SSIA

Optimal Volatility

Mechanics of Dynamic Risk Control

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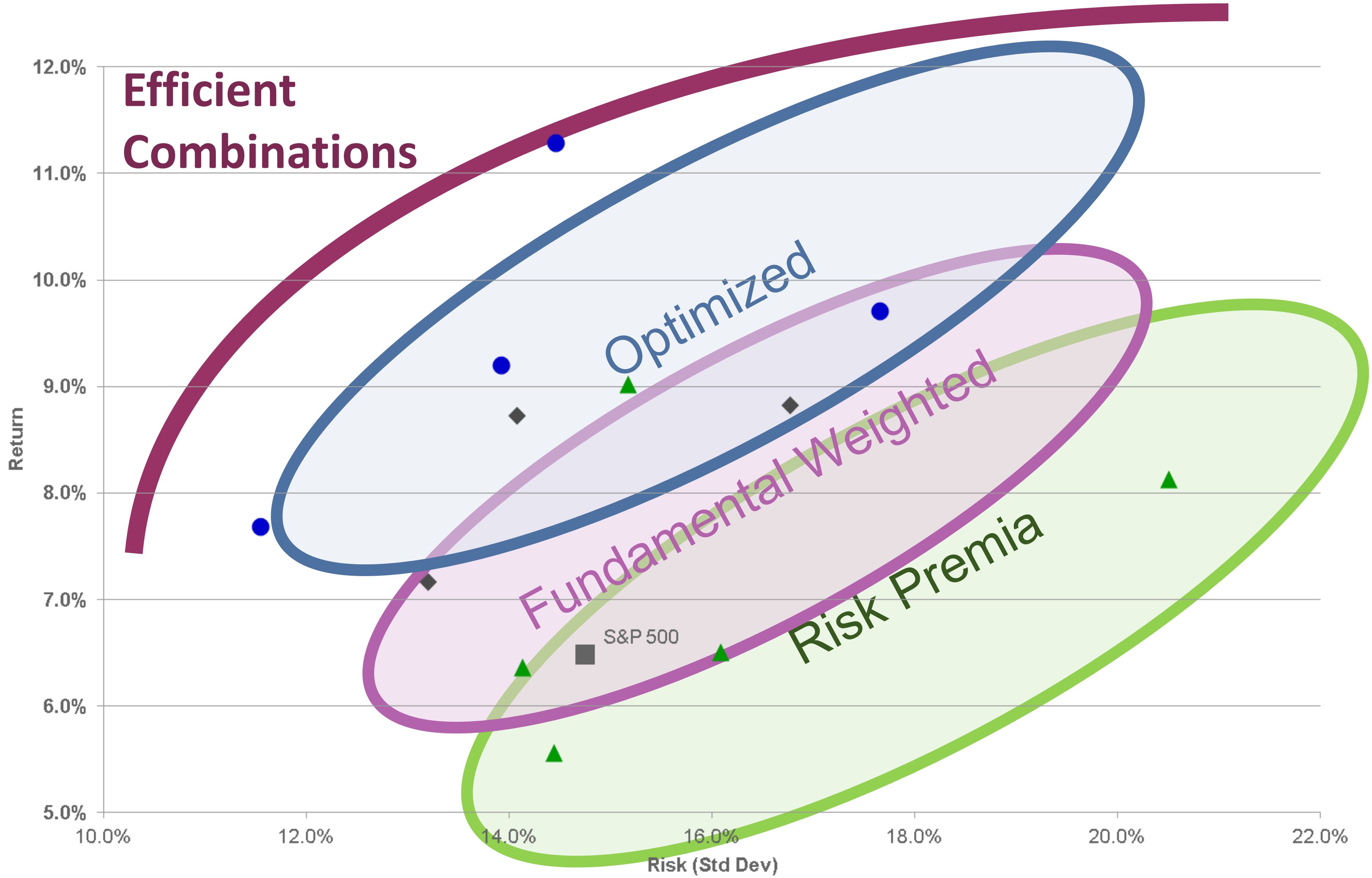
Achieving Good Reward for Risk

- Smart Beta strategies continue to gain favor
- Low Volatility strategies are successful and gaining AUM
- Optimization strategies provide good reward for risk
- New dynamic risk optimization strategies are emerging

Smart Beta Classifications and Example Strategies

Fundamentals	o Book Value o Sales o Cash Flow o Dividends
Risk Premia	o Value o Size o Momentum o Quality
Optimized Risk	o Minimum Volatility o Risk Weighting o Risk Parity (Equal Risk Weighting) o Maximum Diversification o Dynamic Managed Volatility

Return vs. Risk for Smart Beta Strategies



Building Simple Portfolios Based on Trailing Risk

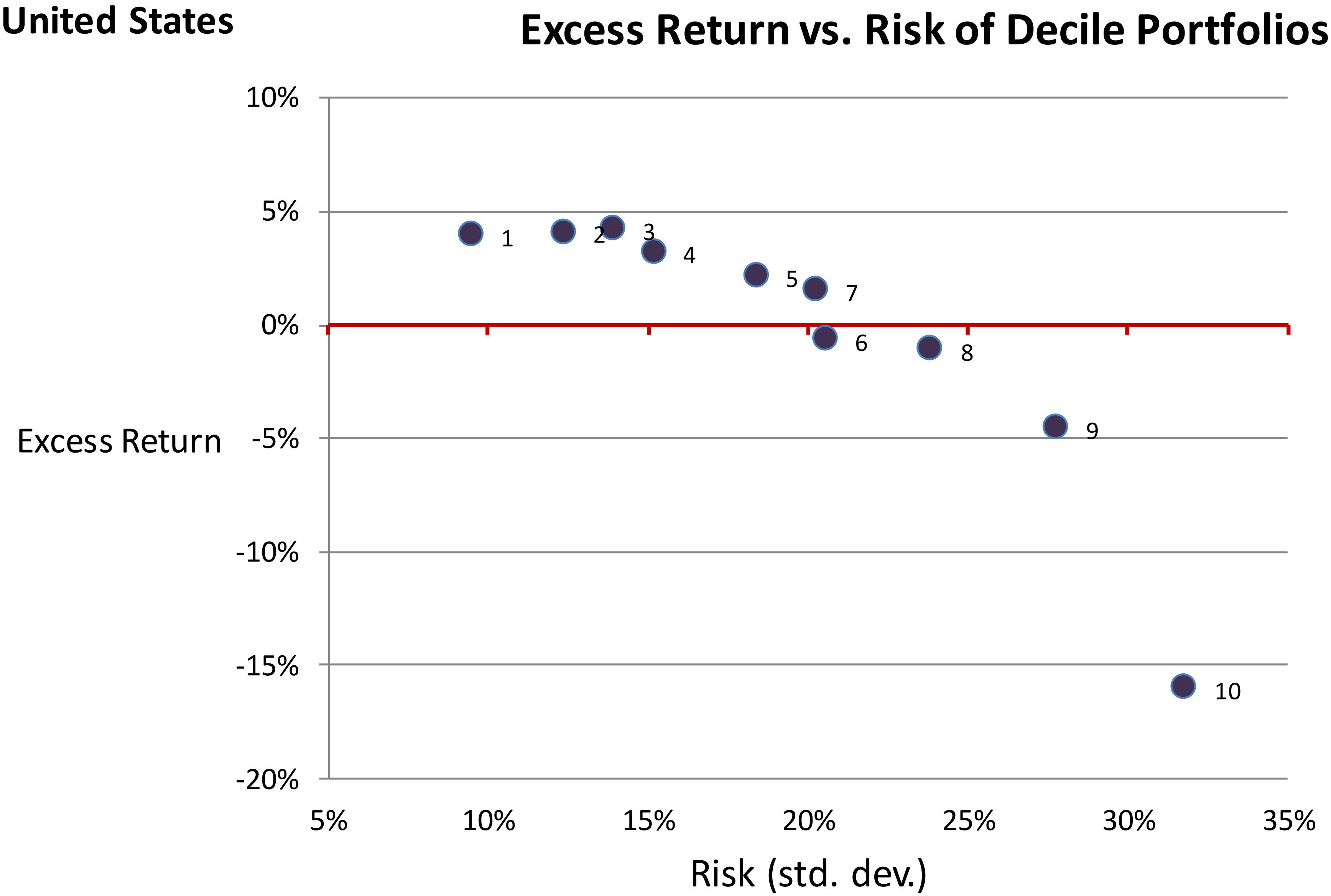
- Calculate trailing 24-month volatility for largest stocks in the USA (99.5%)
- Rank from lowest to highest volatility
- Form 10 decile and 5 quintile portfolio groups based on volatility ranks
- Create equal-weighted and capitalization-weighted portfolios for each group
- Calculate return for each portfolio over the next month
- Repeat procedure using a new 24-month window including latest month

See paper for details:

- "Low Risk Stocks Outperform within All Observable Markets of the World", SSRN, 2012

