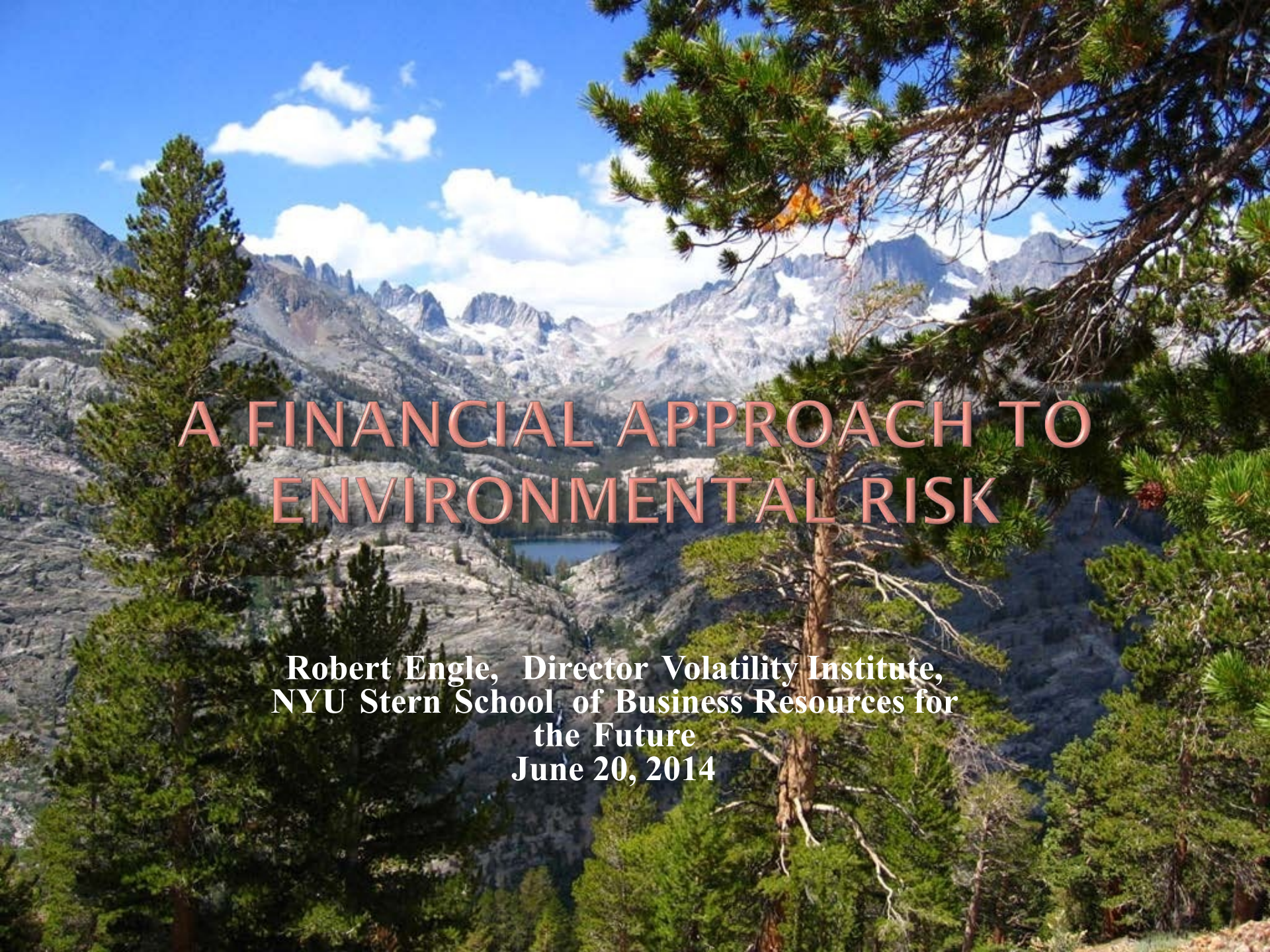

A FINANCIAL APPROACH TO ENVIRONMENTAL RISK

Robert Engle, Director Volatility Institute, NYU Stern School of Business Resources for the Future

