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# Stress Testing of Portfolios

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- Methodology
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  - Stressed Betas
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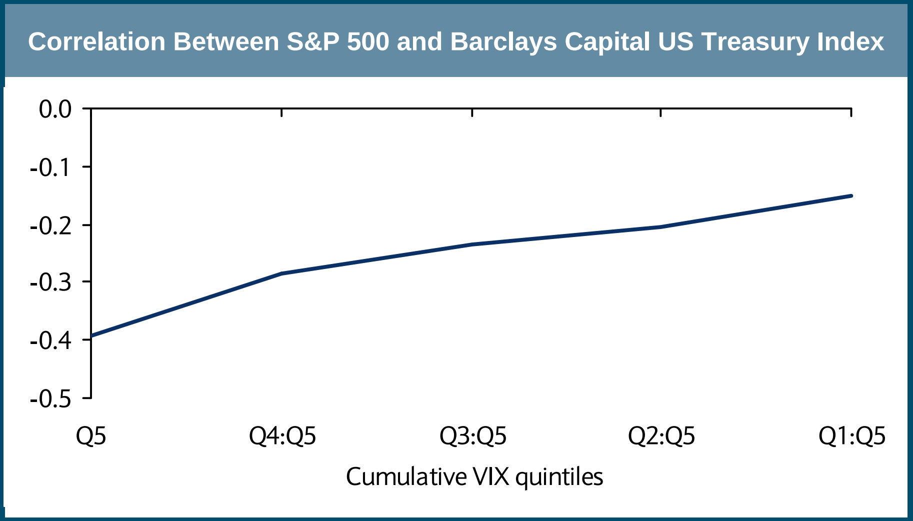
- Conclusions
- Future Extensions

# Motivation

- Scenario analysis: typically views on a small set of market variables
  - Need to estimate the relationships among all market variables under specified scenario
  - Use a *Covariance Matrix* to estimate scenario returns of other variables
  - Under ***stressed scenarios***
    - Current matrix is unlikely to represent the potential behavior of market variables
      - Breakdowns in correlations
      - Jumps in volatilities
      - Dynamic betas
      - Asymmetric behavior




Source: Barclays Capital

- Can we incorporate these characteristics into a simple and robust methodology?

# Methodology Description

## A simple and generic methodology that addresses these issues and provides intuitive results

**Step 1**

- Estimate the correlations by dynamically weighting historical data
  - Distance function between the scenario and each historical observation
  - Assign a weight to each observation based on that distance
  - Compute the weighted correlation matrix
  - Limited by historical data

Scenario:

-12% US equities

| Month | Weight | US Equity | UK Equity | US Credit Spread | ... |
|---|---|---|---|---|---|
| Aug-98 | 2.8% | -12.6% | -12.5% | 47.7% | |
| Feb-09 | 2.5% | -10.9% | -4.8% | -0.9% | |
| Aug-90 | 2.1% | -9.9% | -7.0% | 1.7% | |
| Nov-08 | 2.0% | -9.6% | -3.8% | 19.2% | |
| Jun-08 | 1.6% | -8.6% | -8.4% | 11.4% | |
| Jul-02 | 1.5% | -8.0% | -10.0% | 21.5% | |
| Sep-01 | 1.5% | -7.9% | -12.2% | 28.0% | |
| Jan-09 | 1.4% | -7.5% | -2.8% | -17.6% | |
| Jan-90 | 1.3% | -7.0% | -3.5% | -2.8% | |
| Sep-02 | 1.3% | -7.0% | -9.1% | 8.7% | |
| ⋮ | | | | | |

Source: Barclays Capital

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# Methodology Description

| | |
|---|---|
| **Step 1** | • Estimate the correlations by dynamically weighting historical data |
| **Step 2** | • Update volatilities<br>• Stressed volatility is a function of the size of the shock<br>• Not limited by historical data |
| **Step 3** | • Compute the covariance matrix from the above<br>• Further manipulate this matrix if needed |
| **Step 4** | • Perform scenario analysis using this covariance matrix |

→ The procedure delivers a different covariance matrix for each scenario

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# Alternative Approaches

- Construct a custom covariance matrix for each scenario
  - Preserving the positive definiteness of the matrix
  - Make them consistent across scenarios
  - Hard to generalize

- Move sample covariance matrix towards a target
  - Mixture of distributions/regime shift/latent factors
  - Hard to incorporate complex dynamics

- Use a matrix from a historical crisis episode
  - Results depend on the very specific episode chosen
  - Possible for a restricted set of factors