Risk and Return of Deciles: 1990-2017

United States



Risk and Return of Deciles: 1990-2017

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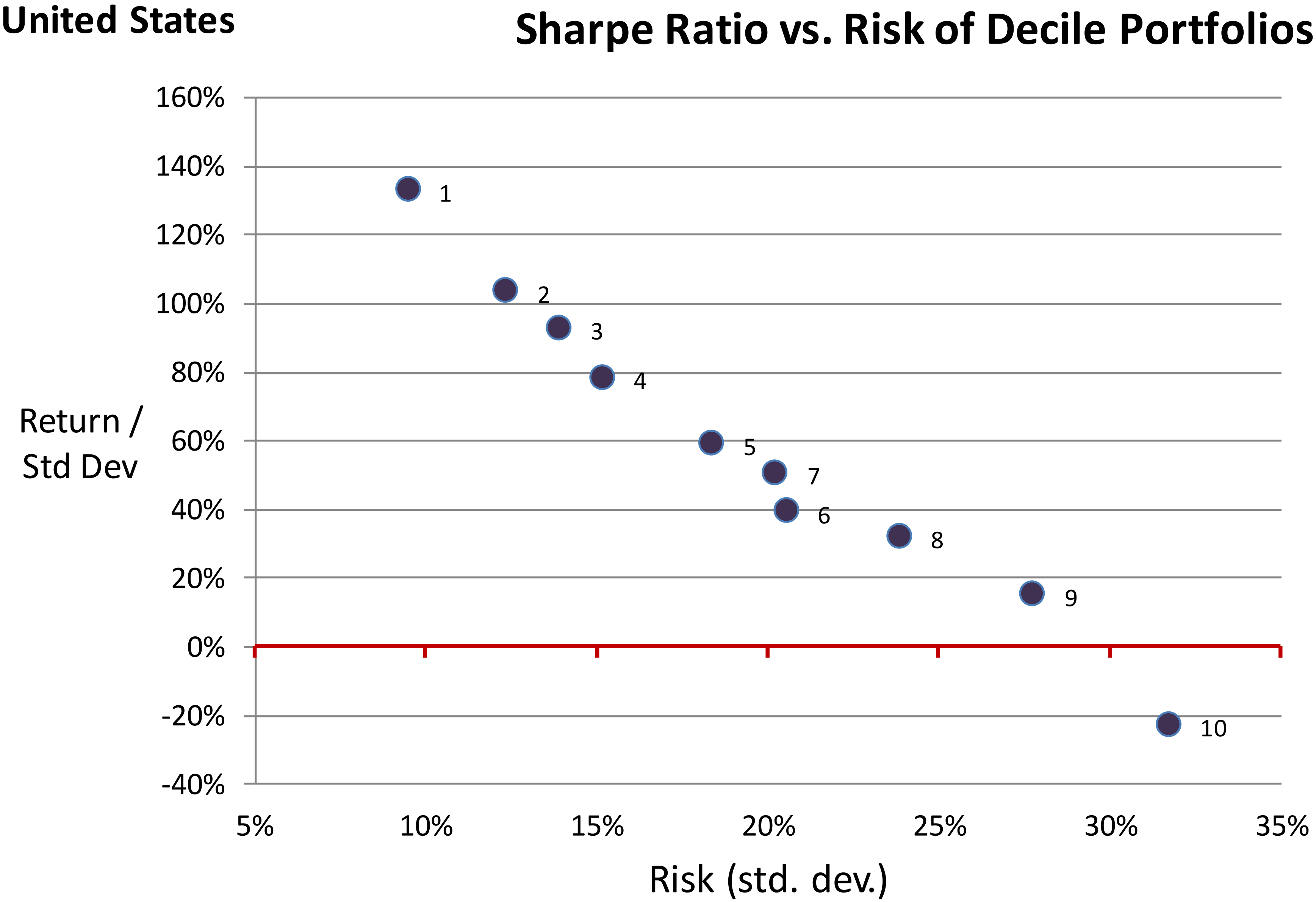
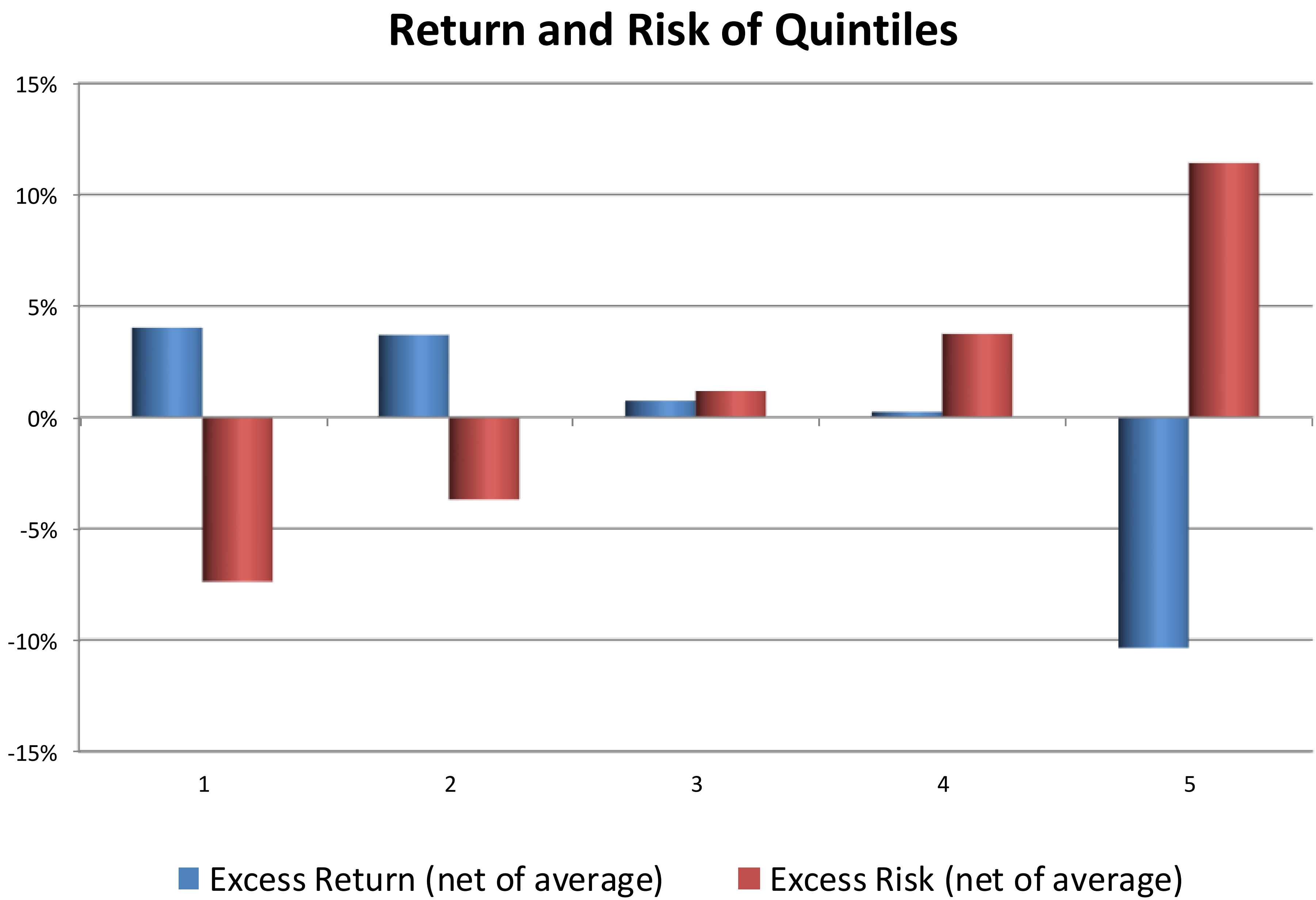


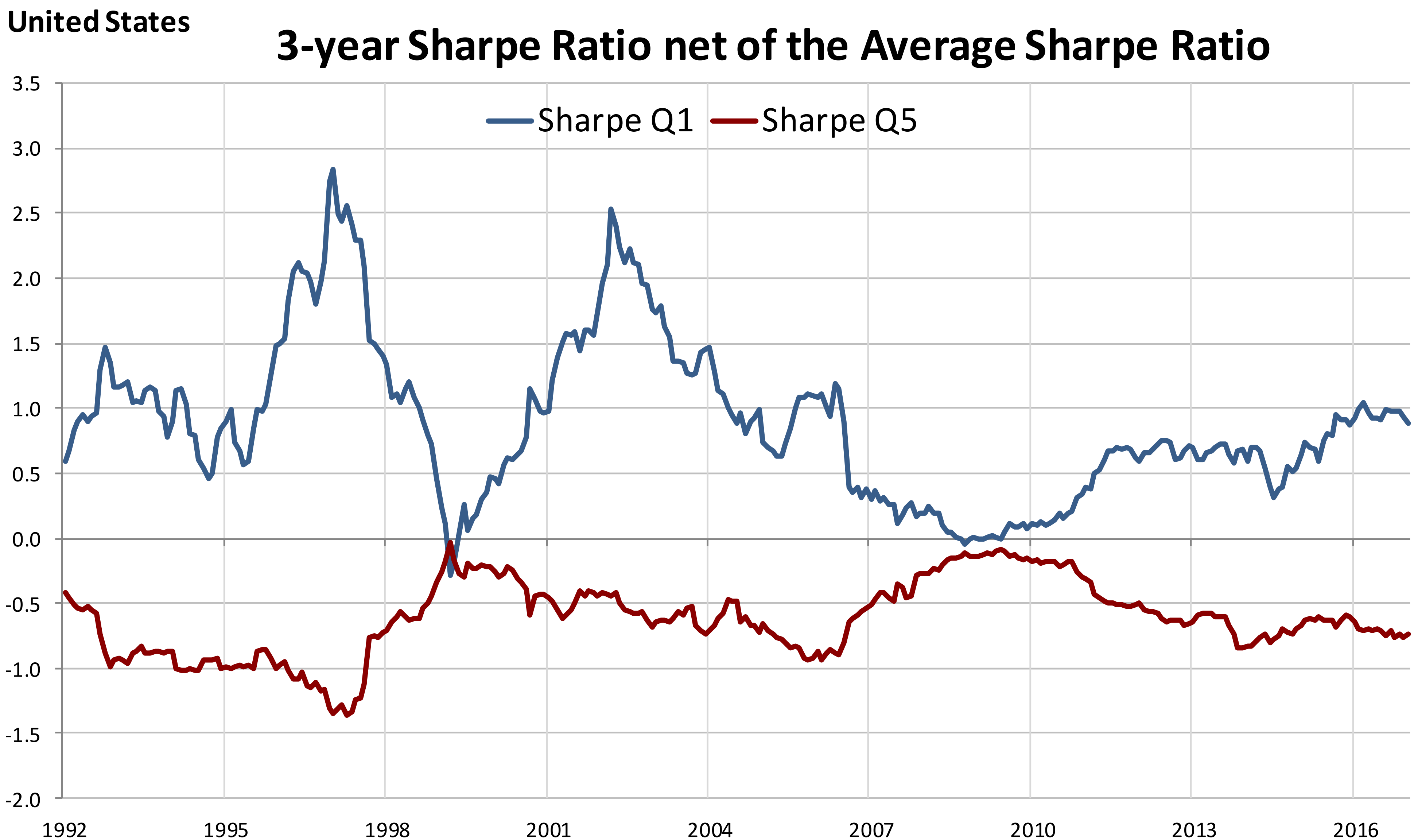
Annualized Results for Volatility Sorted Groups: 1980 - 2017