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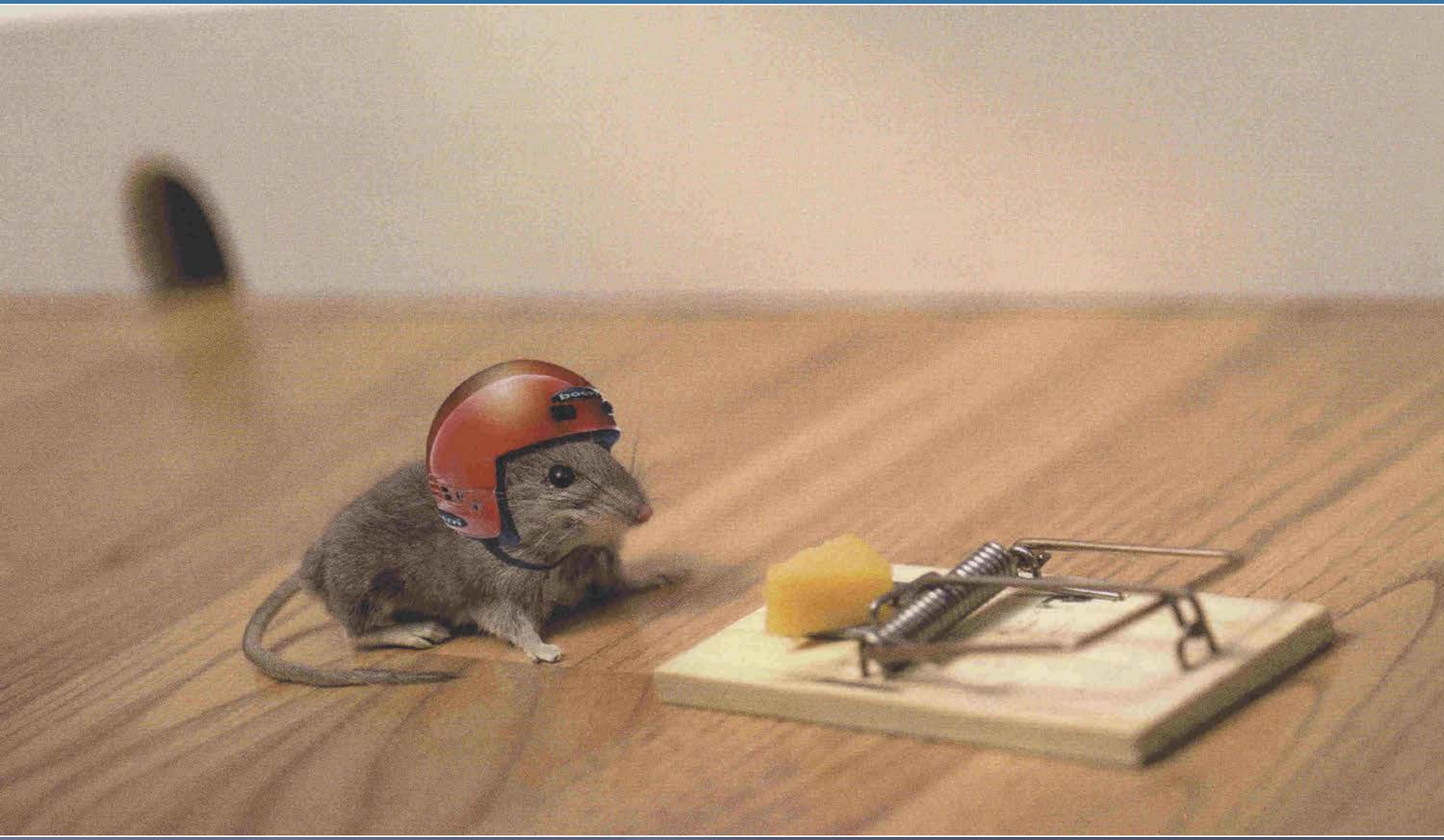
RISK

- RISK IS THE POTENTIAL OF LOSING SOMETHING OF VALUE. THE OUTCOME IS UNCERTAIN AND IN THE FUTURE.
- In finance we often mean loss of value of assets or portfolios. This is measured statistically by Value at Risk, Expected Shortfall, or other types of tail risk.
- Volatility (annualized predicted standard deviation) increases most measures of risk and is often used as a direct measure of risk.

THE FINANCIAL CRISIS: WERE WE PREPARED?



