMATE RISK
  - Invest a portion of your portfolio in assets that will do especially well if the climate turns out to be especially bad
  - This means investing in companies prepared for climate change and/or shorting those that will suffer the most.
  - This will act as insurance and reduce the risk to consumption
  - It will also lower the cost of capital for companies preparing for climate change.

ASSET PRICING AND CLIMATE PORTFOLIOS

- Climate risk is a pervasive factor that may be insufficiently priced and is not included in standard asset pricing models.
- Firms that are exposed to climate risk should be less desirable and therefore less expensive with higher expected returns.
- Investors willing to bear this risk can expect a risk premium
- Investors desiring to insure against this risk will short this portfolio and can expect a negative risk premium.
- The *alpha of a climate hedge portfolio would generally be negative*.

FINANCE OF CLIMATE RISK HEDGES

- If there is news that climate change will be more severe than the market expects,
- hedge portfolios will rise in value because both long and short positions appreciate.
- Ultimately, if the climate change is more severe than the market expects today, then the hedge portfolio will have an accumulation of positive returns leading to the hedge outperformance.
- Thus when there is little climate news, the negative risk premium should lead to negative alpha, but when there is news, the market will reprice assets and the portfolio should have positive alpha.

TESTING FOR CLIMATE PERFORMANCE: THE VOLATILITY LABORATORY

VLAB.STERN.NYU.EDU

EVALUATION OF PUBLIC CLIMATE PORTFOLIOS

- Return and Volatility
- Sharpe Ratio
- Alpha is the return realized in a portfolio above that achieved by a matched portfolio of standard risk factors.
- Risk adjusted returns are measured by Three factor Fama French Alpha, implemented with investible ETFs.
- Sample period: Trailing 1Y, 3Y, 5Y, Max, Exponential Weight

PORTFOLIOS

- SUSTAINABLE SECTOR
  - ALTERNATIVE ENERGY
    - WIND
    - SOLAR
    - NUCLEAR
  - WATER
  - WASTE
- MORNINGSTAR SELECTED FUNDS
  - FOSSIL FUEL FREE
  - LOW CARBON
  - LOW ENVIRONMENTAL RISK
  - SUSTAINABILITY MANDATE

BENCHMARK PORTFOLIOS

- ACWI
- S&P500
- SPY-XLE : A portfolios long SPY and short XLE an energy ETF
- Stranded Assets: Long SPY short 70% KOL, a coal ETF and short 30% XLE. This is an approximation to the stranded asset portfolio designed by Litterman for WWF.

- **This stranded asset portfolio we consider to be a transition risk factor because it appreciates as fossil fuel firms fall in value relative to the broad market.**

ONE YEAR PERFORMANCE OF FUNDS

Security	Return	Volatility	↓ Sharpe Ratio	Correlation		α	β
				Cos Sim	Tag Index		
KraneShares MSCI China Environment Index ETF	144.67%	38.05%	3.80	-0.229	0.039	63.85 (1.95)	0.60 (11.10)
First Trust NASDAQ Clean Edge Green Energy Index Fund	195.41%	53.78%	3.63	-0.270	0.027	42.39 (1.70)	1.17 (21.90)
Invesco WilderHill Clean Energy ETF	204.87%	58.65%	3.49	-0.248	0.054	41.37 (1.41)	1.23 (33.34)
Invesco Solar ETF	193.85%	58.66%	3.30	-0.196	0.096	46.10 (1.26)	1.16 (21.23)
Invesco Global Clean Energy ETF	142.09%	45.66%	3.11	-0.219	0.086	37.63 (1.42)	1.08 (16.05)
SPDR S&P Kensho Clean Power ETF	164.92%	53.20%	3.10	-0.298	0.074	38.84 (1.41)	1.08 (29.08)
VanEck Vectors Low Carbon Energy ETF	125.42%	44.03%	2.85	-0.290	0.039	26.81 (1.27)	0.99 (17.52)
Global X Lithium & Battery Tech ETF	128.31%	48.44%	2.65	-0.213	0.007	40.45 (1.34)	1.08 (30.57)
ALPS Clean Energy ETF	131.77%	50.04%	2.63	-0.260	0.039	26.53 (1.04)	1.10 (32.48)
Baillie Gifford Positive Change Equities Fund	81.64%	32.53%	2.51	-0.171	-0.013	26.32 (2.81)	0.84 (41.11)

BENCHMARKS AND ALPHAS 179 FUNDS

Alpha Table	1Y	3Y	5Y	EW	Max
All	3.39	-0.84	-1.50	0.00	-1.59
Fossil Fuel Free	5.01	1.14	-1.00	1.19	-1.35
Low Carbon	-0.34	-3.06	-3.34	-2.40	-1.97
Low Environmental Risk	-3.14	-5.57	-5.17	-5.38	-1.88
Sustainability Mandate	3.53	-0.52	-1.53	0.25	-1.84
Sustainable Sector	13.25	7.91	4.63	7.55	-1.91

Benchmark	Return	Volatility	Sharpe Ratio
iShares MSCI ACWI ETF	30.97%	32.23%	0.96
SPDR S&P 500 ETF Trust	34.00%	33.36%	1.02
SPY:US - XLE:US	22.80%	43.05%	0.53
Stranded Assets	30.72%	22.93%	1.34

PERFORMANCE OF V-LAB FUNDS
OCTOBER 31, 2019

Average FF Alpha by Window Length					
Category	1Y	3Y	5Y	EW	Max
Alternative Energy	14.65	-4.32	-10.89	-4.94	-20.00
Fossil Fuel Free	-7.63	-5.88	-6.59	-5.77	-4.77
High Environmental Score	-9.07	-7.58	-8.02	-7.27	-4.02
International Sustainable	-4.24	-4.72	-7.78	-5.55	-6.09
Low Carbon	-8.83	-6.66	-6.89	-6.27	-4.65

WHY ARE CLIMATE FUNDS DOING WELL IN THE PANDEMIC?

- There is a close similarity between the effects of climate change and the effects of COVID-19.
- *Transition risk is occurring*. We saw an upward shift in the supply of fossil fuels from Russia and Saudi competition. At the same time we saw a downward shift in the demand for fossil fuels as the world sheltered at home. This impacted not only energy producers but upstream and downstream supply chains.
- Look at airlines, entertainment, retail, tourism. These all are impacted by transition risk even though most do not have high ESG risk scores.
- And look at the winners - technology.
- And in addition *physical risk* also appears to be rising.