Averages Over All 12-Month Periods: 456 Observations										
USA	**All Stocks**	**Low Half**	**High Half**	**Q1**	**Q5**	**D1**	**D5**	**Low - High**	**Q1 - Q5**	**D1 - D10**
Return	12.2%	15.6%	9.0%	15.7%	4.4%	15.5%	-0.5%	6.5%	11.3%	16.0%
Pct > 0	72.6%	84.2%	65.6%	87.7%	55.5%	88.4%	45.8%	72.6%	74.6%	78.3%
Risk (std dev)	16.1%	11.9%	21.1%	9.8%	24.7%	8.9%	26.5%	-9.2%	-14.9%	-17.6%
Pct > 0	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	0.0%	0.0%	0.0%
Sharpe	1.03	1.68	0.65	2.06	0.33	2.22	0.09	1.04	1.73	2.12
Pct > 0	72.6%	84.2%	65.6%	87.7%	55.5%	88.4%	45.8%	88.8%	89.5%	91.7%

Return and Risk of USA Quintiles: 1990-2017



Sharpe Ratio of Quintiles: 1990-2017



Portfolio Risk Depends on Average Stock Volatilities and Correlations

Risk = **Volatility** × **Correlation**

Portfolio Volatility = weighted average volatility of stocks · weighted average correlation

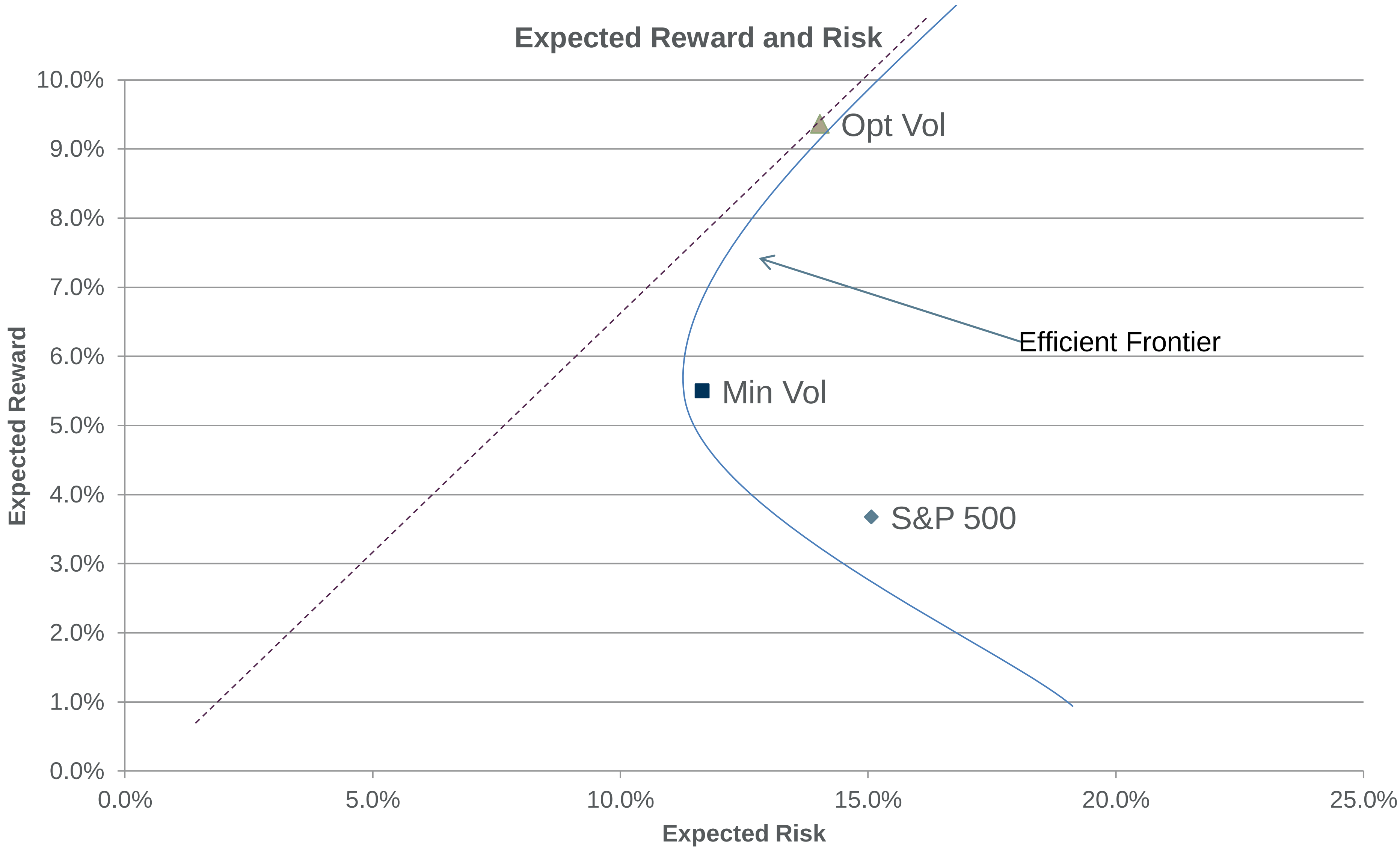
$$\sigma^2_p = \Sigma_i \; x_i \cdot \sigma^2_i \quad \cdot \quad \Sigma_i \; x_i \cdot \rho_i$$

where:

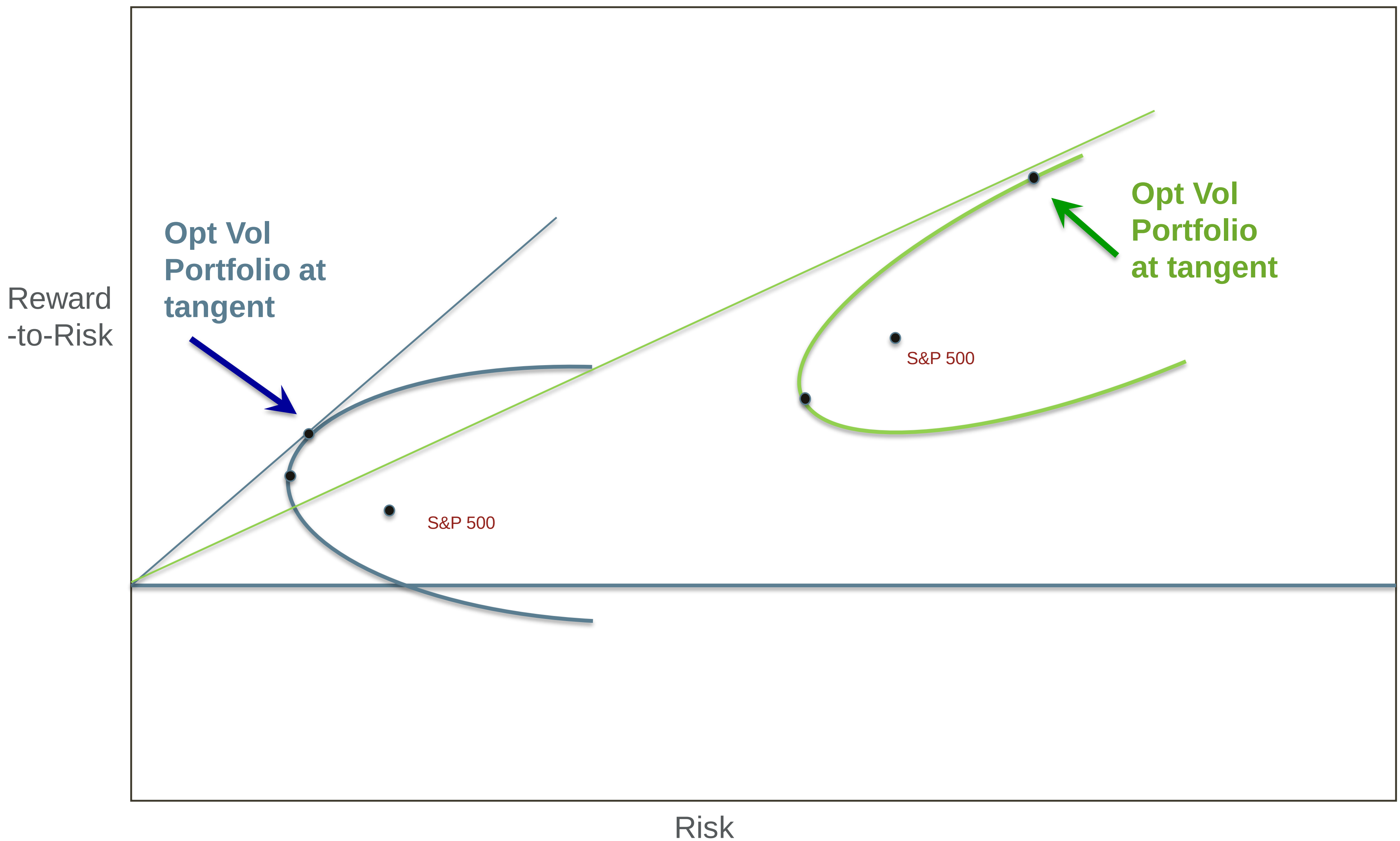
σ^2_p	portfolio volatility
$\Sigma_i \; x_i \cdot \sigma^2_i$	weighted average volatility of stocks in the portfolio
$\Sigma_i \; x_i \cdot \rho_i$	weighted average correlation among stocks in the portfolio
ρ_i	weighted average correlation of stock i with all other stocks