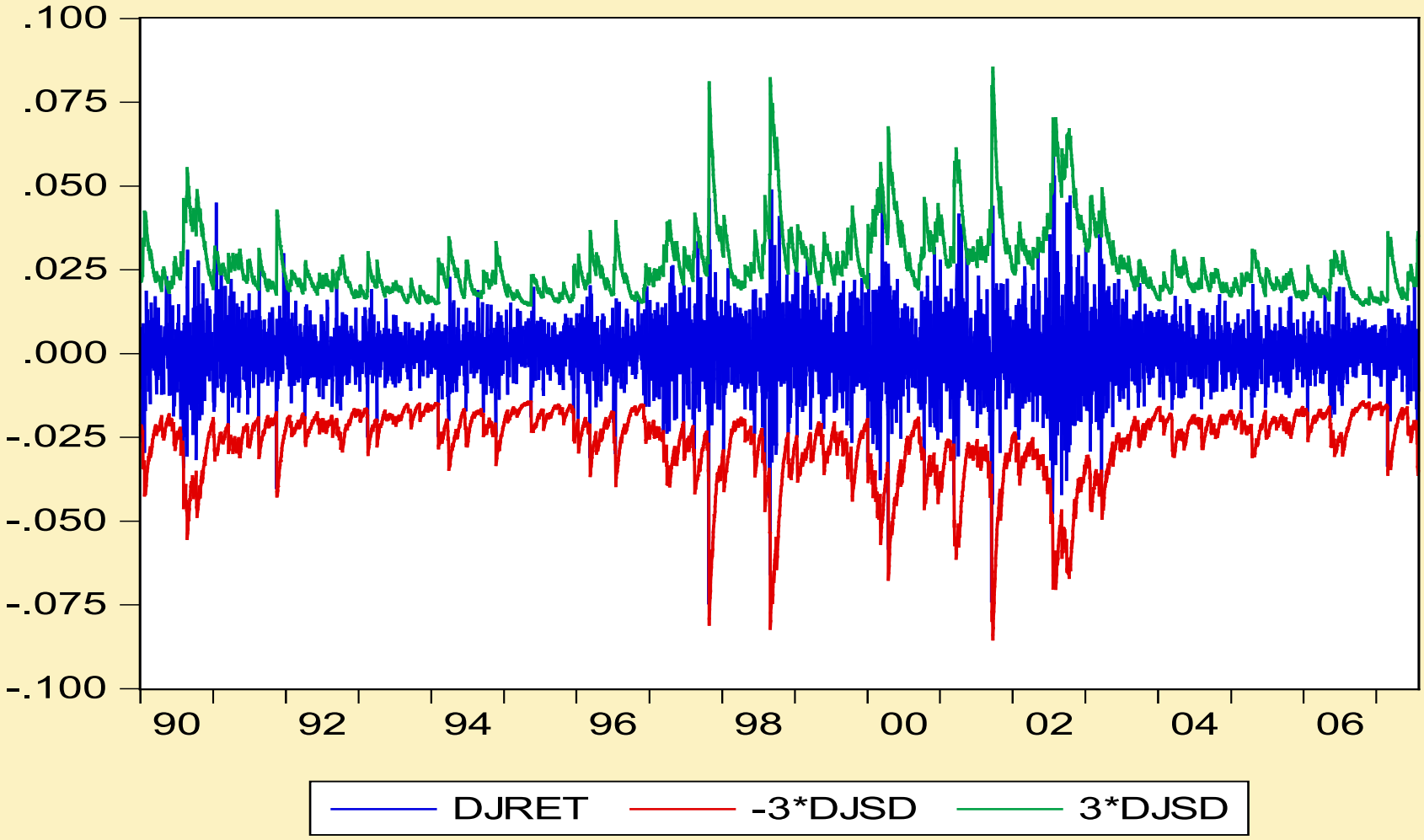
SHOULD WE HAVE KNOWN?

- Did our sophisticated risk management systems predict the financial crisis?
- Would a good econometrician have known that the financial crisis was coming?
- Would the crisis have been in the confidence set?
- Did the models we use break?

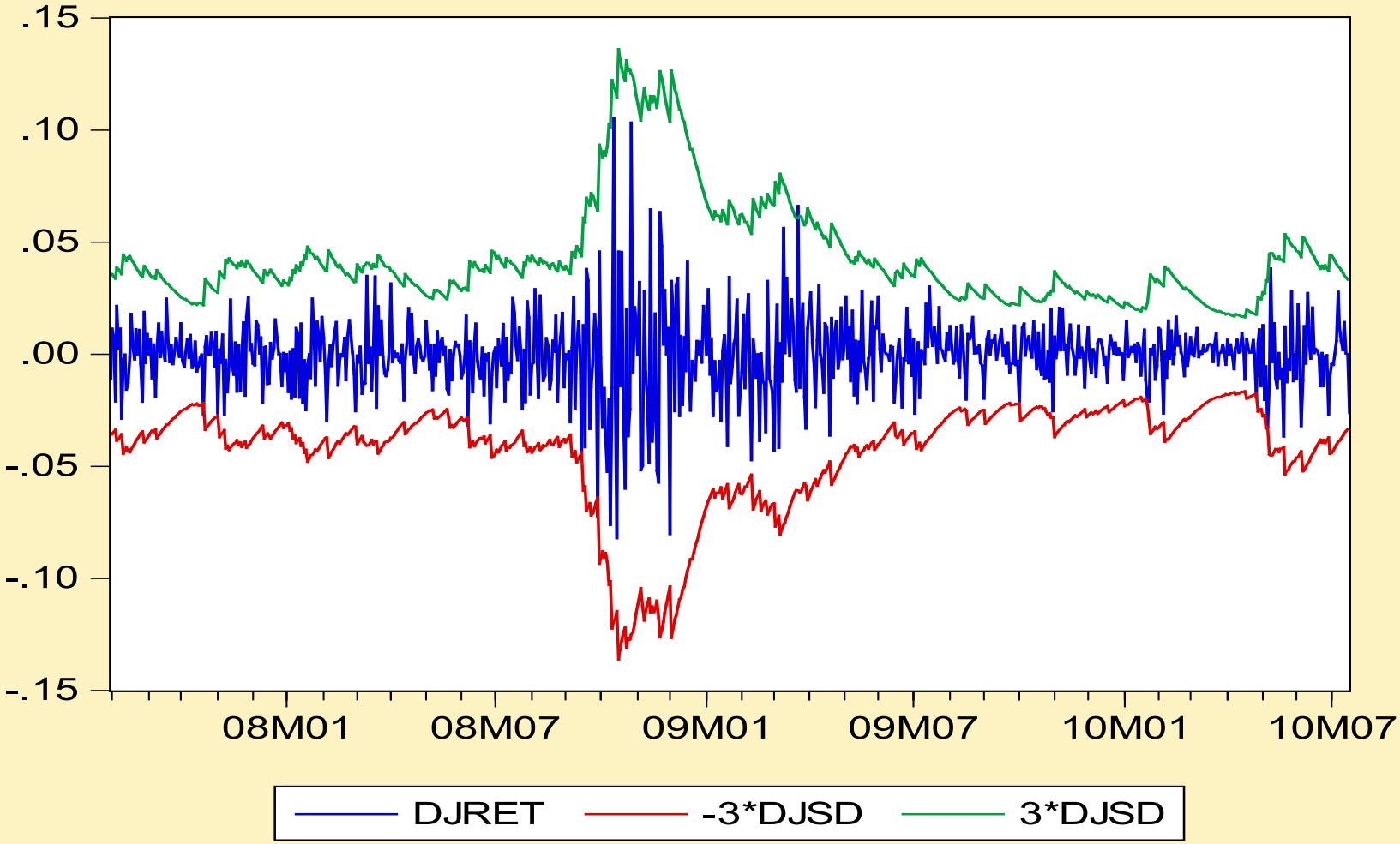
IS THIS AN EXAMPLE OF Sir David Hendry's STRUCTURAL BREAKS AND PREDICTIVE FAILURE or Nassim Taleb's BLACK SWAN?

