

# Multivariate CAViaR and Extensions

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# Roadmap

- ▶ Background: Summarize M.S. thesis
- ▶ Describe extensions and get feedback:
  - ▶ Extension 1: Improve forecast from thesis
  - ▶ Extension 2: Combine predictions between models
  - ▶ Extension 3: Build predictive algorithm, from PCA

# Executive Summary

- ▶ I developed a new risk prediction model that is easy to interpret but needs help with predictive accuracy.
- ▶ I also developed two potentially novel but unproven extensions based on this model that may need a better application.

## Background: What to forecast?

- ▶ What should we predict in equity returns?
- ▶ The S&P 500 (largest 500 U.S. stocks) earned  $\sim 6.8\%$  pre-tax, post-inflation from 1871-2020
  - ▶ Includes world wars, great depression, stagflation
  - ▶ “In the long run we are all dead”
- ▶ Short-term gyrations drive long-term performance

# Background: How to forecast?

- ▶ Fully generative vs. fully nonparametric
  - ▶ Fully generative (RiskMetrics)
  - ▶ Fully nonparametric (historical simulation)



## Background: Value-at-Risk

- ▶ 1% VaR of -\$10MM = lose \$10MM+ 1 out of 100 days
  - ▶ Boils risk into “one number”
  - ▶ Commonly used by financial regulators

## Background: What is CAViaR?

- ▶ CAViaR = conditional autoregressive value at risk
  - ▶ Developed by Engle and Manganelli in 2004
- ▶ Directly predicts  $\alpha$  % quantile
  - ▶ Balances between too little and too much
- ▶ Statistically robust
  - ▶ Builds upon rich methodology literature

## Background: Potential Issues with CAViaR?

- ▶ How to incorporate information from other stocks?
- ▶ How can we have clear, explainable results?



## Background: Proposed Extensions as “Multivariate CAViaR”

- ▶ Include meaningful ETFs (exchange traded funds)
  - ▶ ETFs avoid issues like bankruptcy & mergers
- ▶ I used mostly sector ETFs (utilities, industrial, energy, etc.)
- ▶ I used SPY (S&P 500 ETF) as a response

# Background: Proposed Extensions as “Multivariate CAViaR”

- ▶ Idea: Combine ETFs into principal components at forecast origin (diffusion indices, or DIs)
  - ▶ Builds upon the diffusion index literature from Stock and Watson in 2002
- ▶ Add nonlinear autoregressive (AR) terms from SPY into model
- ▶ 4 configurations of univariate model
- ▶ 4 configurations of multivariate model

## Background: Fitting Process

- ▶ Take 5 years of SPY returns
  - ▶ ~3 years: Training set
  - ▶ ~1 year: Validation set
  - ▶ ~1 year: Test set
- ▶ Choose number of DIs & AR lags on validation set
- ▶ Evaluate performance of 1%, 5%, and 10% VaR
- ▶ Evaluate in 2008, 2010, 2014, and 2016

## Background: Results

- ▶ Results from 2008 were poor
- ▶ Results were comparable in 2010, 2014, and 2016

## Extension 1

- ▶ How to improve this forecast?
- ▶ One idea: Include MA terms in MV CAViaR
  - ▶ Pro: Likely dramatically improves accuracy
  - ▶ Con: Harder to interpret model
  - ▶ Cons: Harder to fit model

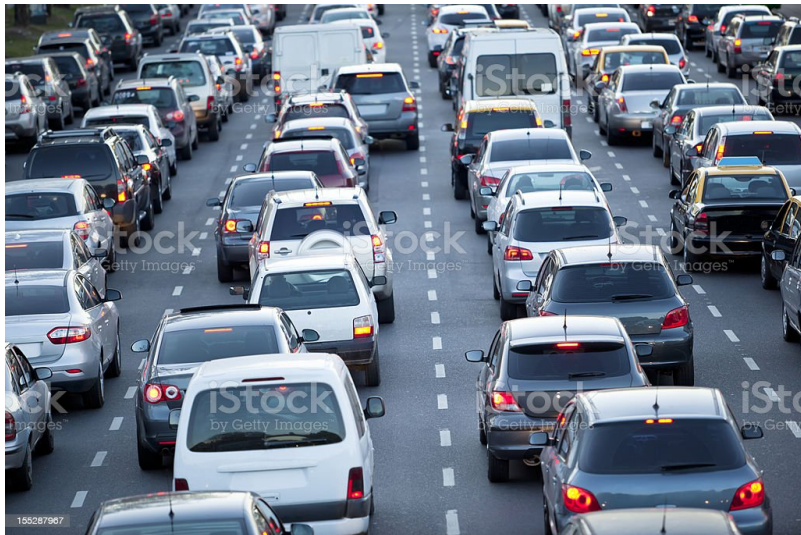
## Extension 2: Motivation



## Extension 2: Motivation



## Extension 2: Motivation





## Extension 2: A Tale of Two Approaches

1. “Rational” forecast
  - ▶ Day of week, weather, time, etc.
2. “Irrational” forecast
  - ▶ Anchor to recent behavior