Price information drives Returns, Volatilities and Correlations

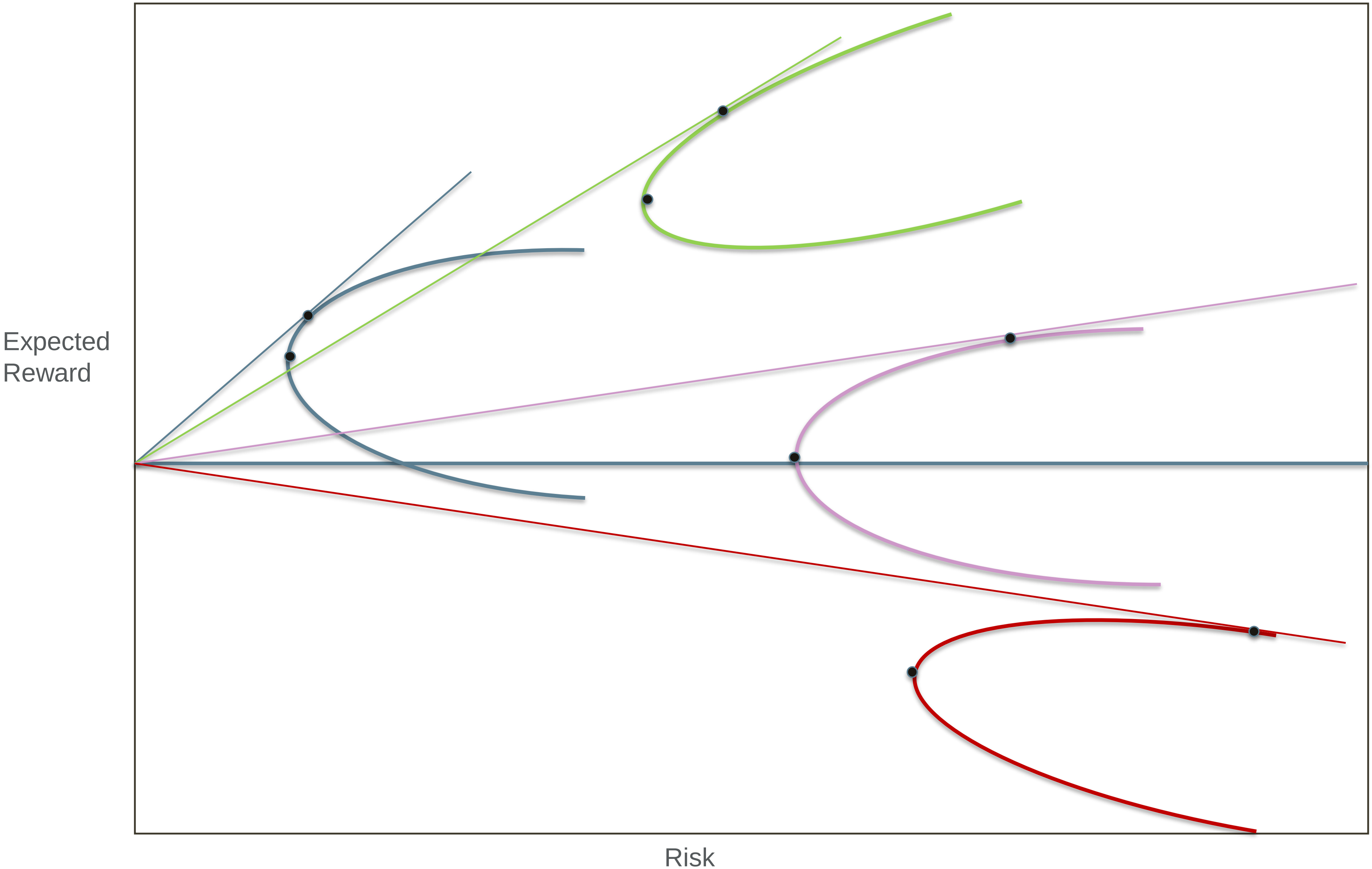
Dynamic Approach - Optimal Volatility



Frontiers: Opt Vol portfolio is selected to Maximize Portfolio Reward-to-Risk

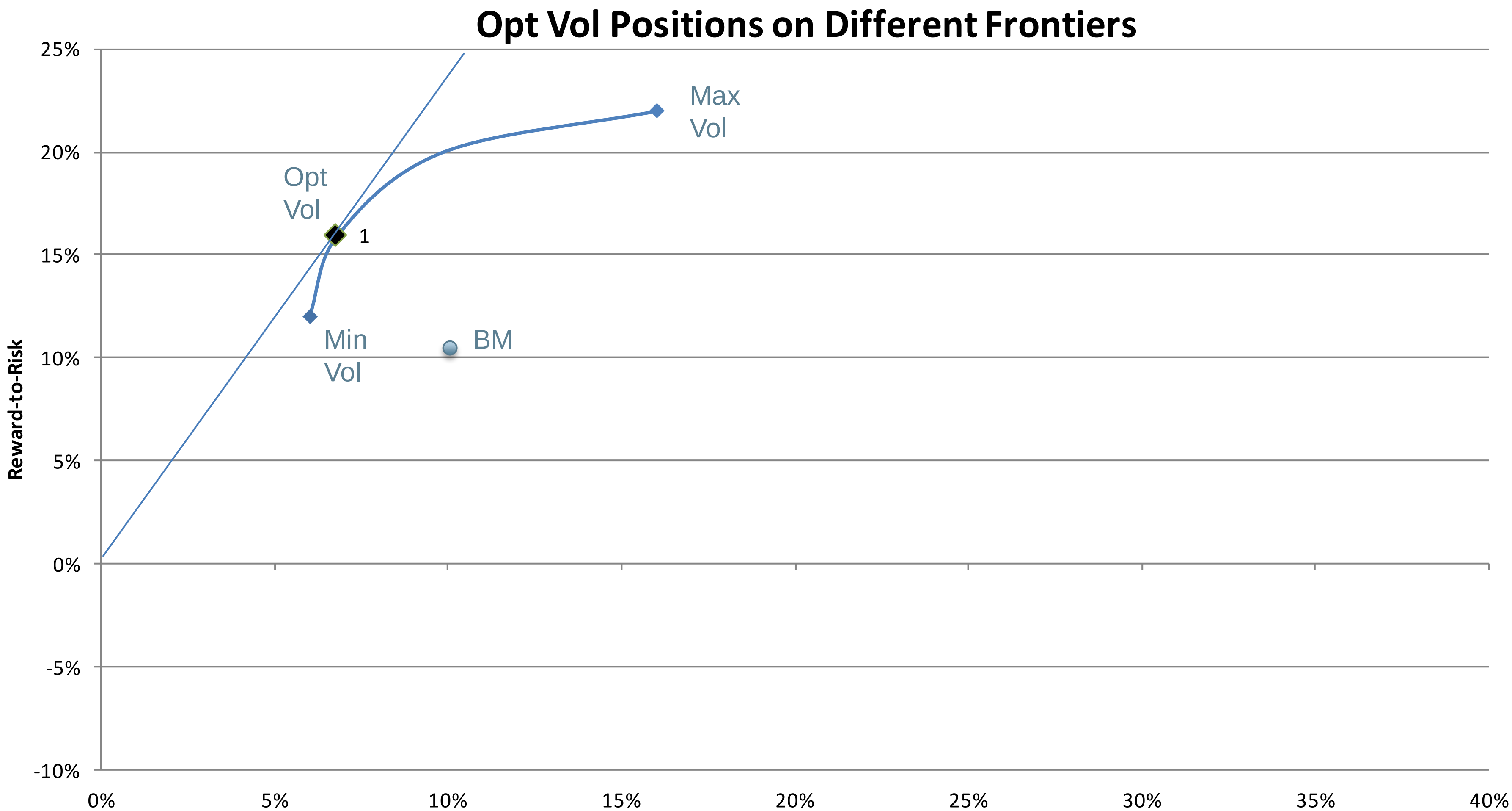


Frontiers Depend on Recent Risk and Return Market Conditions



Sample Efficient Frontier: When Market Risk is Low and Reward is High