- Quite possibly, but which models are we thinking about?
- Models which assume constant volatilities or correlations did very badly.
- VaR based on standard volatility models like GARCH didn't do so badly in this crisis.
- What is the evidence?

3 Sigma Bands before Aug 2007



Out-of-Sample 3 Sigma Bands after Aug 2007



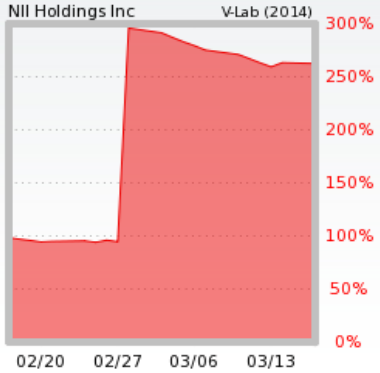
FORECASTING VOLATILITY in V-LAB

- VLAB.STERN.NYU.EDU
- VLAB forecasts volatilities of a thousand assets every day with a variety of models
- Assets include equity indices, individual equities, bonds, FX, international equities, commodities, and even volatilities themselves.

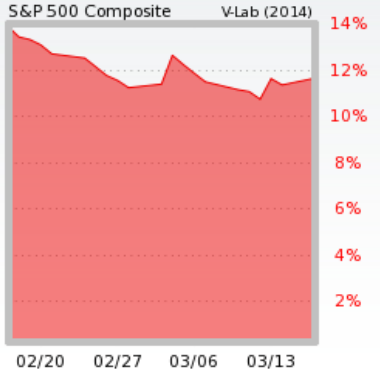
V-LAB ANALYSIS OVERVIEW

VOLATILITY | CORRELATIONS | SYSTEMIC RISK | LONG RUN VALUE AT RISK

HOT	Volatility	Change
NIHD:US	262.60	-0.77
CALL:US	113.60	-3.54
HLF:US	84.91	+17.69
ETAK:US	81.49	-0.31
HEATING	**Volatility**	**Change**
USMO:US	56.63	+21.51
HLF:US	84.91	+17.69
SHEN:US	50.71	+15.88
VHI:US	70.08	+11.57



MARKET SUMMARY	Volatility	Change
SPX	11.65	+0.29
UKX	12.93	-0.23
DAX	21.16	-0.04
CAC	17.78	+0.29
EUR	6.25	-0.08
JPY	8.28	-0.03
MXWD	10.49	+0.14
EEM	20.09	-0.04



The Volatility Laboratory (V-Lab) provides real time measurement, modeling and forecasting of financial volatility, correlations and risk for a wide spectrum of assets. V-Lab blends together both classic models as well as some of the latest advances proposed in the financial econometrics literature. The aim of the website is to provide real time evidence on market dynamics for researchers, regulators, and practitioners.

The V-Lab is currently running 8491 analyses on 2055 datasets producing a total of 39374 series each day!

An Introduction to Financial Volatility: Professor Rob Engle's video lectures on the Financial Times

V-Lab Related Documents

- Dynamic Conditional Beta
  Engle (2014)
- AEA Paper - Capital Shortfall: A New Approach to Ranking and Regulating Systemic Risks
  Acharya, Engle, and Richardson (2012)
- Prof. Rob Engle Discusses Risk with Tom Keene and Ken Pruitt of Bloomberg Surveillance

What's in V-Lab?