- Search for risk factors with more stable conditional correlations

# Portfolio I – US Multi-Asset Class

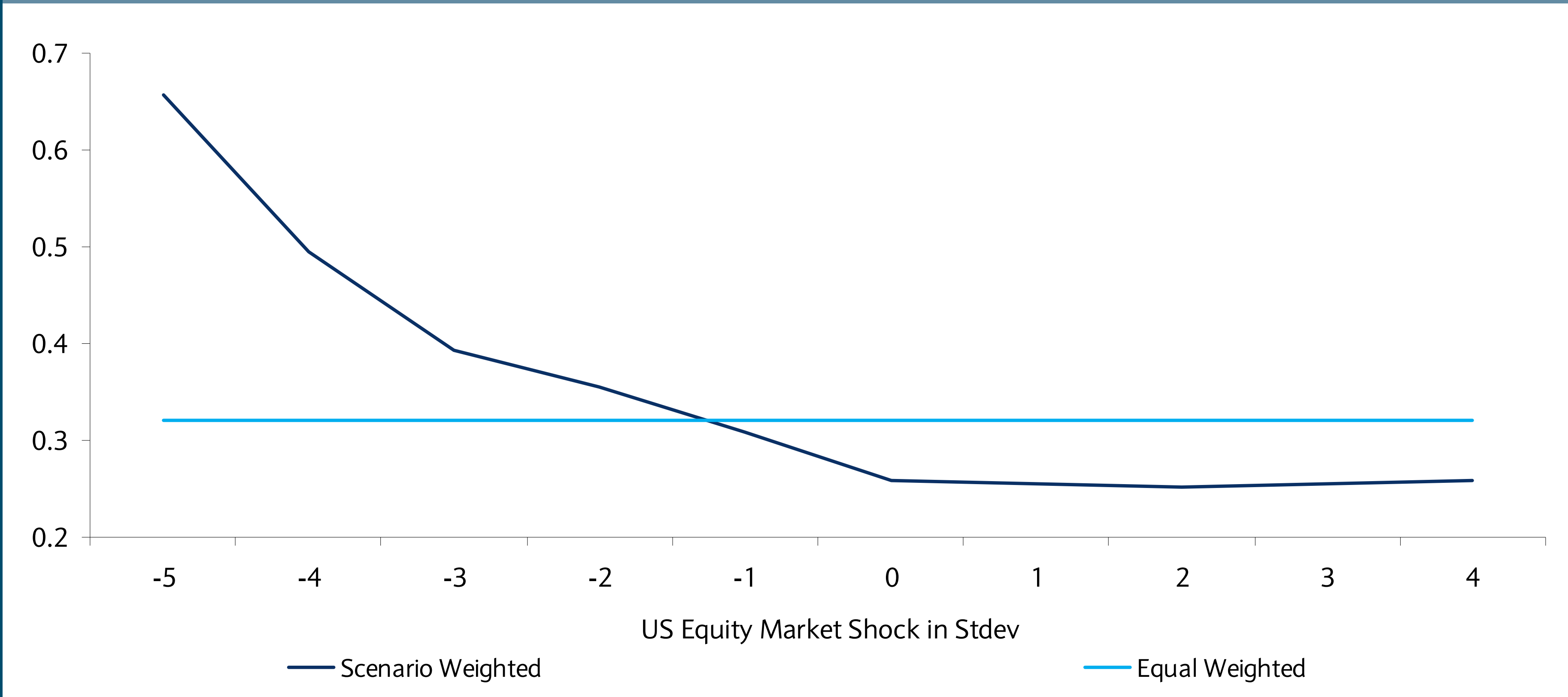
**PORTFOLIO I: Multi-asset class US portfolio with equal weights in**

- Barclays Capital US Treasury Index
- Barclays Capital US Credit Index
- Barclays Capital US HY Caa Index
- S&P 500 Index
- Barclays Capital US Commodity Index

- Data Period: 1990-2011
- Using 10 different scenarios on the US Equity market (shocks from -5 to +4 stdev)
  - Compute the conditional covariance matrix for each scenario
  - Analyze the portfolio statistics conditional on each scenario

# Portfolio I – Correlations

**Average Absolute Correlation across Factors**

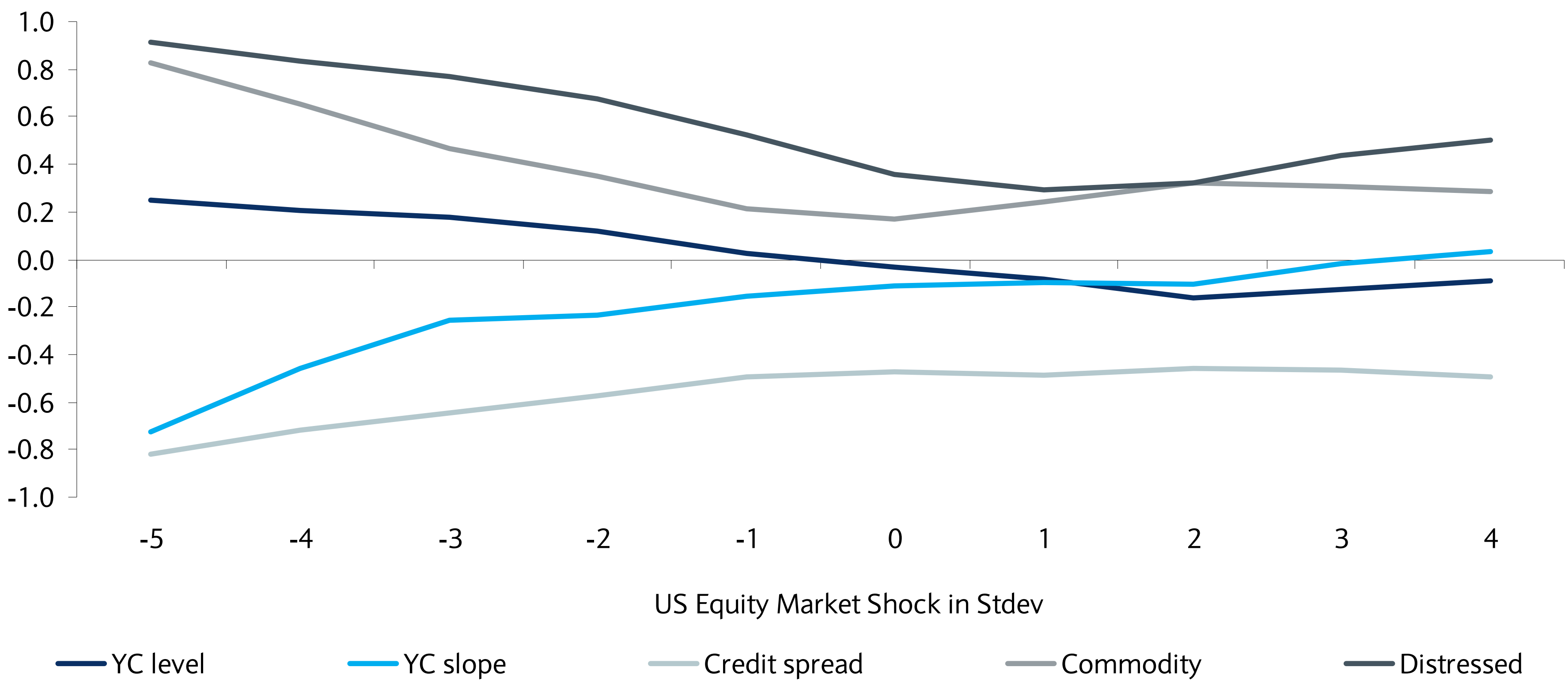



Source: Barclays Capital

- Flight-to-quality effect across different asset classes
- Significant asymmetrical behavior