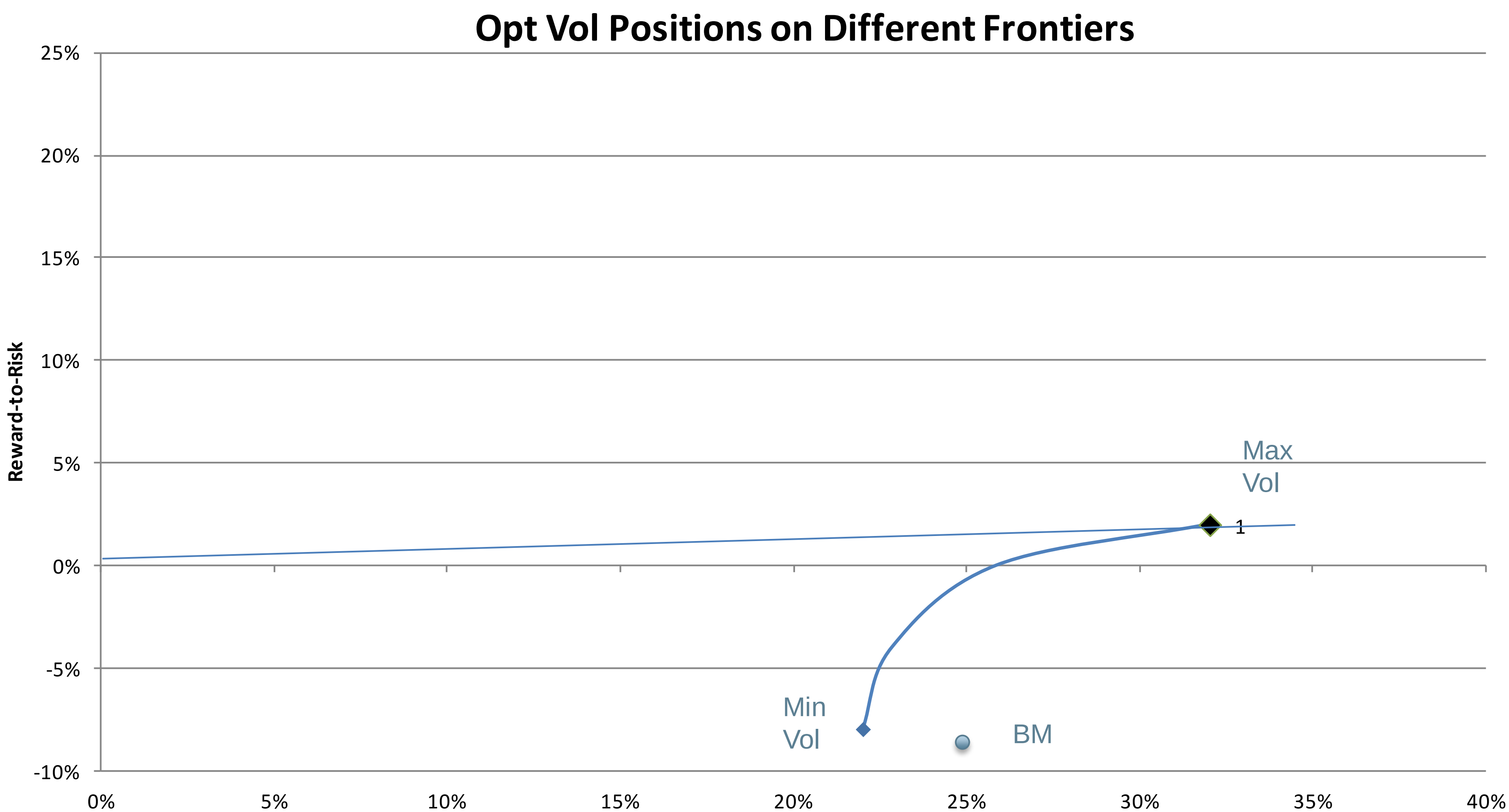
Opt Vol Risk is close to Min Vol Risk. It is only 7% of the way to the Max Vol Risk



Aggressiveness: $= \frac{(\text{Opt Vol risk} - \text{Min Vol risk})}{(\text{Max Vol risk} - \text{Min Vol risk})}$

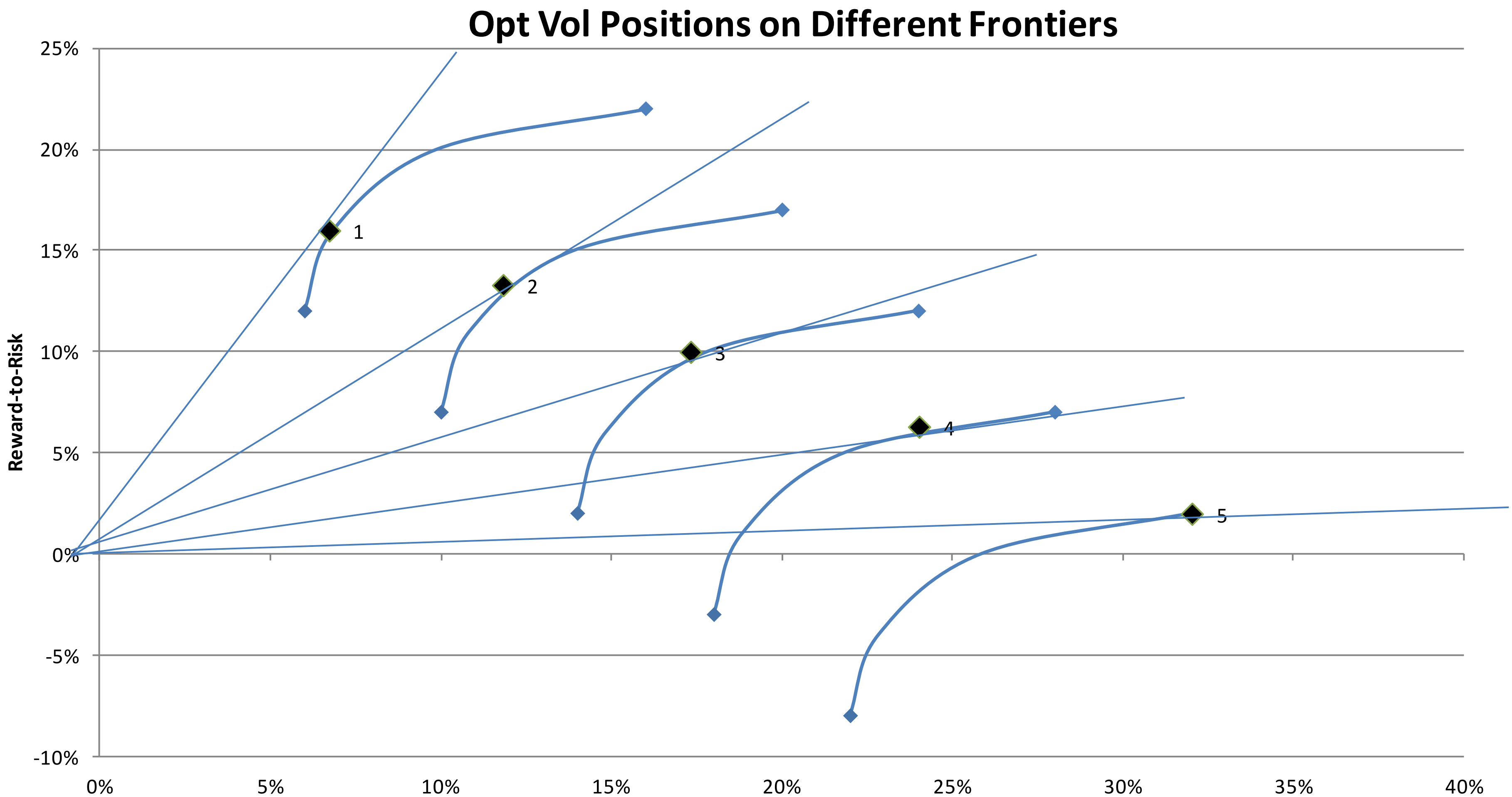
Sample Efficient Frontier: When Market Risk is High and Reward is Low

Opt Vol Risk Equals the Max Vol Risk. It is 100% of the way to through the risk range.