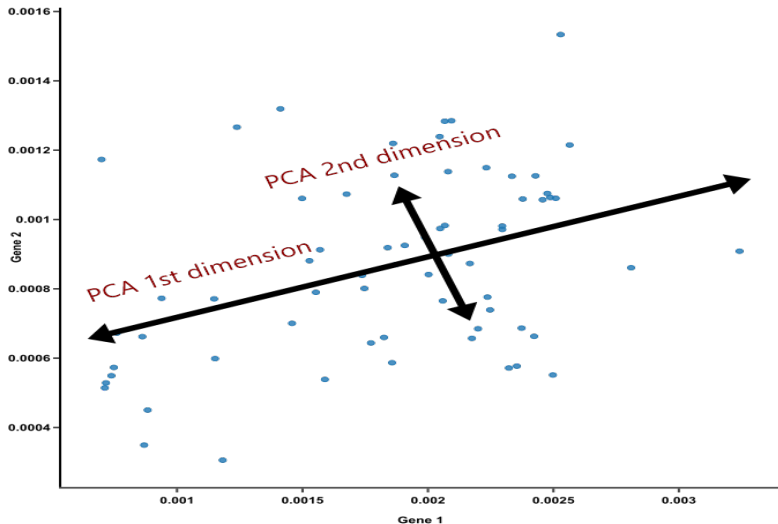
## Extension 2: Application to Earlier Work

- ▶ When multivariate CAViaR dominates, we're in a “rational” state
- ▶ Otherwise, in a “irrational” state
- ▶ Find posterior probability of latent state using Hidden Markov Model – Some details omitted (see appendix)

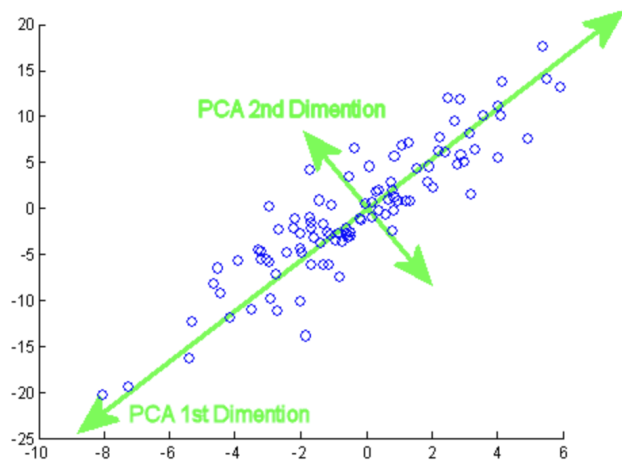
## Extension 2: Application to Earlier Work

- ▶ Results are not overly promising, but may require another dataset

## Extension 3: Motivation from PCA

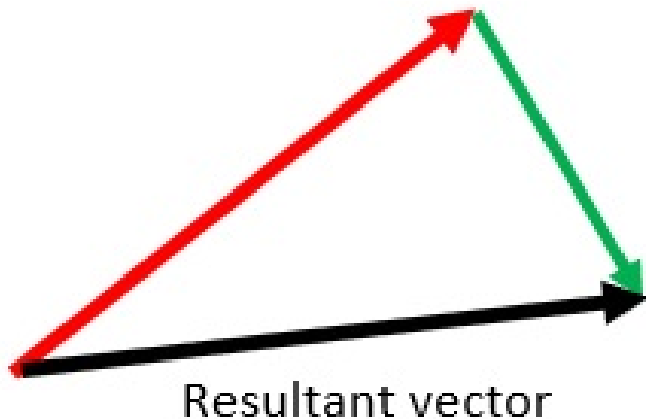


### Extension 3: Motivation from PCA



### Extension 3: Calculating Resultants

Tip of red vector to the tail  
of the green vector.



## Extension 3: Procedure

- ▶ Compute the resultant for  $t$  points and  $m$  vectors
- ▶ Measure the angle between resultants; 90 degrees implies “orthogonal”
- ▶ Results are promising

Thank you!



# Appendix