Asset Class	Number of Assets
International Equities	1032
Equities	672
Credit Default Swaps	292
Equity Indices	174
Currencies	103
Commodities	59
Volatility Indices	14
Equity Sectors	9
Treasuries	8
Corporate Bonds	6
Real Estate	3

FORECAST PERFORMANCE IN VLAB

- During the financial crisis, the short run forecasts were just as accurate as during the low volatility period.
- One month ahead forecasts were less accurate during the crisis but were still within the 1% confidence interval of historical and theoretical experience.
- See Brownlees, Engle, Kelly," A Practical Guide to Forecasting in Calm and Storm" *Journal of Risk, 2011*

SHORT RUN VS. LONG RUN RISK

- Widely used risk measures are Value at Risk and Expected Shortfall.
- These measure risk at a one day horizon (or 10 day which is calculated from 1 day)
- However, many positions are held much longer than this and many securities have long horizons. The risk for these securities is a long run measure of VaR or ES.
- See Engle JOIM (2009)

- ***There is a risk that the risk will change!!***

INVESTING IN A LOW RISK ENVIRONMENT

- Many investors took low borrowing rates and low volatilities as opportunities to increase leverage without much risk. *RISK MYOPIA*
- Structured products such as CDOs were very low risk unless volatility or correlations rose.
- Insurance purchased on these positions made the risks even lower as long as the insurer had adequate capital.
- Credit spreads were low because volatility was low.

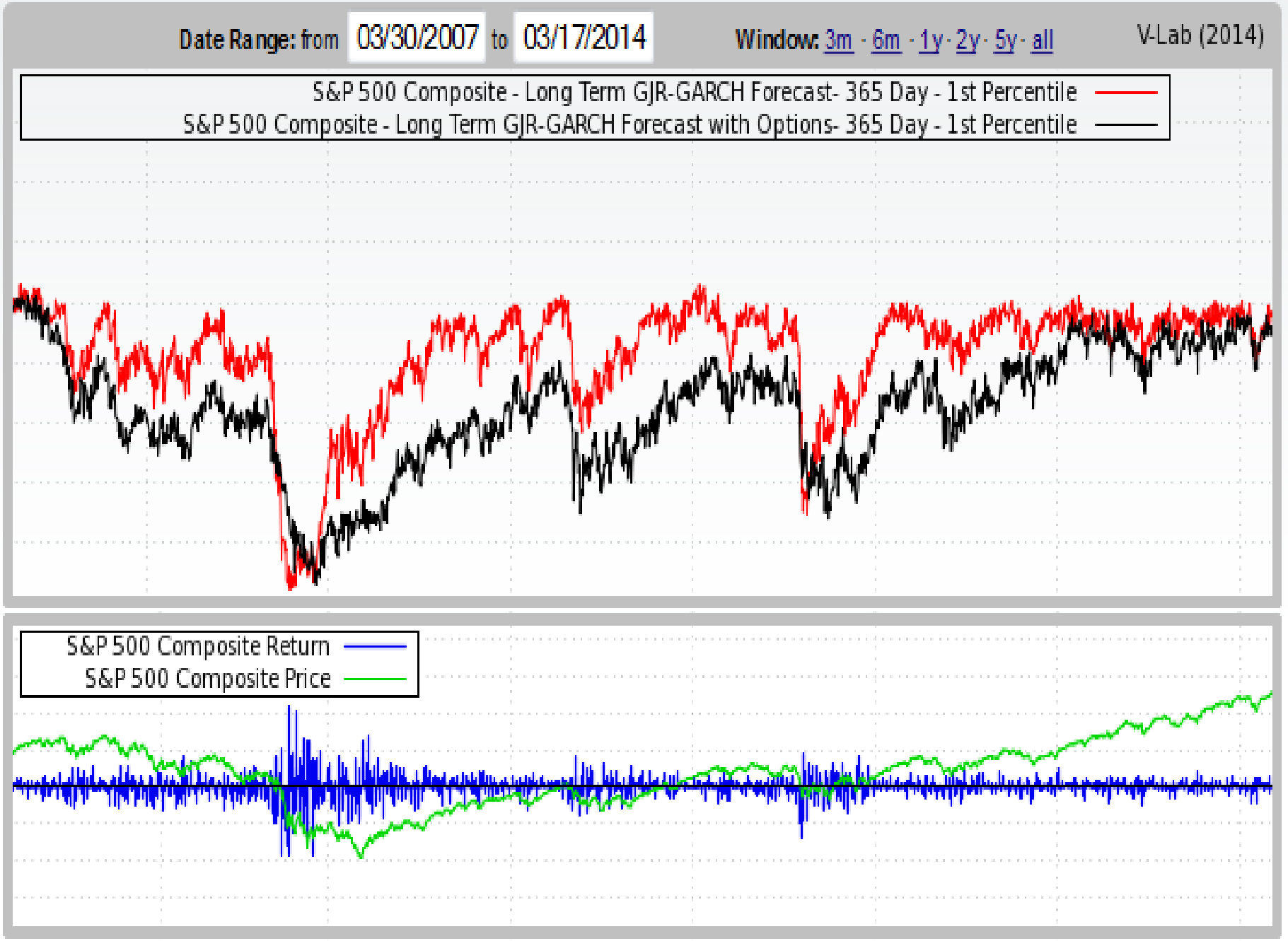
WHAT HAPPENED?