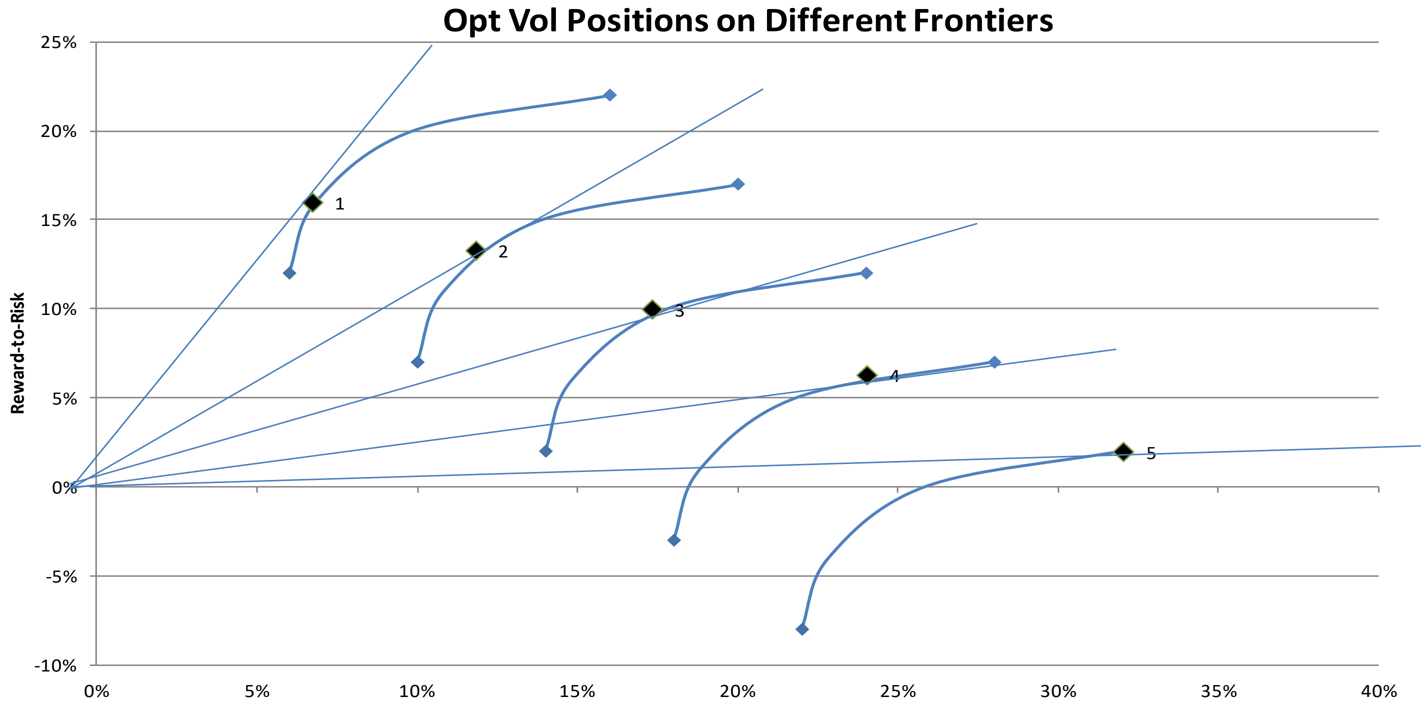


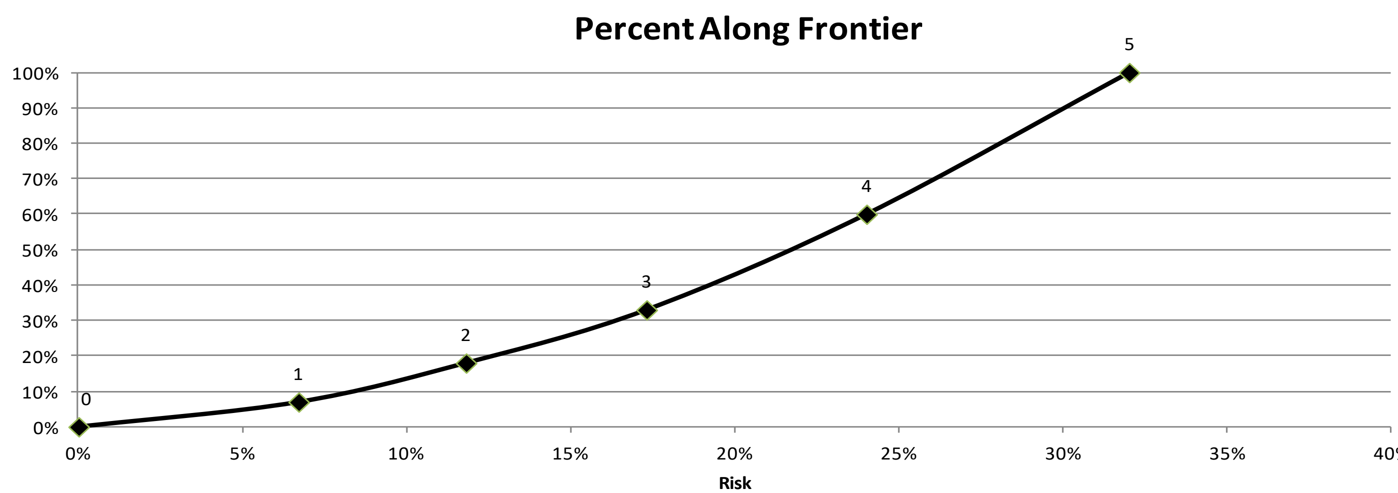
Efficient Frontiers Under Various Market Conditions

Opt Vol moves to higher risk as the frontier shifts. Efficient frontiers can both move and tilt.



Percentage Along Frontier Risk Range as Efficient Frontiers Shift





Function for Determining the Optimal Volatility Index Holdings

A Reward-to-Risk characteristic can be calculated using four factors for each stock in the Selection Universe:

- Volatility (60 months)
- Correlation (60 months)
- Change in Volatility (last 24 months *less* last 60 months)
- Change in Correlation (last 24 months *less* last 60 months)

$$\mathbf{R_{12} = \beta_0 + \beta_1 F_1 + \beta_2 F_2 + \beta_3 F_3 + \beta_4 F_4 + \varepsilon}$$

Where:

$\mathbf{R_{12}}$ = **Vector of returns for stocks over the last 12 months**

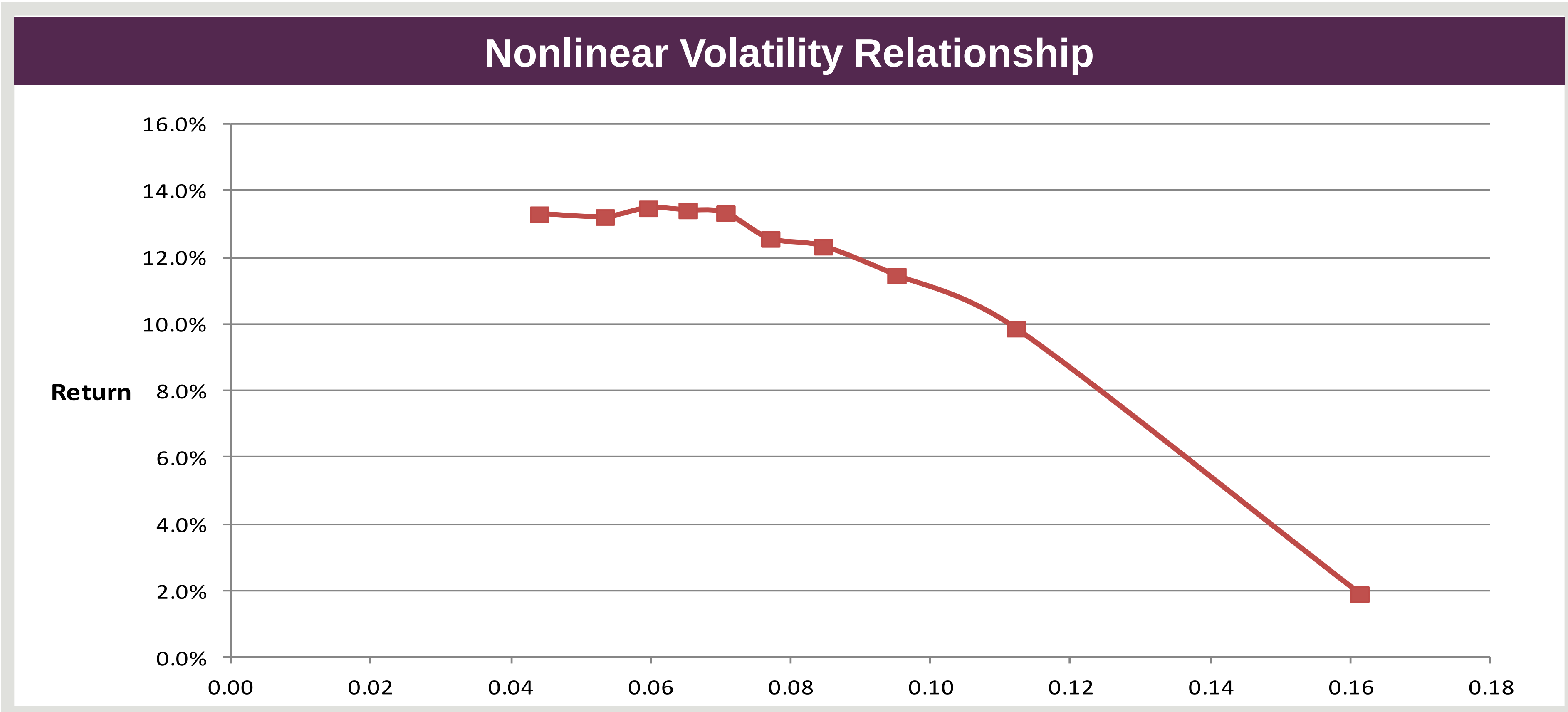
$\mathbf{F_{1-4}}$ = **Vectors of volatility or correlation factors for stocks**

Optimization

Maximize: $$\frac{Expected\ Reward\text{−}to\text{−}\ Risk}{Expected\ Portfolio\ Risk} = \frac{\mathrm{E(RR)}}{\mathrm{E(PR)}}$$

Optimal Volatility Increases Risk Dynamically Based on Market Conditions

- Estimated based on 4 factors



$$Max:\left(\frac{(E.return)}{(E.risk)}=\frac{(x'\cdot Er)}{(\sqrt{(x'\cdot COV\cdot x)}}\right)$$

Optimal Volatility Index Construction: GLCOV Index by S&P

Selection Universe

- Constituents of the Standard and Poor's 500 index.
- Market capitalization of 5 USD billion or more
- Annual dollar value traded to float adjusted cap > 1.0
- Minimum of 250,000 shares traded in prior 6 months

Constraints

- Sector constraints:
  - +/- 10 % relative to capitalization weighted sectors
- Stock upper limits:
  - smaller of 3 % or 10x market weight
- Lower limit of 0% on all positions (no short selling)
- Weights in the portfolio must sum to 100%

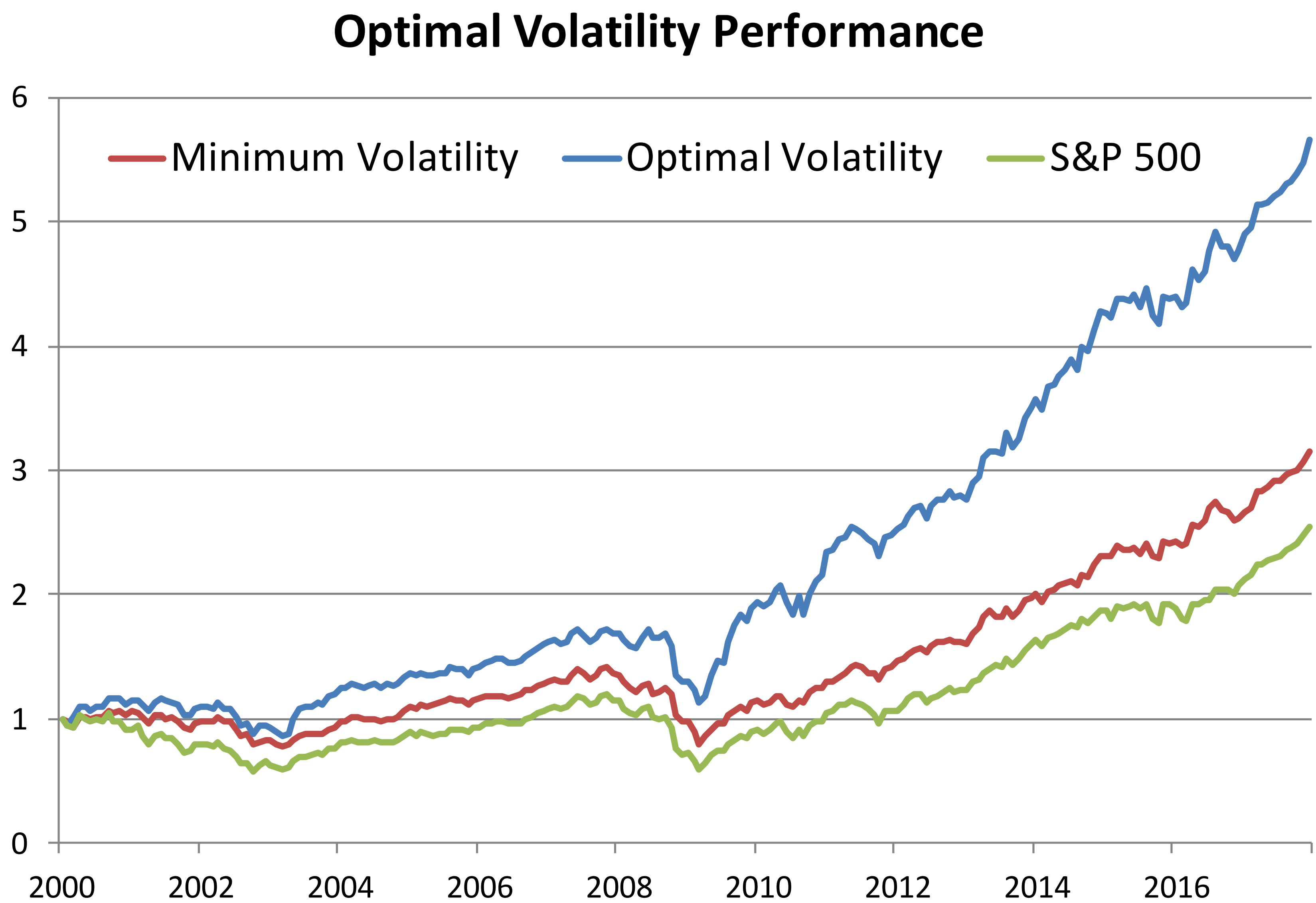
Index Construction and Performance Results