SECTOR RETURNS AND VOLATILITIES

	ret21	vol21	ret20	vol20	ret19	vol19	ret18	vol18
xlb	1.59	21.57	18.62	38.56	21.62	15.67	-16.11	19.17
xlc	5.88	19.81	23.83	33.44	27.04	16.42	-18.49	22.33
xle	23.94	36.01	-39.56	61.16	11.10	18.99	-20.11	22.30
xlf	9.17	22.82	-1.75	45.52	27.67	15.51	-13.99	19.62
xli	2.30	18.37	10.35	39.77	25.53	15.59	-14.21	19.10
xlk	0.51	21.67	36.20	40.38	40.45	18.08	-1.69	23.37
xlp	-6.35	11.45	9.63	27.86	24.24	10.73	-8.42	14.52
xlre	2.11	17.17	-2.21	40.49	25.22	12.62	-2.42	16.29
xlu	-7.17	18.87	0.51	38.49	23.06	11.39	3.86	15.18
xlv	-0.73	13.59	12.48	30.52	18.61	13.36	6.09	17.56
xly	0.23	22.34	25.95	34.10	24.99	14.06	1.57	19.35

Red is lowest return and highest volatility
Green is highest return

THE SAME CHART BACK TO 2013

	ret17	vol17	ret16	vol16	ret15	vol15	ret14	vol14	ret13	vol13
xlb	21.52	10.41	15.53	17.83	-9.09	18.49	6.94	14.12	23.10	14.37
xlc	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
xle	-0.89	13.29	24.71	24.60	-24.20	24.89	-9.08	18.48	23.31	14.30
xlf	19.88	13.07	20.22	18.70	-1.79	17.62	14.02	12.86	30.40	14.32
xli	21.49	9.19	18.24	14.70	-4.42	16.08	9.86	13.72	34.04	12.94
xlk	29.46	10.40	13.99	15.34	5.32	17.75	16.42	12.65	23.30	11.53
xlp	12.21	7.64	4.86	11.81	6.65	13.81	14.60	9.64	23.36	11.34
xlre	10.16	9.41	2.72	17.64	4.27	17.02	NA	NA	NA	NA
xlu	11.38	9.76	14.91	15.84	-5.05	17.11	25.27	13.54	12.28	12.31
xlv	19.70	8.73	-2.80	15.26	6.61	18.32	22.42	14.38	34.65	12.14
xly	20.56	8.11	5.80	14.48	9.44	16.38	9.04	13.19	35.58	12.60

What did we learn? Energy has typically had the highest volatility and frequently lowest returns for a long time. Transition risk is not a new phenomenon but it is most extreme in 2020 during the Pandemic!! It is a more abrupt transition than anything proposed for climate change.


Constructing climate hedge portfolios

FUNDAMENTAL HEDGE PORTFOLIOS

- Analysis of firm performance and government policies may identify hedge portfolios.
- An example is the price of carbon emission certificates. These are directly impacted by the severity of climate damages. As emissions rise the expected damages will rise and so will the market price of emissions certificates. Policies on coverage and aggregate allowances will affect this relationship.
- Emissions certificates can be purchased and sold and now there is a global ETF that allows users to trade these easily, KRBN.

Climate News Performance

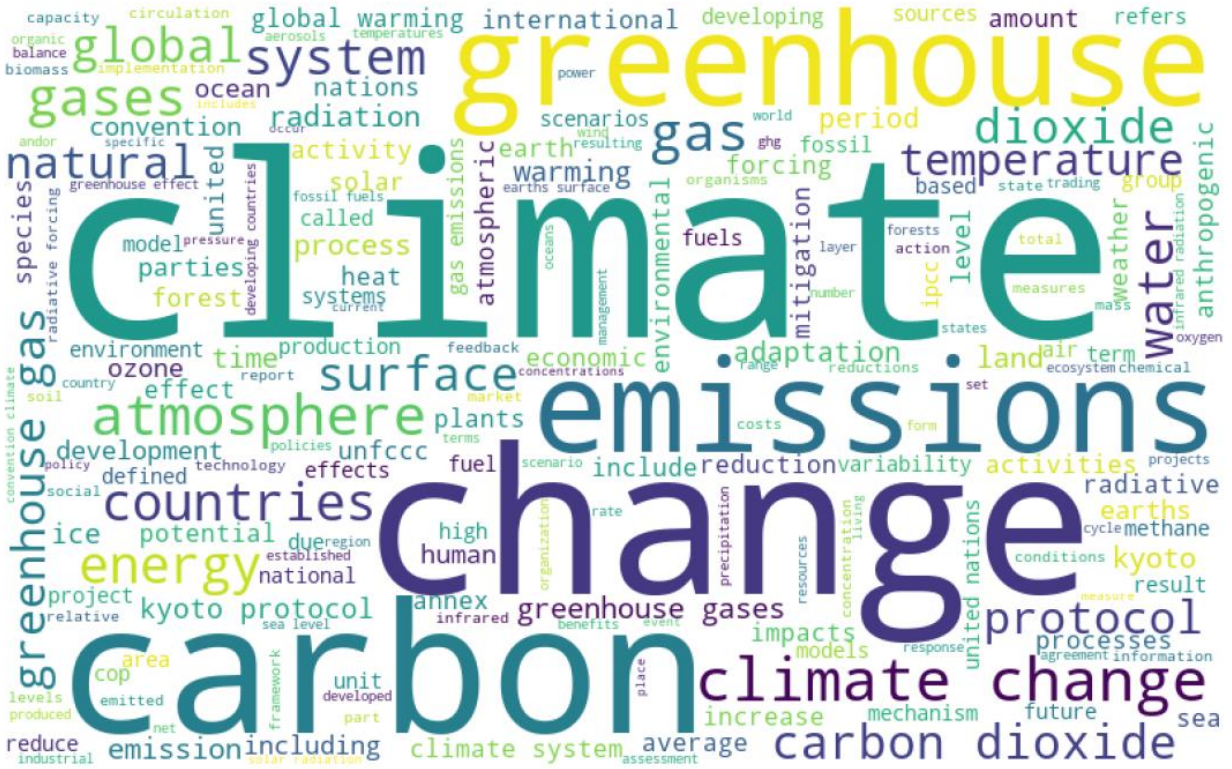
- A tool for validating a climate hedge portfolio is to see whether it responds positively to climate news.
- In V-LAB we have two climate news measures from the NY Times. One is simply a count of articles which are classified as about either *global warming* or *climate change.*
- A more sophisticated measure using natural language processing tools measures the word frequency in the newspaper and compares it with word frequency in climate references.
- This is called cosine similarity.
- These are measured weekly and updated every day.