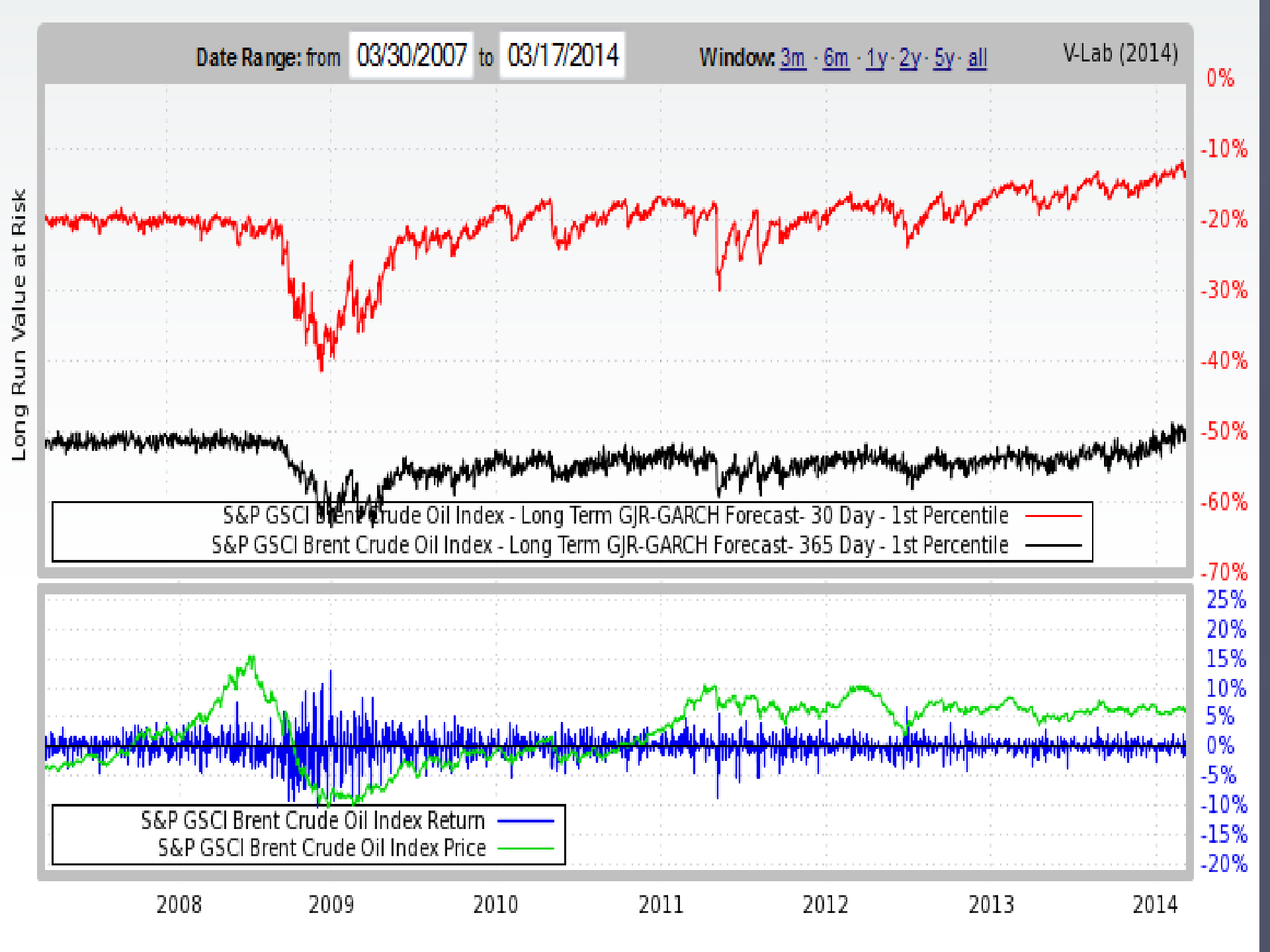
- Volatilities and correlations rose and all these low risk positions became high risk and impossible to sell without deep discounts.
- Insurance became worthless as insurers were undercapitalized.

- Options market and many forecasters including myself believed volatility would rise.
- Risk measurement does not have a good way to incorporate this information.

ESTIMATING LONG RUN VALUE AT RISK

- Model the rate at which volatility has changed as a random process using historical data. Asymmetric GARCH.
- Every day, simulate many scenarios and report the 1% and 5% quantiles. Use resampled residuals to allow fat tailed distributions. Days differ because the initial conditions change, and also the process can change a little.
- If there are options with different maturities available, adjust the GARCH models to match option term structure.