- Index is rebalanced quarterly based on Optimal Volatility solution
- Stocks must be members of updated quarterly S&P 500
- S&P 500 calculates performance of GLCOV Index

Results:

2000 - 2017	S&P 500	Minimum Volatility	Optimal Volatility
Return	5.4%	6.6%	10.2%
Risk (Std. Dev.)	14.5%	11.1%	13.0%
Risk / S&P 500 Risk	100%	77%	90%
Return / Risk	37%	59%	78%
Beta	100%	70%	81%

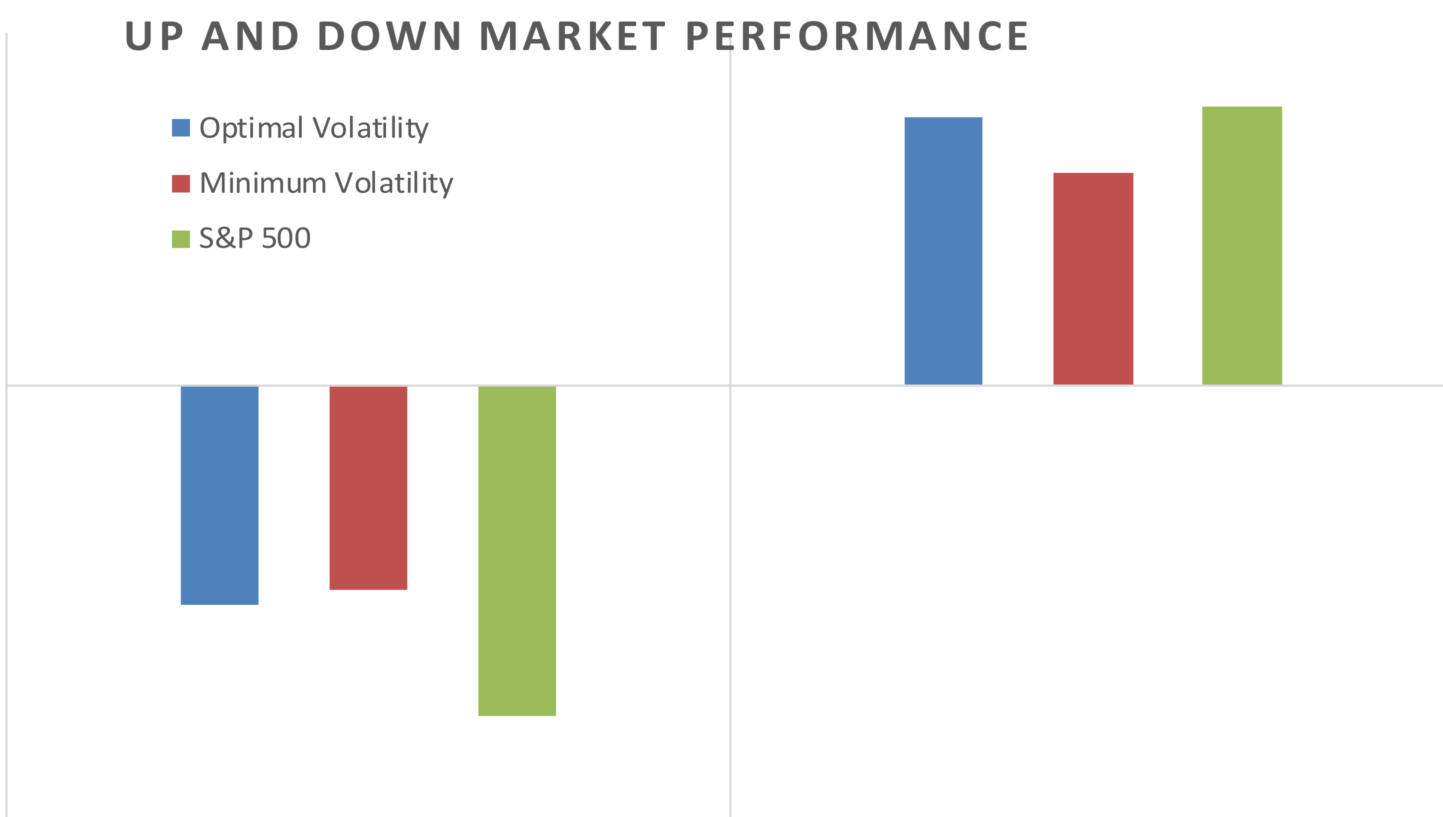
Performance Comparison



Performance in Up vs. Down Markets is Participation Ratio Difference - PRD

2000 - 2017	S&P 500	Minimum Volatility	Optimal Volatility
Down Markets	-3.8%	-2.3%	-2.5%
Up Markets	3.2%	2.4%	3.1%
Down Capture	100%	62%	66%
Up Capture	100%	76%	96%
PRD (Up – Down Capture)	0%	14%	30%

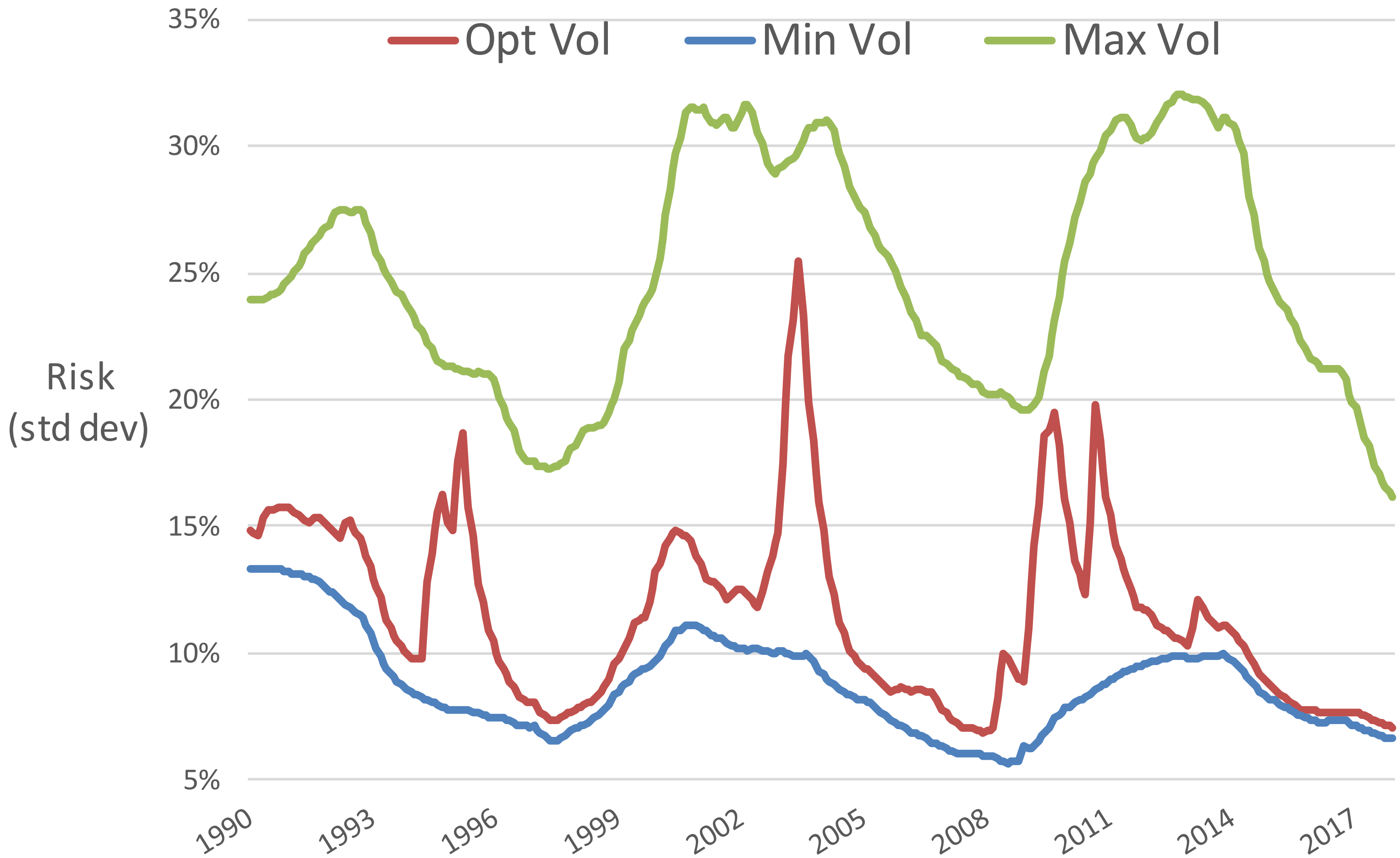
Up and Down Market Capture



	Down Markets	Up Markets
Optimal Volatility	-2.5%	3.1%
Minimum Volatility	-2.3%	2.4%
S&P 500	-3.8%	3.2%