THE ROLE OF NEWS IN FINANCE

- We often examine the impact of news on asset prices. Event studies take a familiar quantitative approach.
- When there is good news, we expect to see asset prices rise.
- When there is no news we have no expectation of price moves.
- Thus the level of news arrival and its content is expected to affect returns, not the innovation in news arrival. News should have a permanent effect on prices.
- When there is climate news, it is typically bad news and therefore should have a positive impact on hedge portfolios.

1. What News?

WSJ CC Index - Climate Change Vocabulary



Construct Climate Change Vocabulary from authoritative texts

- 19 climate change white papers on from the IPCC, EPA, USGCRP
- 55 climate change glossaries (UN, BBC, IPCC, NASA, EPA, etc.)

HOW TO BUILD A HEDGE PORTFOLIO

- Engle, Giglio, Kelly, Lee, and Stroebel(2019) seek portfolios that are long stocks that go up when there is bad climate news, and short stocks that go down on this news.
- They use textual analysis from the Wall Street Journal, and observe that long short portfolios with weights based on high E scores respond positively to bad climate news.

Factor Mimicking Climate Portfolio

WHAT IS THE BEST WAY TO USE ESG?

- There are many vendors of ESG data
- There are many ways to incorporate these data into portfolio construction.
- Some portfolios are passive and some are active
- Some are simply greenwashing and others do their own research

- Is there one optimal answer or does it change over time?

A FACTOR MIMICKING CLIMATE PORTFOLIO

Gianluca Denard, Robert Engle and Bryan Kelly

- Our Factor Mimicking Portfolio is a long only weighted average of the Morningstar candidate funds. These funds all have some ESG input but use different vendors and use it differently.
- FMP solves a problem of minimizing the variance of the idiosyncratic shocks while maximizing the beta on the news.
- This problem is the same as Fama MacBeth(1973) and Huberman et al.(1987) and Lamont(2001) as shown by Jurczenko and Teiletche(2019)

A SIMPLE CASE

- Rolling regressions give betas for each fund over time. (126 day window)
- The FMP weights are zero for negative betas and are proportional to beta with a unit sum for positive betas. A slight improvement is to use beta*t-stat.
- These weights are used to define the FMP returns for the next 21 days. Thus the FMP returns are all out of sample.
- Validation of this model comes from the out of sample beta on news and factors.
- I will show the results from this case.

Framework: candidate funds, factors and climate news:

Find

$$\pi_t \equiv \sum_{i=1}^{n} w_{i,t} r_{i,t}$$

$$returns: \ \{r_{i,t}\},\ i = 1,..n,\ t = 1,...,T$$

$$factors: \ \{f_{k,t}\},\ k = 1,...,K,\ t = 1,...,T$$

$$news: \ \{cc_t\},\ t = 1,...,T$$

$$r_{i,t} = cc_t \beta_{i,t} + \sum_{k=1}^{K} f_{k,t} \gamma_{i,k,t} + e_{i,t}$$

$$\min_{w} \left[\lambda_1 Var_{t-h} \left(\sum_{i=1}^{n} w_{i,t} e_{i,j,t} \right) - \lambda_2 \sum_{i=1}^{n} w_{i,t} \tilde{\beta}_{t-h} \right]$$

subject to

$$w_{i,t} \geq 0,\ \sum_{i=1}^{n} w_{i,t} = 1,\ \tilde{\beta}_{i,t} = \max(\beta_{i,t}, 0) / \sum_{j=1}^{n} \max(\beta_{j,t}, 0)$$

$$(\lambda_1, \lambda_2) \geq 0$$

A MORE SOPHISTICATED CASE

- More generally, the covariance matrix of the residuals is time varying.
- Estimating a 179x179 dynamic covariance matrix requires advanced methods.
- Denard, Ledoit and Wolf in a series of papers have developed non-linear shrinkage estimators for very large covariance matrices and with Engle these have been extended to dynamic covariance matrices.
- Assuming $\lambda_1 = 0$ delivers a minimum variance long only portfolio. If $\lambda_2 = 0$ the solution is to invest in only the best fund and ignore diversification.
- Intermediate values are likely to be preferred such as the preceding slide where $\lambda_2 = 2$