Date Range: from 03/30/2007 to 03/17/2014
Window: 3m · 6m · 1y · 2y · 5y · all
V-Lab (2014)
S&P 500 Composite - Long Term GJR-GARCH Forecast- 365 Day - 1st Percentile
S&P 500 Composite - Long Term GJR-GARCH Forecast with Options- 365 Day - 1st Percentile
0%
-10%
-20%
-30%
-40%
-50%
-60%
-70%
-80%
-90%
S&P 500 Composite Return
S&P 500 Composite Price
20%
15%
10%
5%
0%
-5%
-10%
-15%
2008
2009
2010
2011
2012
2013
2014


Date Range: from 03/30/2007 to 03/17/2014
Window: 3m · 6m · 1y · 2y · 5y · all
V-Lab (2014)
Long Run Value at Risk
0%
-10%
-20%
-30%
-40%
-50%
-60%
-70%
S&P GSCI Brent Crude Oil Index - Long Term GJR-GARCH Forecast- 30 Day - 1st Percentile
S&P GSCI Brent Crude Oil Index - Long Term GJR-GARCH Forecast- 365 Day - 1st Percentile
25%
20%
15%
10%
5%
0%
-5%
-10%
-15%
-20%
S&P GSCI Brent Crude Oil Index Return
S&P GSCI Brent Crude Oil Index Price
2008
2009
2010
2011
2012
2013
2014

LONG RUN RISKS


OR

LONG RUN RISKS

- FINANCIAL CRISIS
- ECONOMIC RECESSION
- INFLATION
- WAR AND TERRORISM
- CLIMATE CHANGE

WHAT ARE THE RISKS?

- Scientific evidence seems clear that the climate is changing.
  - CO_2 concentrations are rising rapidly
  - Glaciers and polar ice are melting
  - Warmest years on record are almost all within 10 years.

- But what are the costs? Scientific evidence is not precise.

ECONOMIC COSTS

- THE GLOBAL ECONOMY WILL BE UNABLE TO PRODUCE AS MUCH IN THE FUTURE AS IT WOULD WITHOUT CLIMATE CHANGE
- TAXES WILL BE RAISED TO PAY FOR PUBLIC EFFORTS TO MITIGATE THESE COSTS
- COMPANIES WILL HAVE EXTRA COSTS OF DOING BUSINESS.

MARKET RESPONSES TO LONG RUN RISKS

- Two stocks have the same expected returns and same short term risk but different long term risk. Will they trade at the same price?
- No. The stock with high long term risk will be cheaper.
  - Note, investors might consider buying it with the expectation that they will sell before the long run arrives – however who will they sell it to? Market timing leads to panic selling and firesale prices at the moment when the risks change.

CONTINUE

- One stock that suddenly has higher long run risk but has no other changes will decline in price.
- For the market as a whole, long run risk will depress asset prices.
- If long run risks can be reduced, then the market should rally.
- ***The benefits to reducing long run risk can be realized today. We don't have to wait!!***


HEDGING LONG RUN RISKS

MERTON'S ICAPM

- The CAPM is a static model with constant risk and expected returns.
- Merton(1974) showed that if the "investment opportunity set" can change, an investor should want to hedge against adverse changes.
- The investor should hold assets that increase in value if the change occurs.
- These assets are called hedge assets and are especially desirable and consequently sell at a higher price than they otherwise would.

HEDGING A FINANCIAL CRISIS

- In a financial crisis, volatility rises and so do secure assets such as gold, treasuries and the dollar.
- Questions: how much to hedge, how expensive are the hedges, and how effective are the hedges?

HEDGING OTHER BUSINESS DOWNTURNS

- Similar story.
- Volatility, treasuries, gold and the dollar rise as equities fall

HEDGING INFLATION

- Hedge with commodities, real estate, gold, equities, volatility, TIPS.
- We have not had serious inflation for decades so must rely on theory rather than empirical performance.

HEDGING CLIMATE CHANGE

- Hedge with companies expected to do well in a new low carbon environment. This could be alternative energy strategies, non-carbon transportation and manufacturing solutions, sequestration technologies, etc.
- Are investors doing this hedge?

PROPERTIES OF HEDGE PORTFOLIOS

- Should outperform in a crisis
- Should underperform on average
- Forecasts of high volatility make these assets more valuable.
- Asymmetric volatility should have opposite sign.

PRICING A SECOND FACTOR in ICAPM

- Suppose assets are priced with two factors, a risk factor f_1 and a hedge factor f_2. That is, there is a two factor pricing kernel.
- The expected return on the second factor is:

$$E_t\left(f_{2,t+1}\right) = r^f_{t+1} - \left(1 + r^f_{t+1}\right)\left(b_1 \operatorname{cov}_t\left(f_{1,t+1}, f_{2,t+1}\right) + b_2 \operatorname{var}_t\left(f_{2,t+1}\right)\right)$$

- Notice that the first term is the risk premium from the covariance with the first factor.
- The second term is due to the hedge role. For a hedge portfolio, b_2 is positive reducing the risk premium.
- From the second term, increasing volatility of the hedge asset leads to lower expected returns – the opposite of ordinary assets. Why? Because increased volatility means increased value for the hedge.