# Portfolio I – Correlations

**Correlation between US Equity Market and Other Factors**

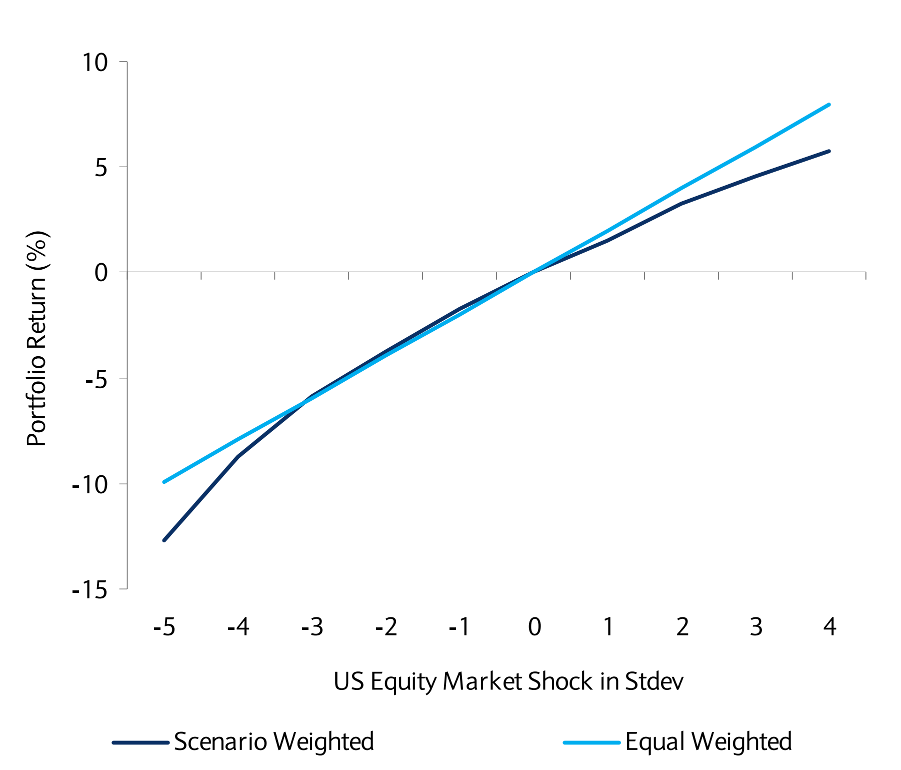



Source: Barclays Capital

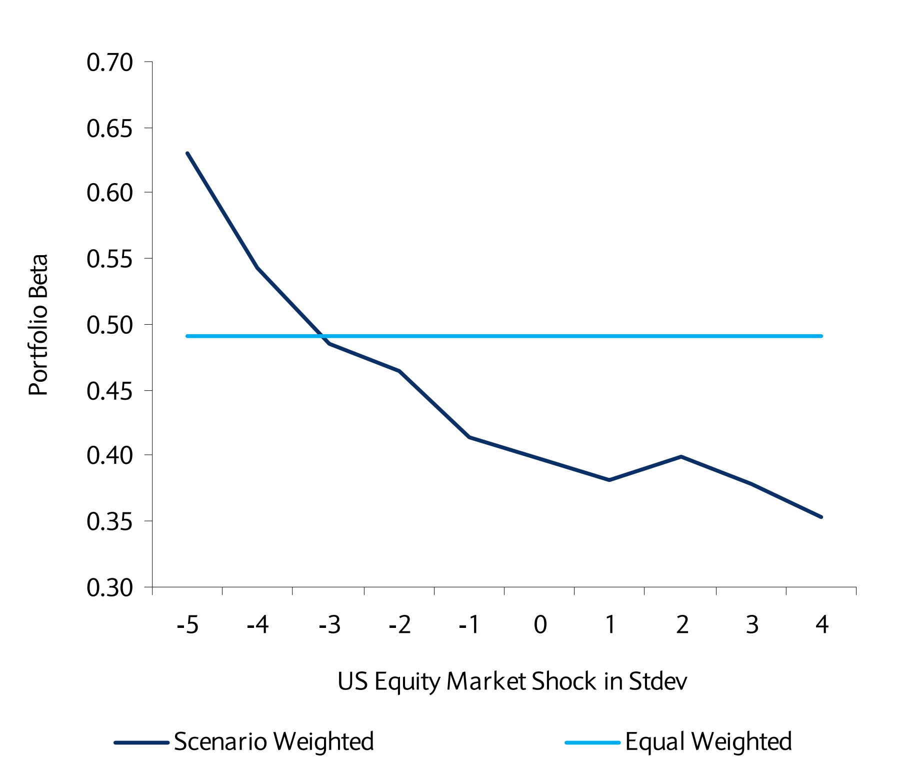
- Varying behavior across different factors
- Correlations move to 1 under the extreme scenario