	$\widehat{\Sigma} = \mathbf{I}$				$\widehat{\Sigma} = \text{CVC}$				$\widehat{\Sigma} = \text{AFM-DCC-CVC}$				$\widehat{\Sigma} = \text{None}$	
	$\lambda_2 = 2$	$\lambda_2 = 10$	$\lambda_2 = 20$	$\lambda_2 = \text{opt}$	$\lambda_2 = 2$	$\lambda_2 = 10$	$\lambda_2 = 20$	$\lambda_2 = \text{opt}$	$\lambda_2 = 2$	$\lambda_2 = 10$	$\lambda_2 = 20$	$\lambda_2 = \text{opt}$	$\lambda_1 = 0$	$1/N$
	NYT COSINE													
$\hat{\alpha}$	0.04	0.06	0.06	0.07	0.05	0.06	**0.07**	0.07	0.02	0.05	0.06	0.06	0.07	−0.01
t-Stat	2.36	2.26	2.25	2.24	2.80	2.65	2.64	2.45	1.27	2.12	2.43	2.42	1.94	−1.43
$\hat{\beta}$	0.05	0.08	0.08	0.08	0.06	0.08	**0.09**	0.09	0.02	0.06	0.08	0.08	0.08	−0.01
t-Stat	2.29	2.20	2.19	2.18	2.75	2.59	2.56	2.38	1.21	2.05	2.36	2.35	1.86	−1.50
AV	9.78	12.33	12.96	13.10	9.30	12.41	13.44	13.14	5.80	10.24	12.22	12.38	13.06	4.88
SD	19.25	21.94	22.72	22.99	15.63	20.26	21.68	21.97	13.36	18.59	20.47	20.79	24.25	18.24
IR	0.51	0.56	0.57	0.57	0.60	0.61	0.62	0.60	0.43	0.55	0.60	0.60	0.54	0.27
TO	0.61	0.89	0.94	0.92	0.72	1.03	1.03	1.01	0.70	1.08	1.04	1.02	1.04	–
Cor	−0.01	−0.01	−0.01	−0.01	−0.02	−0.02	−0.02	−0.02	−0.01	−0.01	−0.01	−0.01	−0.02	−0.01
PCor	−0.02	−0.02	−0.02	−0.02	−0.03	−0.03	−0.03	−0.02	−0.02	−0.02	−0.02	−0.02	−0.02	−0.02
	NYT TAG													
$\hat{\alpha}$	0.04	0.06	0.06	0.06	0.05	0.06	**0.07**	0.07	0.02	0.05	0.06	0.07	0.07	−0.01
t-Stat	2.36	2.26	2.25	2.16	2.80	2.65	2.64	2.61	1.27	2.12	2.43	2.65	1.94	−1.43
$\hat{\beta}$	0.02	0.03	0.03	0.03	0.02	0.03	**0.03**	0.03	0.00	0.02	0.03	0.03	0.03	−0.01
t-Stat	2.34	2.15	2.12	2.05	2.81	2.61	2.43	2.39	0.84	2.20	2.35	2.53	1.93	−1.50
AV	9.78	12.33	12.96	12.79	9.30	12.41	13.44	13.54	5.80	10.24	12.22	12.90	13.06	4.88
SD	19.25	21.94	22.72	22.87	15.63	20.26	21.68	21.91	13.36	18.59	20.47	20.68	24.25	18.24
IR	0.51	0.56	0.57	0.56	0.60	0.61	0.62	0.62	0.43	0.55	0.60	0.62	0.54	0.27
TO	0.61	0.89	0.94	0.91	0.72	1.03	1.03	0.99	0.70	1.08	1.04	1.01	1.04	–
Cor	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	−0.01	0.01	0.01	0.01	0.01	−0.01
PCor	0.03	0.02	0.02	0.02	0.03	0.03	**0.03**	0.03	0.00	0.02	0.03	0.03	0.03	−0.02

Table 5: This table presents various annualized performance measures of the **monthly** re-estimated and rebalanced climate factor mimicking portfolio based on the I, CVC and AFM-DCC-CVC covariance matrix estimator and the **β×t-statistics signal**. $\hat{\alpha}$ stands for the (estimated) alpha of the portfolio; $\hat{\beta}$ stands for the (estimated) beta of the news variable; and t-Stat stands for the t-statistic based on HC3 standard errors. Additionally, AV stands for average return; SD stands for standard deviation; IR stands for information ratio; TO stands for (average) turnover; Cor stands for the out-of-sample correlation between the factor mimicking portfolio and the climate index; and PCor stands for the partial out-of-sample correlation between the factor mimicking portfolio and the climate index. All measures are based on 4,935 daily (out-of-sample) returns from 06/19/2001 until 01/29/2021. In the rows labeled $\hat{\alpha}$, $\hat{\beta}$, and PCor the largest number

VALIDATION OF OPTFMP

Dependent Variable: OPTFMP
Method: Least Squares
Date: 03/03/21 Time: 19:44
Sample (adjusted): 6/19/2001 1/29/2021
Included observations: 4897 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
CCCS	0.098171	0.035900	2.734546	0.0063
CCSA	-0.029187	0.009087	-3.211919	0.0013
MKTFACTOR	0.869587	0.009612	90.46465	0.0000
HMLFACTOR	-0.011968	0.010931	-1.094884	0.2736
SMBFACTOR	0.102896	0.008788	11.70855	0.0000
ROIL	0.018981	0.005262	3.606789	0.0003

AVERAGE PERFORMANCE OF CLIMATE MIMICKING PORTFOLIOS: *ALPHA*

7.6%/YEAR

Dependent Variable: OPTFMP
Method: Least Squares
Date: 03/03/21 Time: 19:50
Sample (adjusted): 6/19/2001 1/29/2021
Included observations: 4897 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.030210	0.010704	2.822300	0.0048
CCSA	-0.029196	0.009087	-3.213107	0.0013
MKTFACTOR	0.869583	0.009612	90.46972	0.0000
HMLFACTOR	-0.011969	0.010930	-1.094989	0.2736
SMBFACTOR	0.102881	0.008788	11.70740	0.0000
ROIL	0.018968	0.005262	3.604518	0.0003

8.8%/YEAR

Dependent Variable: CCSA
Method: Least Squares
Date: 03/03/21 Time: 19:48
Sample (adjusted): 6/19/2001 1/29/2021
Included observations: 4897 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.035117	0.016833	2.086218	0.0370
OPTFMP	-0.072146	0.022454	-3.213107	0.0013
MKTFACTOR	-0.009961	0.024705	-0.403216	0.6868
HMLFACTOR	-0.160684	0.017030	-9.435483	0.0000
SMBFACTOR	-0.105615	0.013924	-7.584835	0.0000
ROIL	-0.235453	0.007568	-31.11205	0.0000