Dynamic Volatility

- Optimal Volatility index often has lower exposure to market risk than S&P 500
- Risk is typically closer to that of the Minimum Volatility strategy
- Max Vol is constructed by maximizing portfolio beta using the same constraints

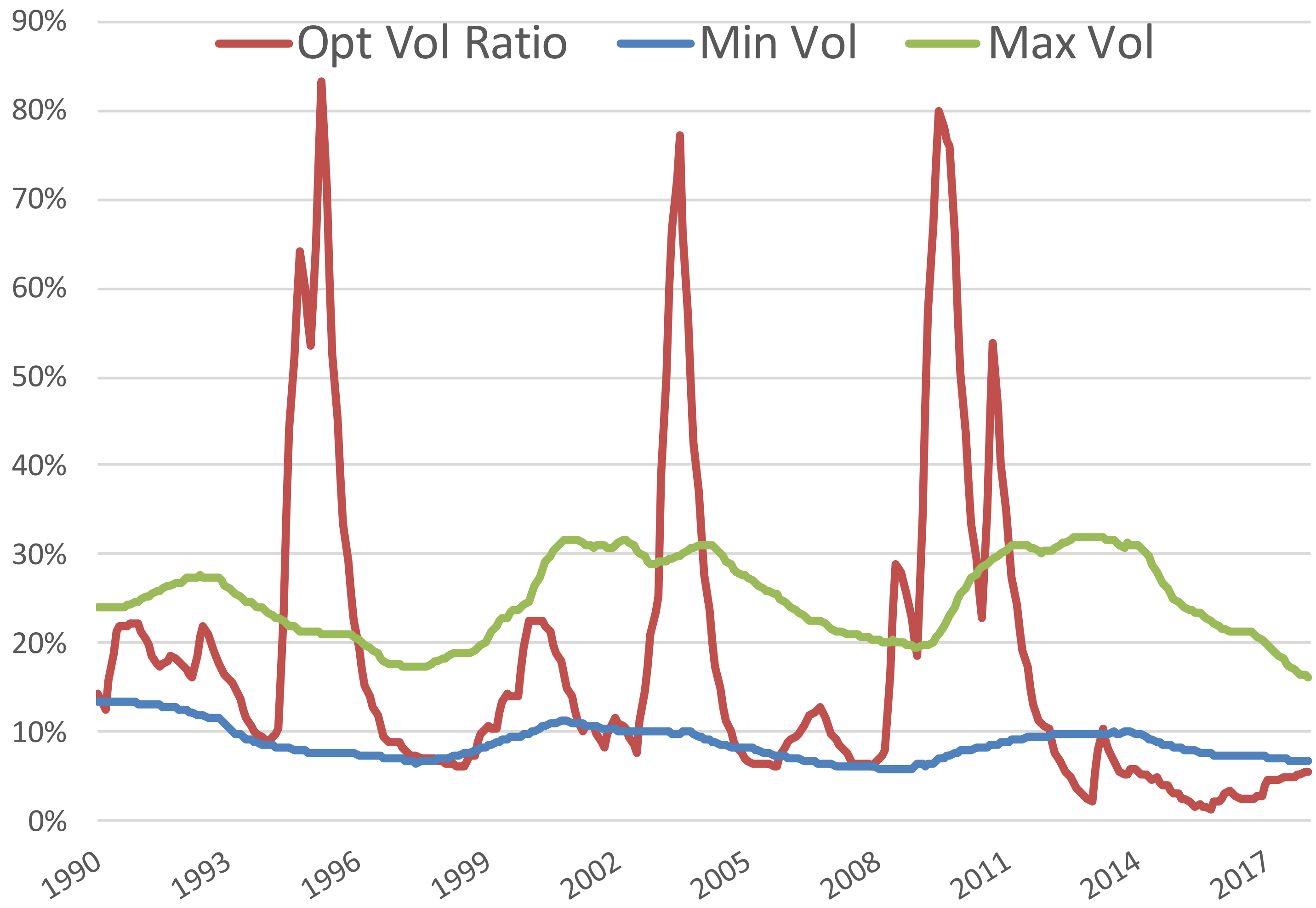


Heartbeat: Optimal Volatility Aggressiveness Ratio in High-Low Volatility Range

$$\text{Aggressiveness:} \quad = \frac{(\text{Opt Vol risk} - \text{Min Vol risk})}{(\text{Max Vol risk} - \text{Min Vol risk})}$$

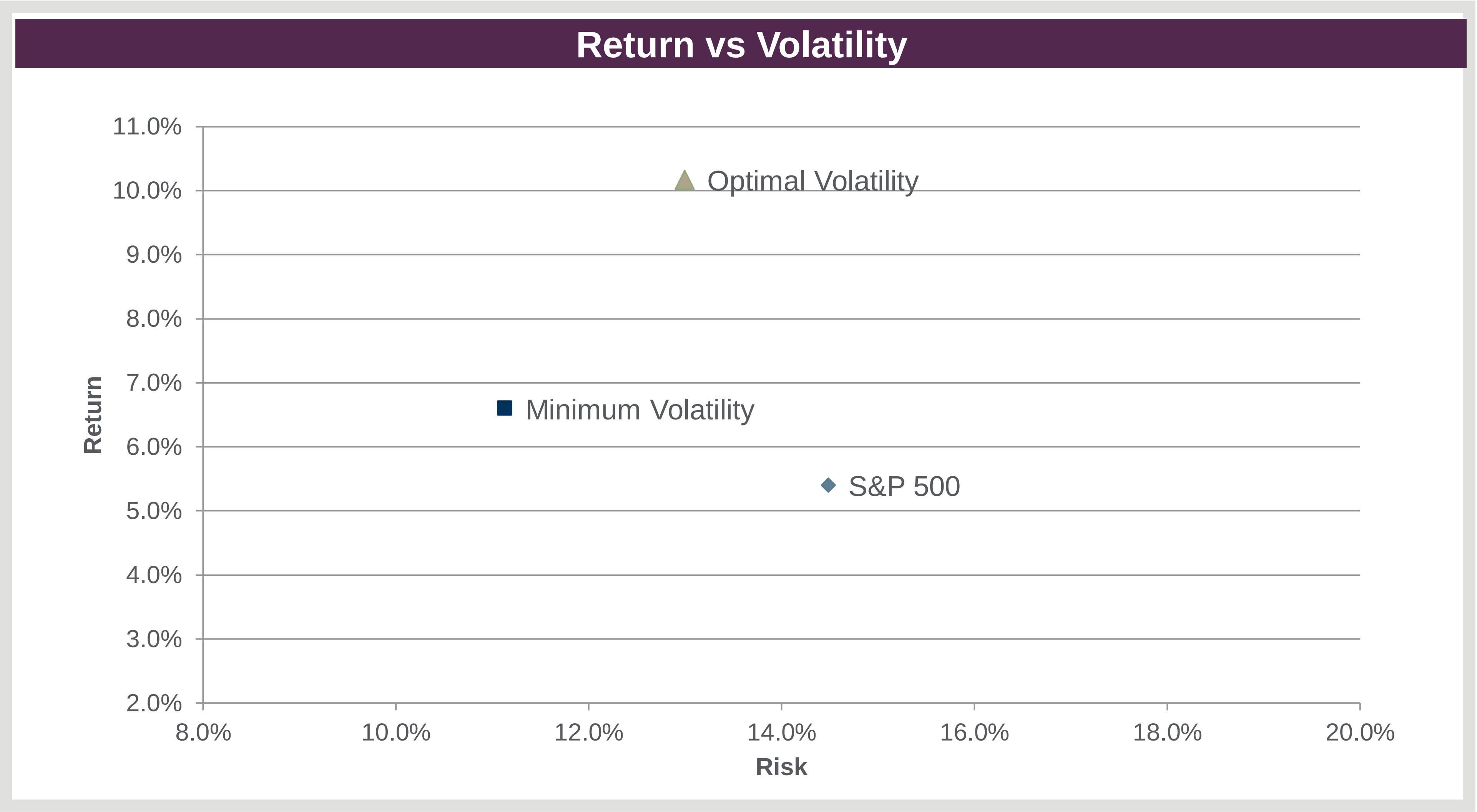
Aggressive Portfolio

Conservative Portfolio



Optimal Volatility Increases Risk Tactically Based on Market Conditions

- Optimal Volatility portfolio has risk lower than the market
- Higher than market return suggest risk exposure is increase only when there is high reward



Optimal Volatility Summary and Investigation Directions

- Price Information: Returns, Correlations, and Volatilities
- Systematic optimization based on market reward
- Dynamically moves to higher risk when it is rewarded
- Defensive most of the time

Where does Optimal Volatility work?

- Sector Applications
- Asset Allocation

Appendix

Notes:

- The optimal volatility portfolio is created to maximize the ratio of reward-to-risk
- Measure the market reward to four risk factors over the last 12 months
- Single number expresses the expected reward-to-risk for each stock
- Highest reward to risk portfolio combination is selected using an optimizer
- Optimization is similar to finding a maximum Sharpe ratio portfolio
- Expected reward-to-risk is used for the numerator (return axis)
- Portfolio volatility over the last 60 months is used for the denominator (risk axis)

- Efficient Frontier changes with market conditions
- Cannot predict when the optimal volatility portfolio will take on high risk or low risk
- When market volatility is low, optimal volatility portfolio generally will be low volatility
- When does volatility of portfolio generally increase?
    - Market volatility has been high recently
    - Market is stabilizing
    - Higher risk stocks demonstrate greater reward-to-risk

  Generally, Optimal volatility portfolio will then become more aggressive

- There is no method to time or predict these shifts
- Market information related to price determines shifts: returns, correlations, and risk