# Portfolio I – Sensitivity to the Shock

## Estimated Portfolio Return




## Estimated Portfolio Beta

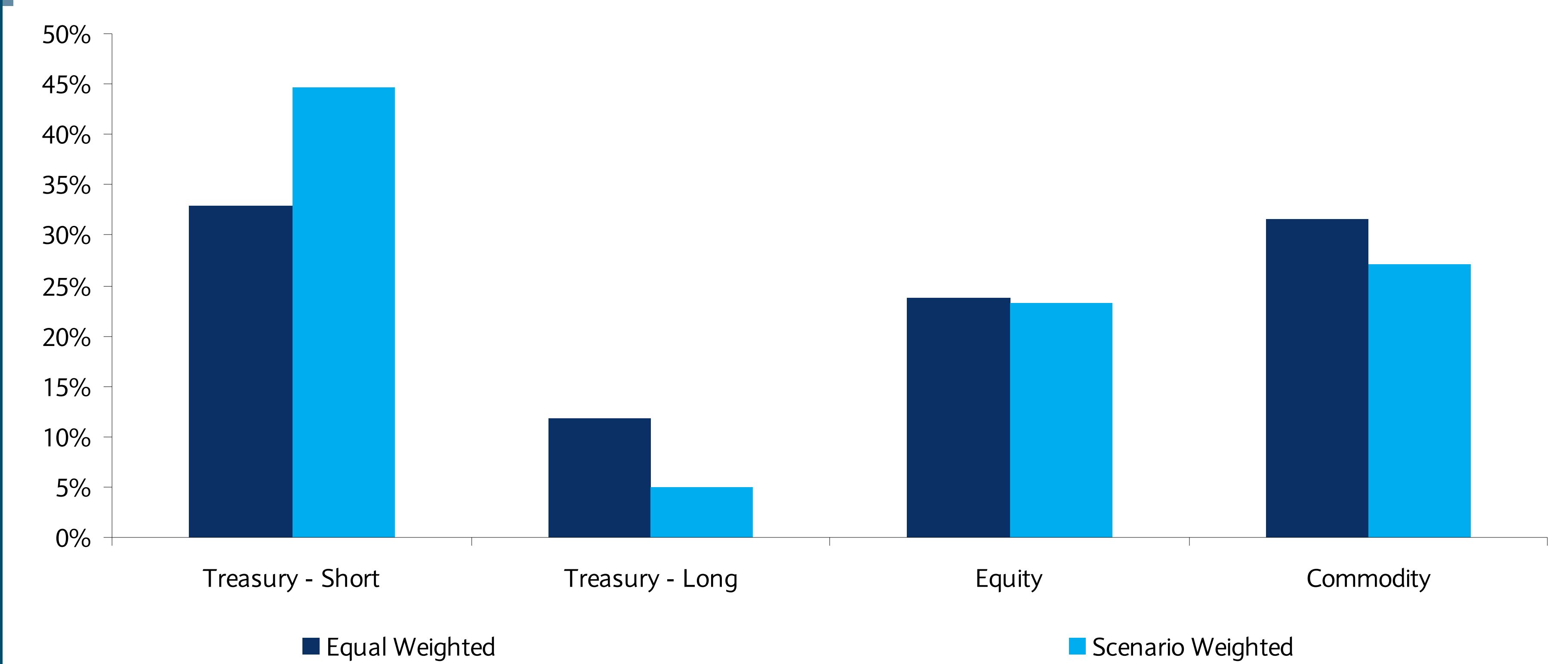



Source: Barclays Capital

- Portfolio return is non-linear (due to dynamic correlations and volatilities)
  - Hedge ratio depends on the size of the move
- Reverse stress testing
  - How large of an equity shock would result in a 10% loss in the portfolio?

# Portfolio I – Minimum Variance Allocation

Minimum Variance Allocation to Underlying Indices




Source: Barclays Capital

- Scenario weighted: -5 stdev. US equity shock
- Using the correlation matrix – “most diversified portfolio”, long-only positions, 5% minimum weight
- Increasing allocation to short Treasuries

# Portfolio I – Further Conditioning on the Matrix

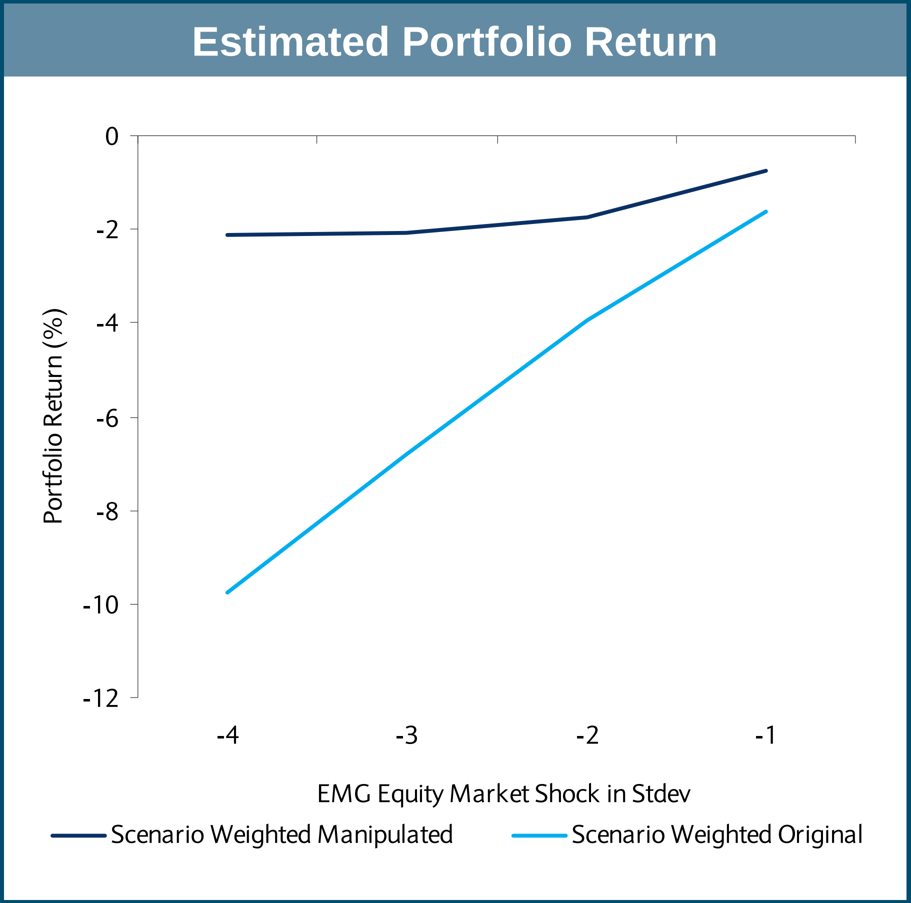
- Scenario: Turmoil in Middle East – North Africa
  - Oil (commodity) prices increase
  - EMG equities in distress