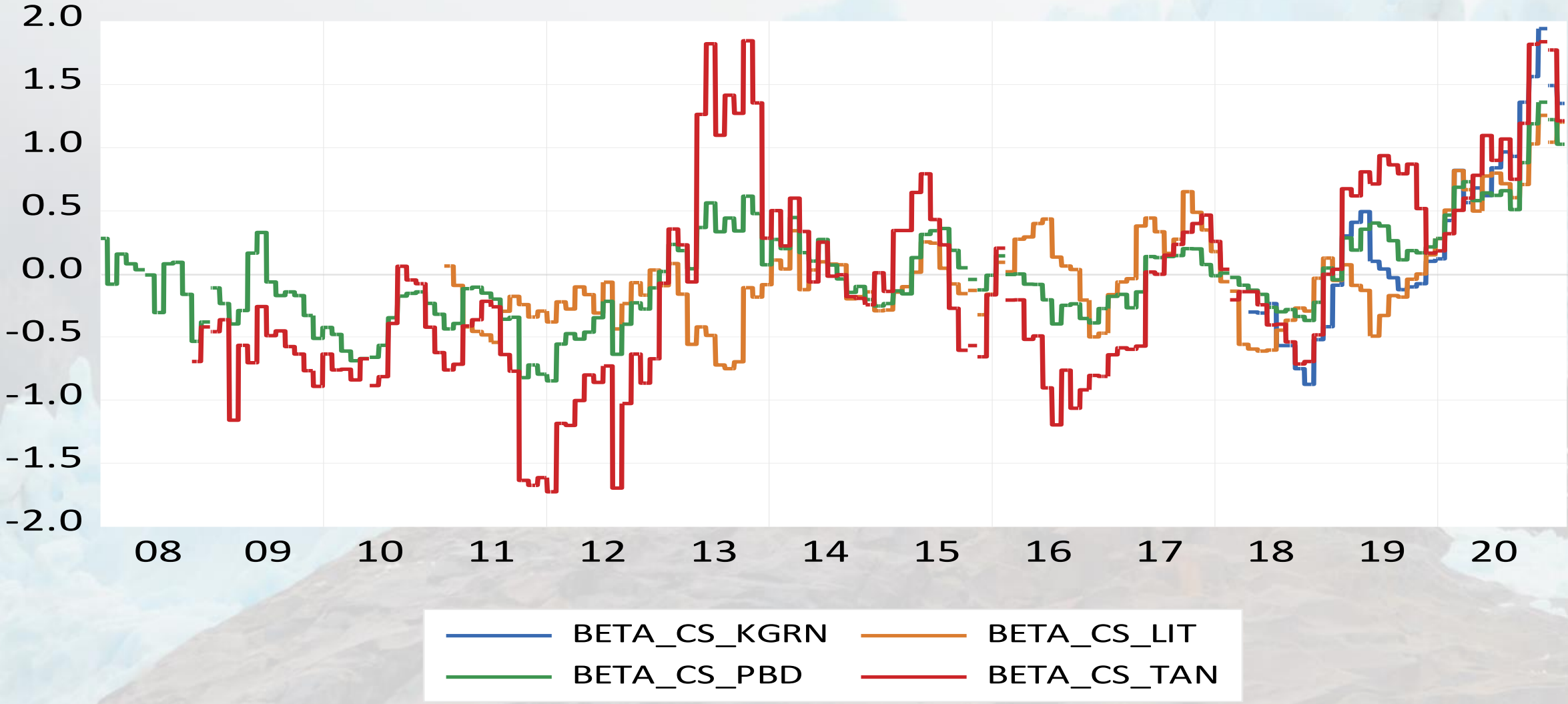
HOW DO WE INTERPRET THIS PORTFOLIO?

- It has a significant coefficient on climate news out-of-sample after correcting for other factors.
- It takes out a measure of transition risk before seeking correlations. Thus it is a candidate for physical risk.
- The components of the portfolio are all long positions in sustainable funds with various strategies and credentials.

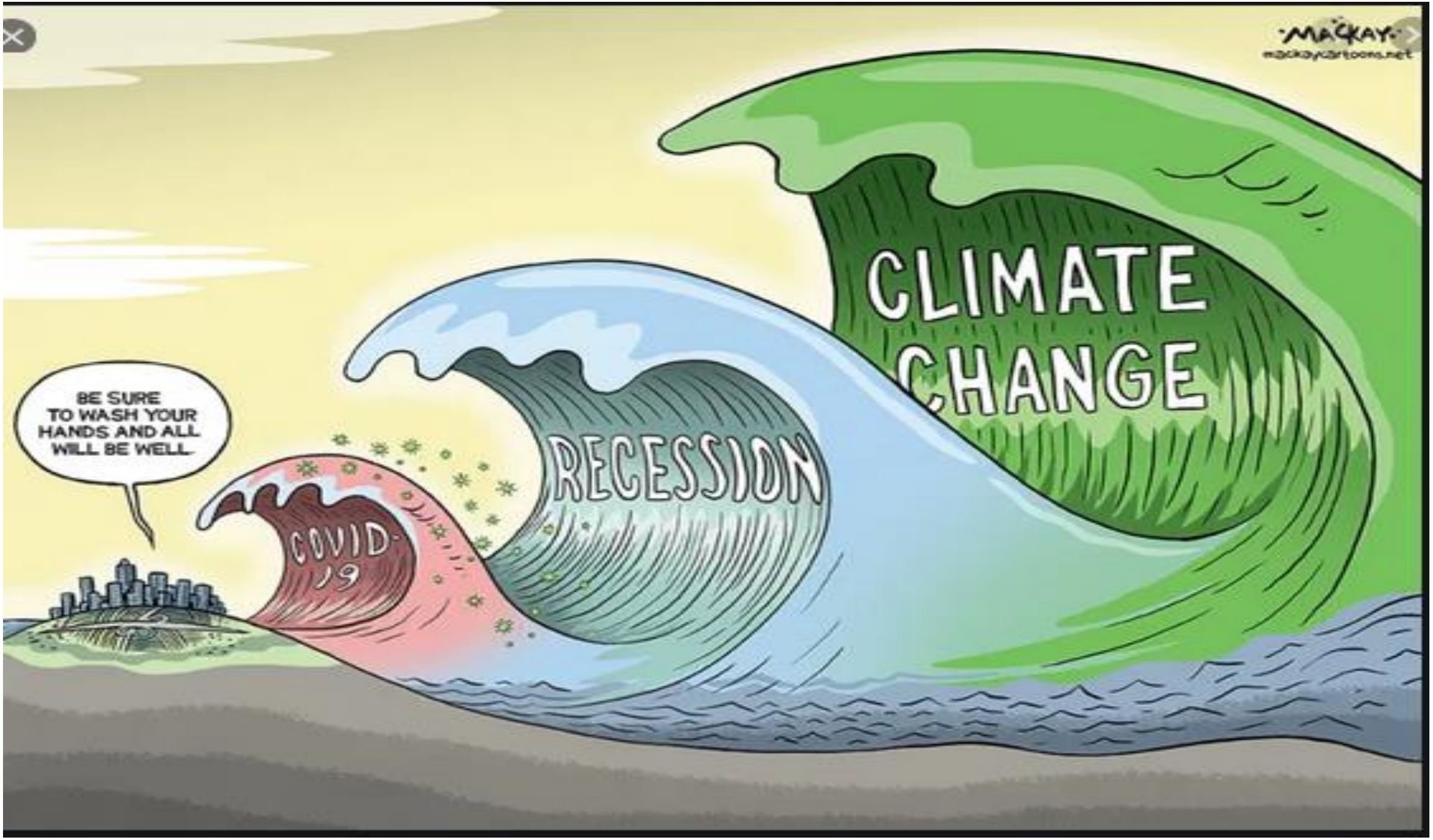
TOP 10 POSITIONS ON FMP RISK INDEX 2/26/2121