PRICING A HEDGE FACTOR

- Substituting this expected return equation into the Campbell Shiller log linearization, and assuming that bs are time invariant,
- the return on a hedge factor should be *positively* related to its change in variance.
- *Asymmetric volatility for a hedge factor should be opposite that for a risk factor*.
- This is not surprising as a risk factor will do especially badly in a crisis and hence shorting it will be a hedge.

ASSETS in V-LAB

- CURRENCIES per dollar, INDICES TRADED AS ETFs, FIRMS, COMMODITIES, VOLATILITIES, TREASURIES, CORPORATES – 843
- Of all these assets, only 13% have negative asymmetry – that is have volatilities and returns that are postively correlated.
- Of these negatives, 70% are assets that can be considered hedges.
  - Currencies are 73% negative
  - Volatilities are 100% negative
  - Commodities (excluding energy are 60% negative
  - Treasuries are 100% negative
  - Corporates are 40% negative
  - Energy assets are 44% negative

EXPLANATION

- The dollar is viewed as a safe haven so for 33 of the 45 currencies traded, the dollar appreciates when its volatility rises.
- Similarly, treasuries and volatilities all increase in value as their volatilities increase.
- Commodities are considered to be inflation hedges and hence appreciate as volatility rises.
- Corporates and Energy have both hedge and risk characteristics so have mixed results.

ENVIRONMENTAL HEDGES

- Biofuels
- Clean Tech
- Efficiency
- Energy Storage
- Fuel Cells
- Geothermal
- Natural Foods and Home
- Natural Health and Supplements
- Recycling/Green Chemicals
- Renewable Energy Project Developers
- Solar
- Transportation
- Water
- Wind

ENVIRONMENTAL RESULTS

- 100 Stocks in these categories
- Average return is 2.5%, Average volatility is 63% - Bad Sharpe ratios.
- Just 7% have negative asymmetry.
- Why such weak support? These stocks may be an environmental hedge but are risk factors for most of the other long run risks. This test is not sufficiently sophisticated to separate these effects.
- Small cap stocks (such as SMB) tend to have positive asymmetry as shown by Engle and Mistry(2014)


POLICY IMPLICATIONS

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- If Environmental Risk is priced, then the stock market will go up in response to a reduction of the risk.
- Implement a comprehensive Carbon Tax and use the revenue to reduce other taxes. This will reduce the risk.
- Voters and investors should all approve!
  - Impacts can be quite different across individuals and industries however.

A POLICY PROPOSAL*

- Implement a comprehensive Carbon Tax and use the revenue to reduce social security payroll taxes.
  - Similar regressiveness
  - Next generation better off
    - Don't have to support both retirees and environmental costs
  - Opposite distortions
  - Current retirees might hesitate but would be happy for 401K benefits and SS viability.

*Engle, 2008 "Two Risks One Solution"

DETAILS(my ideas for implementation)

- Announce the policy several years in advance of its implementation
  - This will reduce the hardship on the most impacted individuals and industries and allow benefits to be achieved in advance of implementation.
  - Investments in consumer durables and business capital and equipment are more efficient with better foresight.
  - This is credible because the tax supports the ever popular social security system

MORE DETAILS

- Put proceeds into a Sovereign Wealth Fund which is invested into a diversified US equity portfolio
  - This will achieve a higher return than US treasuries for reasons already discussed.
  - This will supply capital to US industry lowering the cost of capital and offsetting higher energy costs.
- Social Security system is the beneficiary of SWF

WHAT CARBON TAX RATE SHOULD WE USE?

- If we set it too high, then it will raise the price of carbon and slow extraction. This may slow the economy depending on when payroll taxes are reduced. Exporters will face price competition unless other countries join this effort. Fossil reserves will last longer.
- If we set it too low, then environmental costs will eventually absorb vast resources and social security will require supplemental funding too.
- Rate must be adjustable based on scientific evidence.

ANALYTIC APPROACH

- Van den Bremer, van der Ploeg and Wills(2013) have an Oxford working paper which solves the social planner problem of extracting limited reserves of oil and managing the income with a SWF with a goal of sustainable consumption.
- Portfolio allocation they argue must take oil reserves into account. Rate of extraction depends upon correlation of oil prices and other risky assets.
- This model should be extendable to ICAPM with climate change costs. Solve for optimal carbon tax rate


CONCLUSIONS

CONCLUSION

- Make sure you take only the risks you intend to take - including long run risks.
- Consider reducing exposure to long term risks by hedging.

- Policies to reduce long run risks have benefits today.
- We should implement a comprehensive carbon tax with proceeds supporting social security.


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