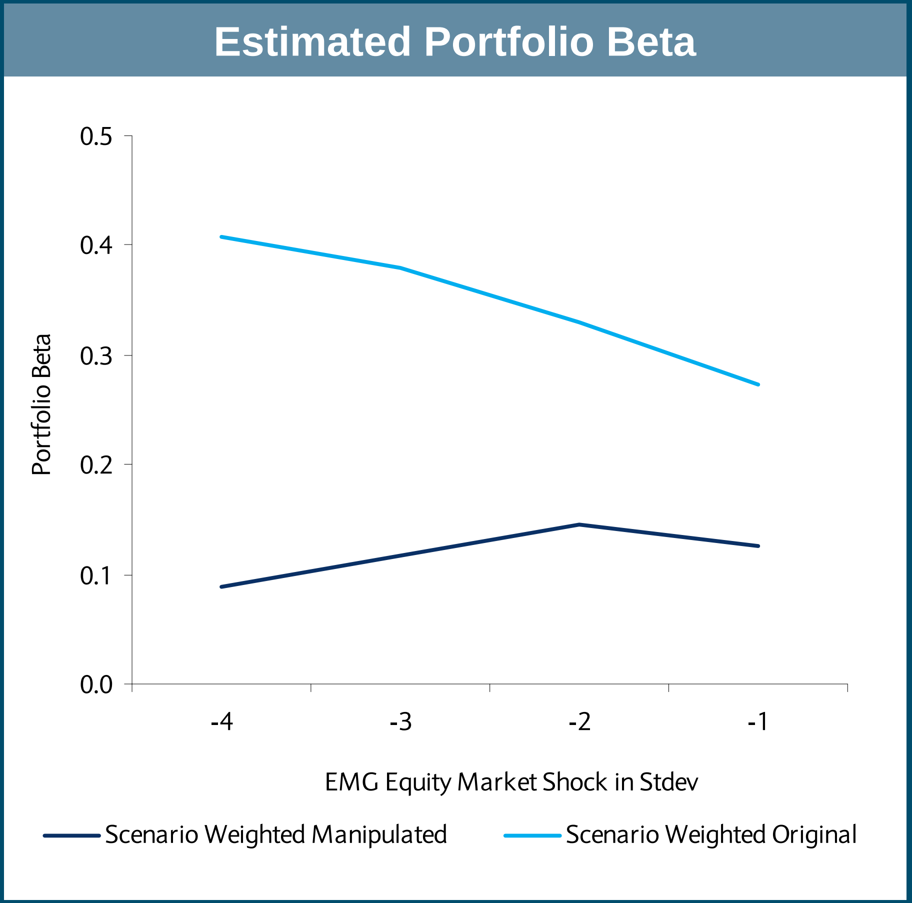
- How can we construct an appropriate matrix for this scenario?

  - Option 1
    - Construct a multi-variate scenario-weighted correlation matrix
    - Problem: Limited historical evidence for this scenario

  - Option 2
    - Construct a stressed matrix consistent with the univariate EMG equity shock
      - When equity markets plummet, commodity prices tend to follow
    - Manipulate the matrix to imply an appropriate rise in commodity prices

# Portfolio I – Further Conditioning on the Matrix




Source: Barclays Capital

- Significant difference between the two matrices
- Commodity component of the portfolio acts as a diversifier under this specific scenario

# Portfolio II – Global Equity

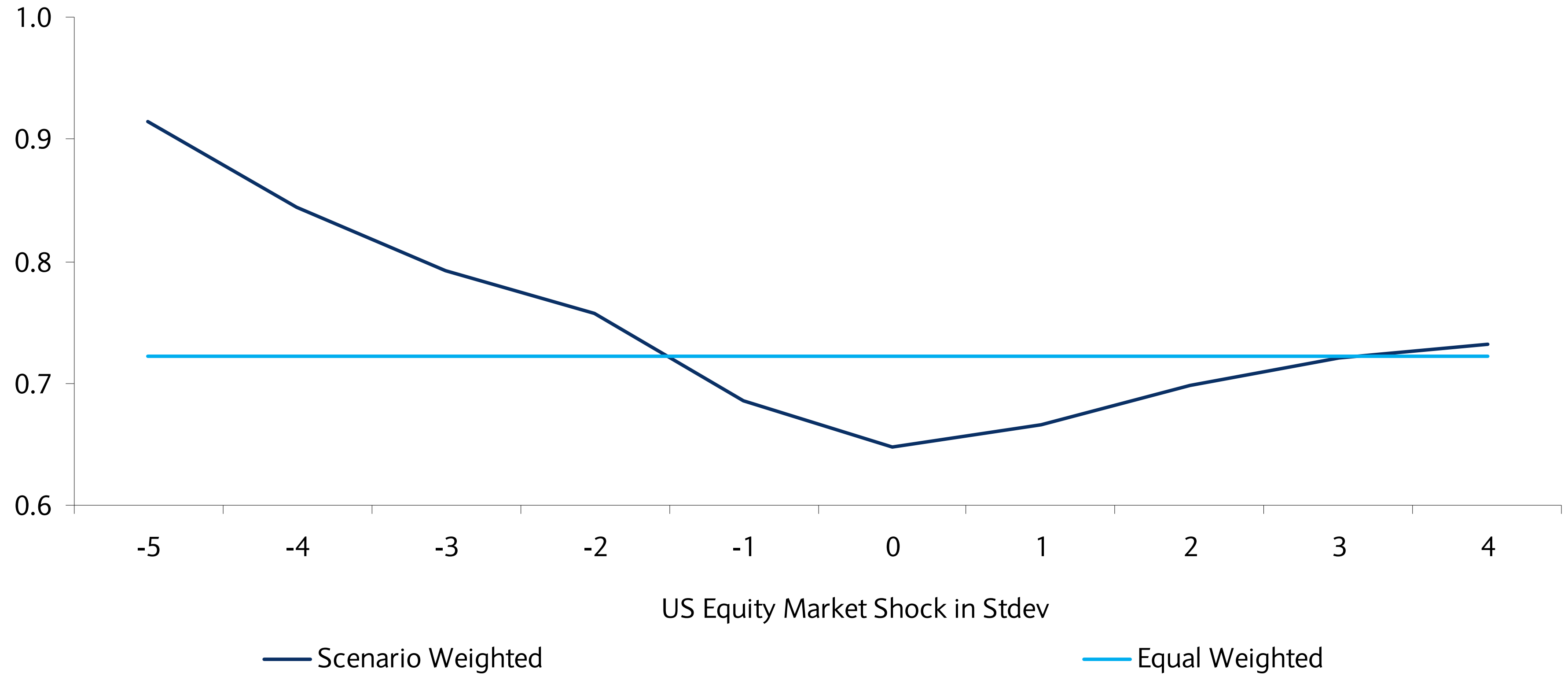
**PORTFOLIO II: Global equity portfolio with equal weights in**