WEIGHT	TICKER	NAME
7.417659	KGRN	KraneShares MSCI China Environment Index ETF
5.988656	LIT	Global X Lithium & Battery Tech ETF
5.596212	PBD	Invesco Global Clean Energy ETF
4.274637	TAN	Invesco Solar ETF
4.265701	ICLN	iShares Global Clean Energy ETF
4.184389	BATT	Amplify Lithium & Battery Technology ETF
3.635714	GCHPX	GMO Climate Change Series Fund Class PS
3.596921	SMOG	VanEck Vectors Low Carbon Energy ETF
3.580311	PBW	Invesco WilderHill Clean Energy ETF
3.371155	QCLN	First Trust NASDAQ Clean Edge Green Energy In...

BETAS OF TOP FOUR POSITIONS



PERFORMANCE IN 2020


MACKAY
mackaycartoons.net
BE SURE TO WASH YOUR HANDS AND ALL WILL BE WELL
COVID-19
RECESSION
CLIMATE CHANGE

PERFORMANCE IN 2020

- ANNUALIZED INVESTMENT IN CLIMATE FMP: ALPHA=**73.4**%
- ANNUALIZED INVESTMENT IN STRANDED ASSETS: ALPHA=**28.8**%
- These results complement the Morningstar and Blackrock analyses but are not sector neutral and consequently have much higher returns.
- Again we see that the pandemic is a very severe form of decarbonization and factor mimicking portfolios show extraordinary returns.


CLIMATE RISK

WHAT CAN WE DO WITH THESE CLIMATE FACTOR 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-M
- 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. At the VRI we are doing this for large US and UK banks and are beginning to do it for a selection of large Latin American banks. This is a measure we call CRISK for Climate Risk and is analogous to SRISK.

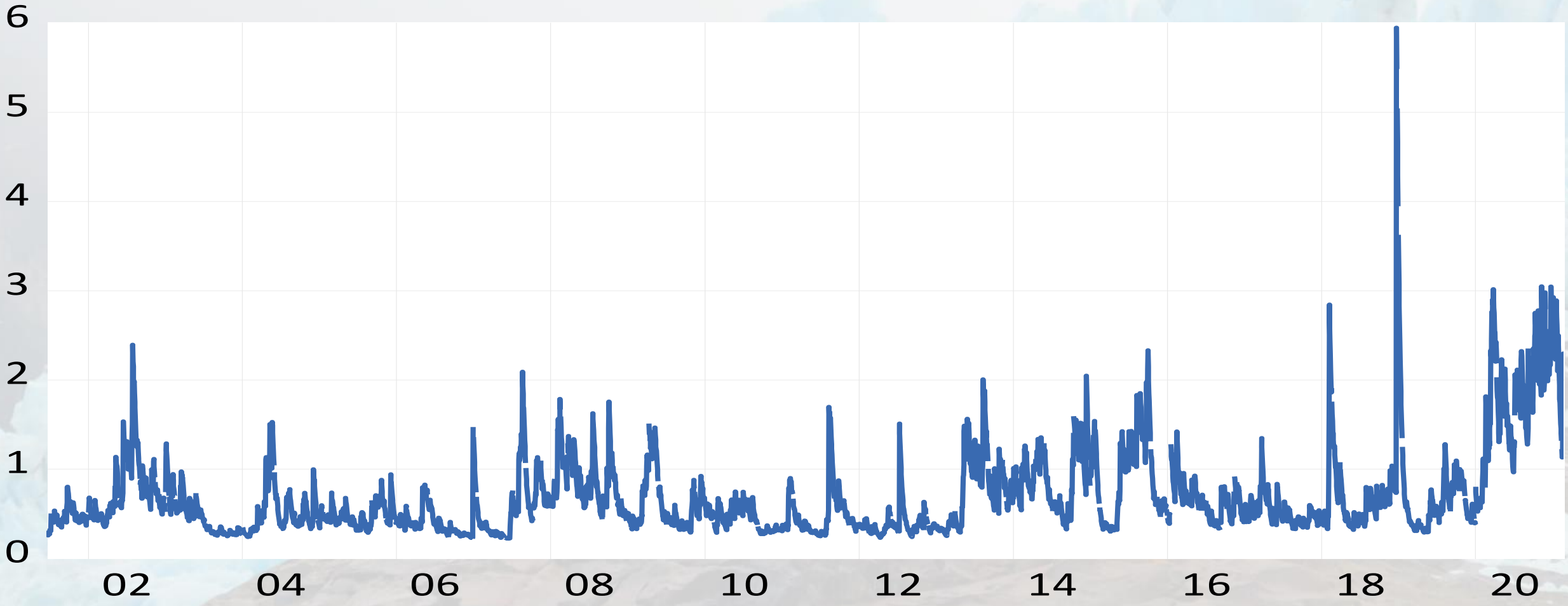
VOLATILITY OF THE FMP

- The volatility of the factor mimicking portfolio is a measure of the risk from climate news.
- As with most risk factors the volatility model is asymmetric . If you are holding the risk, negative returns predict higher volatility in the future and if you are hedging the risk, the asymmetry is in the opposite direction. This is natural because news of future volatility induces investors to hedge more and drives up the price.