- S&P 500 Index
- FTSE-UK 100 Index
- DJ EURO STOXX 50 Index
- NIKKEI 225 Index
- MSCI ASIA ex-JAPAN Index
- MSCI Emerging Markets Index

- Data Period: 1990-2011
- Using 10 different scenarios on the US Equity market (shocks from -5 to +4 stdev)
  - Compute the conditional covariance matrix for each scenario
  - Analyze the portfolio statistics conditional on each scenario

# Portfolio II – Correlations

**Average Absolute Correlation across Factors**

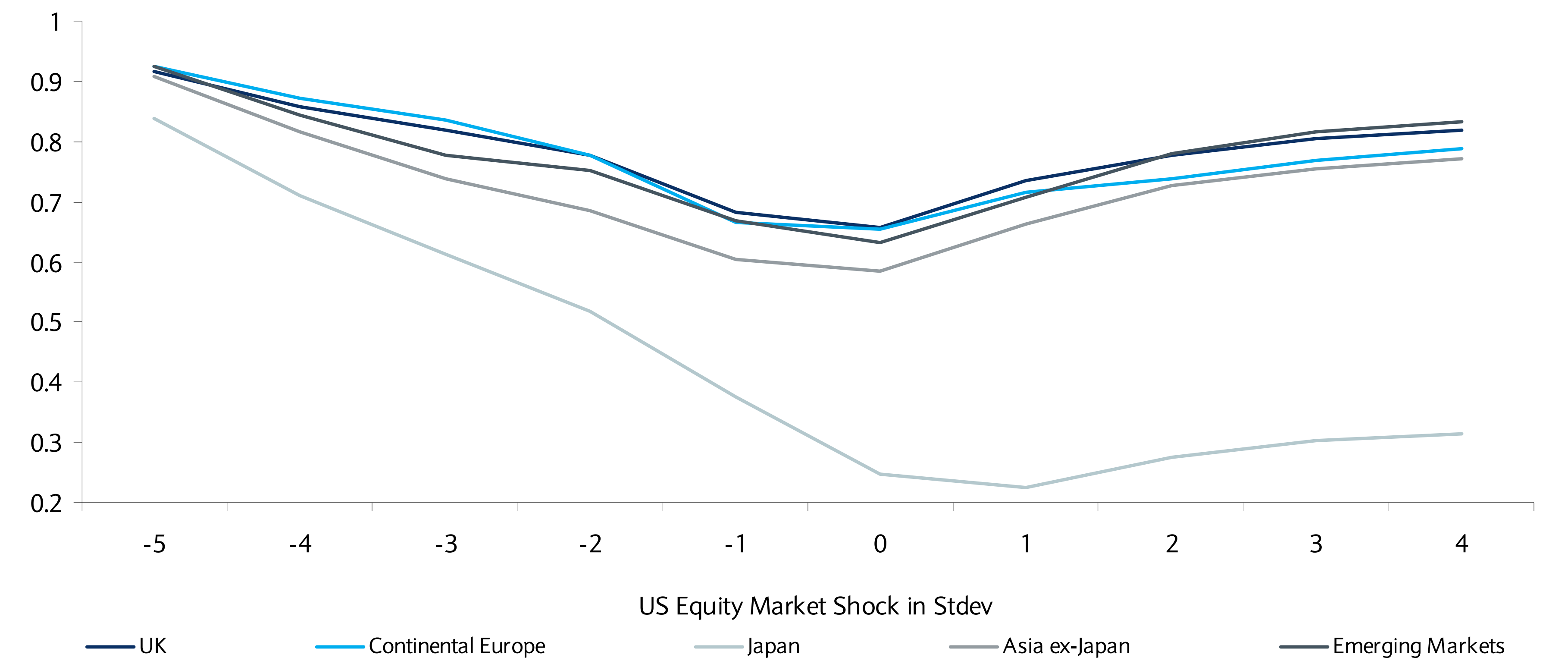



Source: Barclays Capital

- Flight-to-quality effect across different regions within the same asset class

# Portfolio II – Correlations

Correlation between the US Equity Market and Other Regions




Source: Barclays Capital

- Still asymmetrical, but less pronounced
- Japan exhibits distinct behavior

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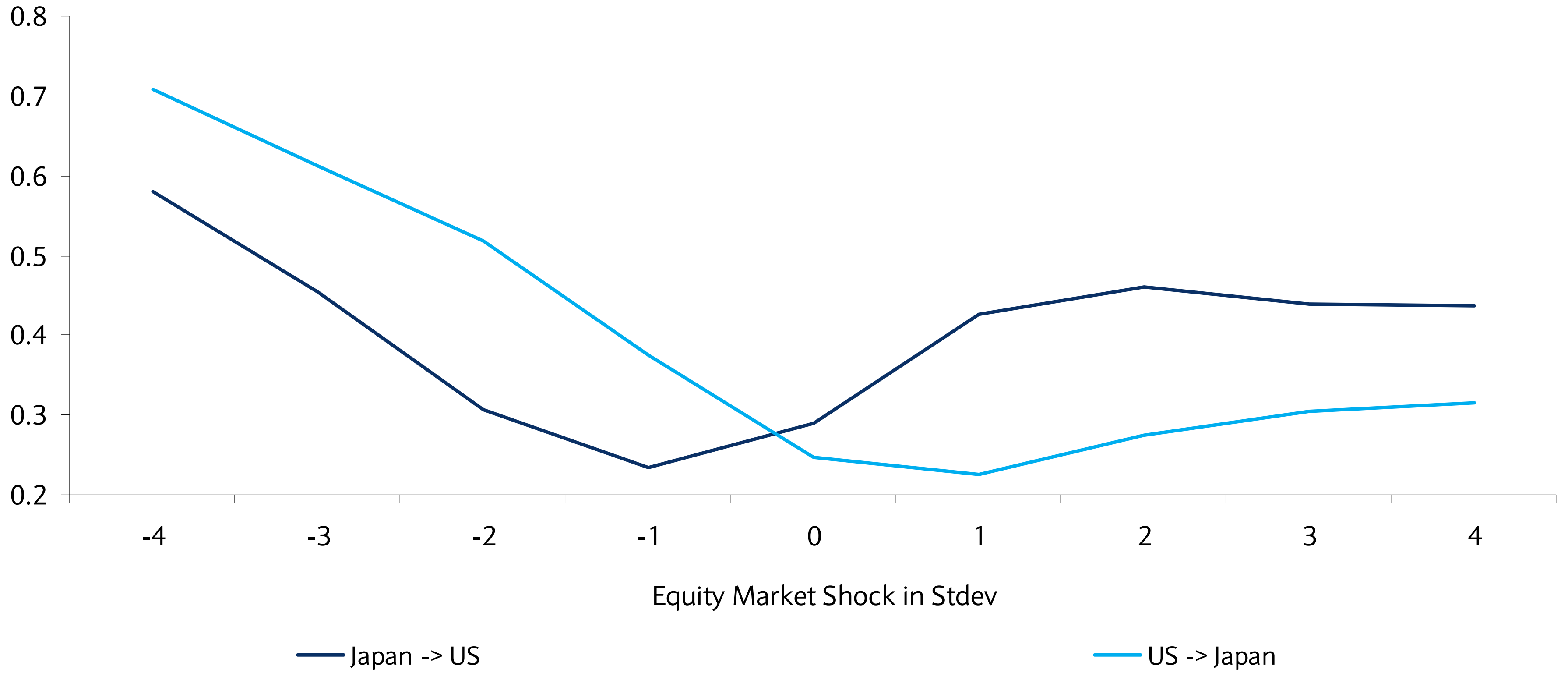
# Portfolio II – Correlations

- The impact of a shock in the US equity market on the Japanese equities versus the impact of a shock in the Japanese equity market on the US equities
- Another type of asymmetry that cannot be captured by the static model

**The Impact of Shocks in the US and Japanese EQ Markets to Each Other**

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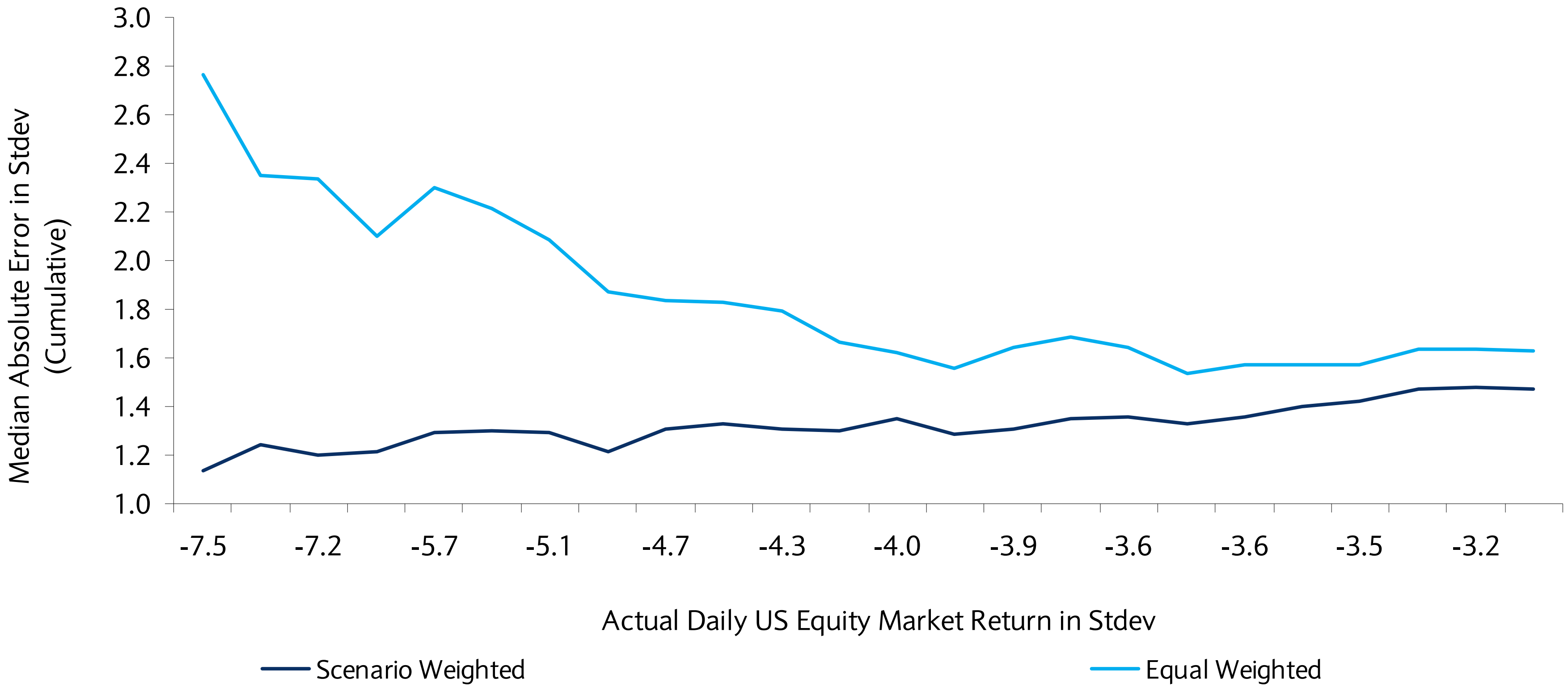
# Out-of-Sample Testing