OPTFMP

Variable	Coefficient	Std. Error	z-Statistic	Prob
C	0.023977	0.006698	3.579527	0.00
CCSA	-0.019691	0.005145	-3.827429	0.00
MKTFACTOR	0.789215	0.005654	139.5891	0.00
HMLFACTOR	0.068676	0.006512	10.54534	0.00
SMBFACTOR	0.036154	0.005504	6.569109	0.00
ROIL	0.026198	0.003066	8.543560	0.00
Variance Equation				
C	0.005706	0.000378	15.10475	0.00
RESID(-1)^2	0.190497	0.011695	16.28881	0.00
RESID(-1)^2*(RESID(-1)<0)	-0.020751	0.013478	-1.539570	0.12
GARCH(-1)	0.844725	0.004550	185.6548	0.00

CLIMATE RISK



WHICH STOCKS ARE GOOD CLIMATE HEDGES?

- Regress stock returns on factors including stranded assets and FMP.
- High betas belong in a hedge portfolio and negative betas should be shorted.
- Analyze SP500 stocks using 7/17/17-7/17/20.
- Look at top betas on transition risk and FMP risk and most negative betas for the same portfolios.

3 YEAR BETAS ON LARGE CAP STOCKS

TRANSITION RISK

BETA_CCSA	TSTAT_CCSA	NAMELONG	NAME
0.637442	9.161057	MID-AMER.APT COM...	MAA
0.582421	8.479848	AMEREN	AEE
0.577333	8.174645	EQUITY RESD.TST.P...	EQR
0.571081	7.931504	AMERICAN WATER W...	AWK
0.569750	7.456621	WEC ENERGY GROUP	WEC
0.555460	7.737945	UDR	UDR
0.545617	8.308063	CMS ENERGY	CMS
0.540859	6.523208	POOL	POOL
0.537765	5.748795	HEALTHPEAK PROPE...	PEAK
0.530940	6.771634	EXTRA SPACE STRG.	EXR
0.528122	7.343408	EVERGY	EVRG

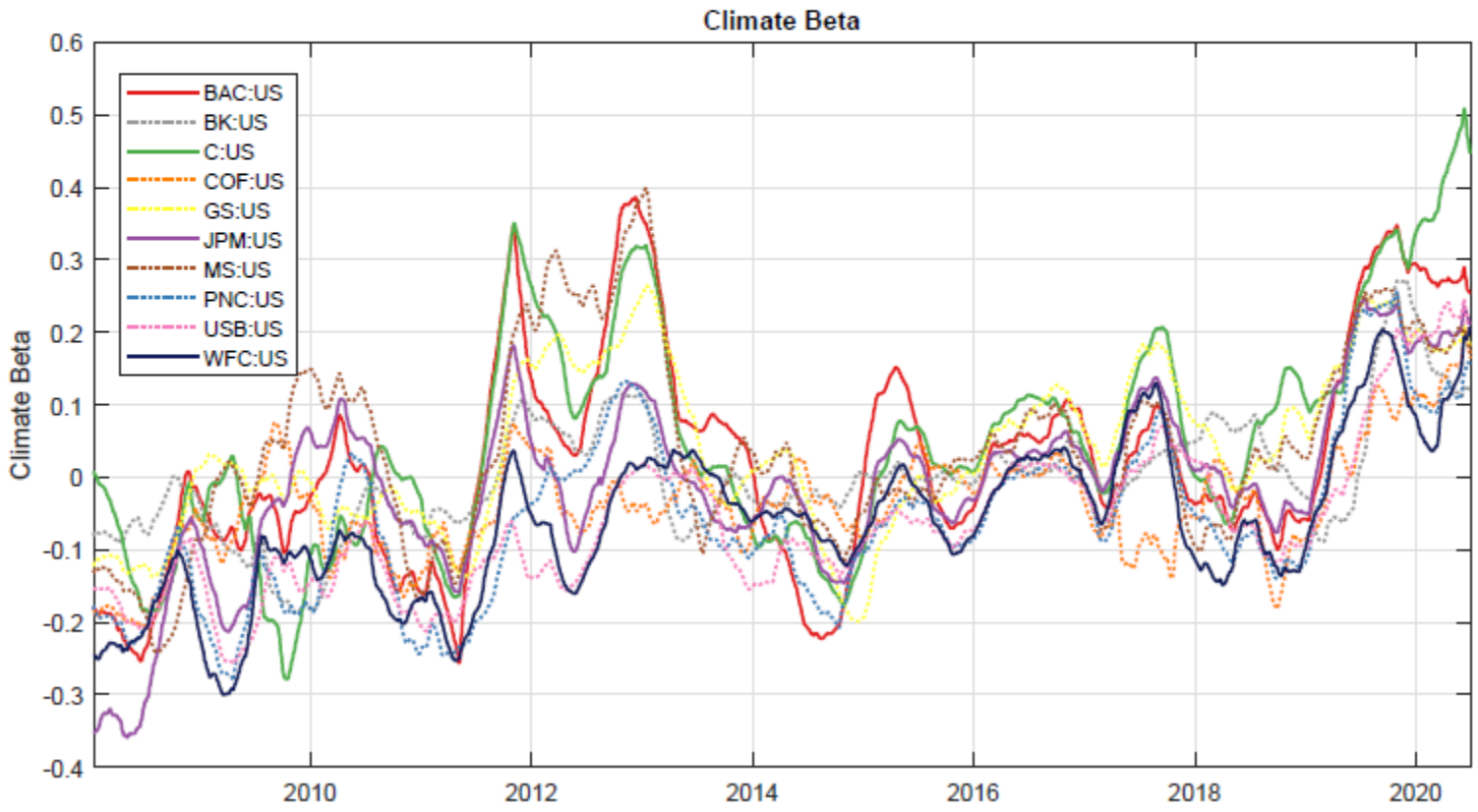
-0.961148	-7.492620	HESS	HES
-0.967059	-10.08009	SCHLUMBERGER	SLB
-1.114796	-8.530533	PIONEER NTRL.RES.	PXD
-1.185862	-10.43981	EOG RES.	EOG
-1.257046	-7.148179	OCCIDENTAL PTL.	OXY
-1.258113	-10.35566	HALLIBURTON	HAL
-1.317543	-7.941061	MARATHON OIL	MRO
-1.347457	-5.869957	APACHE	APA
-1.398818	-10.07296	DEVON ENERGY	DVN
-1.501071	-9.526071	DIAMONDBACK ENER...	FANG

FMP RISK

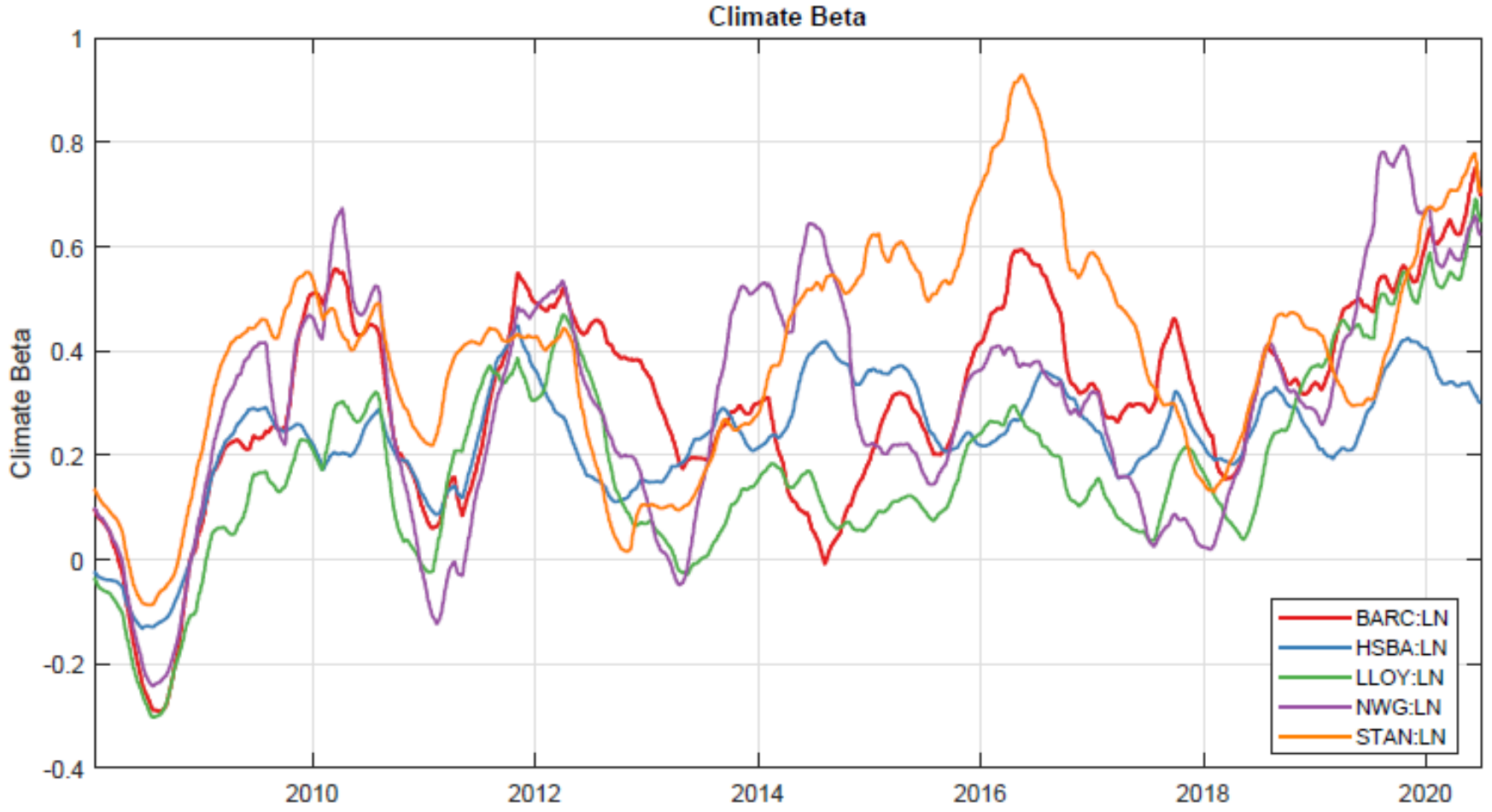
BETA_FMP	TSTAT_FMP	NAMELONG	NAME
3.544424	9.312936	ENPHASE ENERGY	ENPH
2.577436	7.597683	NORWEGIAN CRUISE LINE ...	NCLH
2.388330	7.447774	TESLA	TSLA
2.172782	7.512353	ROYAL CARIBBEAN GROUP	RCL
1.906311	6.533681	CARNIVAL	CCL
1.818467	6.803179	UNITED AIRLINES HOLDINGS	UAL
1.750157	8.288057	EXPEDIA GROUP	EXPE
1.540703	6.434976	MGM RESORTS INTL.	MGM
1.425365	6.581663	DELTA AIR LINES	DAL
1.389969	7.085926	LENNAR 'A'	LEN

-0.259364	-1.437702	ACTIVISION BLIZZARD	ATVI
-0.274597	-1.408852	NETAPP	NTAP
-0.305175	-1.037441	OCCIDENTAL PTL.	OXY
-0.307727	-2.206250	TRACTOR SUPPLY	TSCO
-0.310115	-1.357507	VIATRIS	VTRS
-0.378538	-2.177857	REGENERON PHARMS.	REGN
-0.382364	-1.646047	DEVON ENERGY	DVN
-0.407984	-2.686639	GILEAD SCIENCES	GILD
-0.476784	-2.777382	KROGER	KR
-0.762731	-2.748241	MARATHON OIL	MRO

Time-varying climate beta of U.S. Banks



Time-varying climate beta of U.K. Banks



SOLVING THE TWO PROBLEMS

- ADAPTATION: Better risk evaluation will improve the performance of the financial system and better allocate capital to industries that can most productively use it.

- MITIGATION: Optimal portfolio construction and risk pricing will not eliminate the free rider problem which is fundamental to mitigation. Transition risk is unlikely to be sufficiently important to drive the emission reductions needed to mitigate climate change in a country where carbon pricing and regulation are only remote possibilities. Many firms are committing to achieve net-zero emissions by mid century, however many others are not. Can the private sector financial giants command coordination?

CONCLUSIONS

- We are making progress in measuring and hedging climate risk
  - in the stock market
  - in portfolios of stocks
  - in bank portfolios
- As a result, these risks are forcing repricing of assets. Consequently companies with lower climate risks will face lower costs of capital, ceteris paribus.
- Is this enough? Probably not.


These are my grandsons.
What is in their future?

BUT IF WE CAN TELL THEM BOTH PROBLEMS ARE SOLVED…