- Daily data on 10 factors from
  - FX, yield curve, equity, commodity, credit
- Data period: 1987-2011
- For all days starting from 2000 where US EQ < -3 stdev (24 episodes)
  - Assume perfect foresight on US equity market return
  - Estimate all factor realizations using scenario versus equal weighted matrix
- Absolute error for each estimate
  - |estimate – actual realization|/stdev
- Compare the median absolute error between the two matrices

# Out-of-Sample Testing

**Median Absolute Error Using Scenario vs. Equal Weighted Matrix**



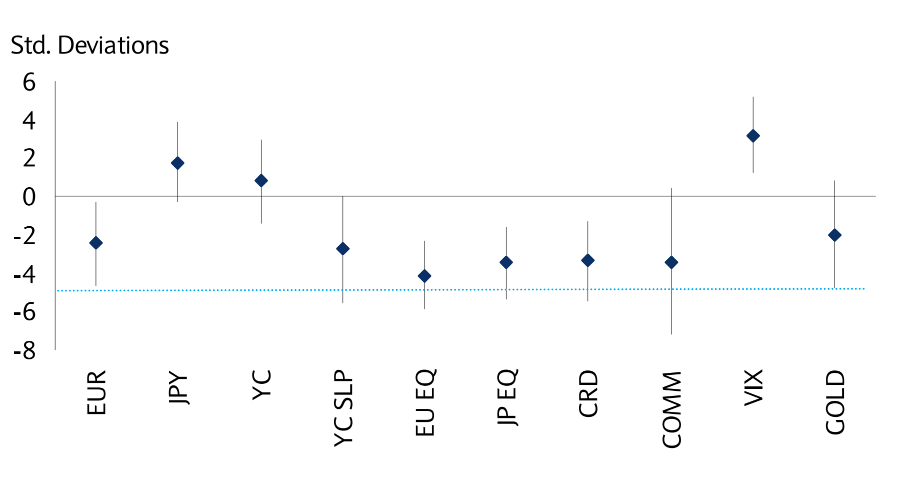

Source: Barclays Capital

- Larger differences as we move to the extremes
- Differences are statistically significant at 5% level

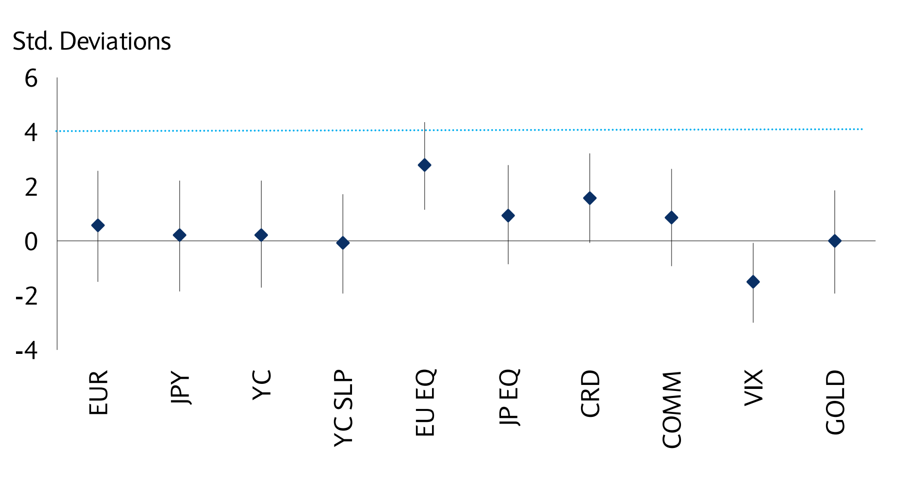
# Confidence Intervals for the Forecasts

- Same example: -5 vs. +4 stdev. shock in the US equity market

**The Impact of a -5 Stdev. Move in US Equity**




**The Impact of a +4 Stdev. Move in US Equity**




Source: Barclays Capital

- Asymmetry of betas
  - On the upside, many cannot be distinguished from zero
- Efficacy of different factors as potential hedges
  - Similar “stressed betas” to equities
  - Very different confidence intervals
  - Potentially very different hedging results

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# Conclusions

- Methodology Highlights
  - Captures increasing correlations and volatilities under distressed conditions
  - Captures asymmetries in the dependence structure
  - Generic solution for all types of scenarios
  - Easy to interpret: Reshuffled exponential weighting

- Methodology Limitations
  - Limited by historical data
  - Might require additional conditioning

# Future Extensions

- Relationship with tail risk
- Upside diversification versus downside concentration
- Asymmetric weighting function
- Incorporating confidence in views
- Implications for portfolio construction
  - Optimal allocations
  - Hedging
  - Diversification

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