MSCI ANNUAL CONFERENCE ON **GLOBAL INVESTING AND RISK MANAGEMENT** WORKSHOP

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STRESS TESTING BEST PRACTICES: EVOLUTION OR REVOLUTION?

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OUTLINE

- Understanding the Shift in Regulatory approach
- Stress Testing Approaches
- Case Study

SHIFT IN REGULATION

- What if: oldest question ever asked in risk management?
- Resurgence of interest after 2008 crisis showed VaR limitations
  - From a polite recommendation in pre-crisis Basel Reg …
  - … to a prescriptive requirement under SCAP, DFAST, CCAR, EBA, BoE, …
- Emerging trend: complementary approaches to risk management

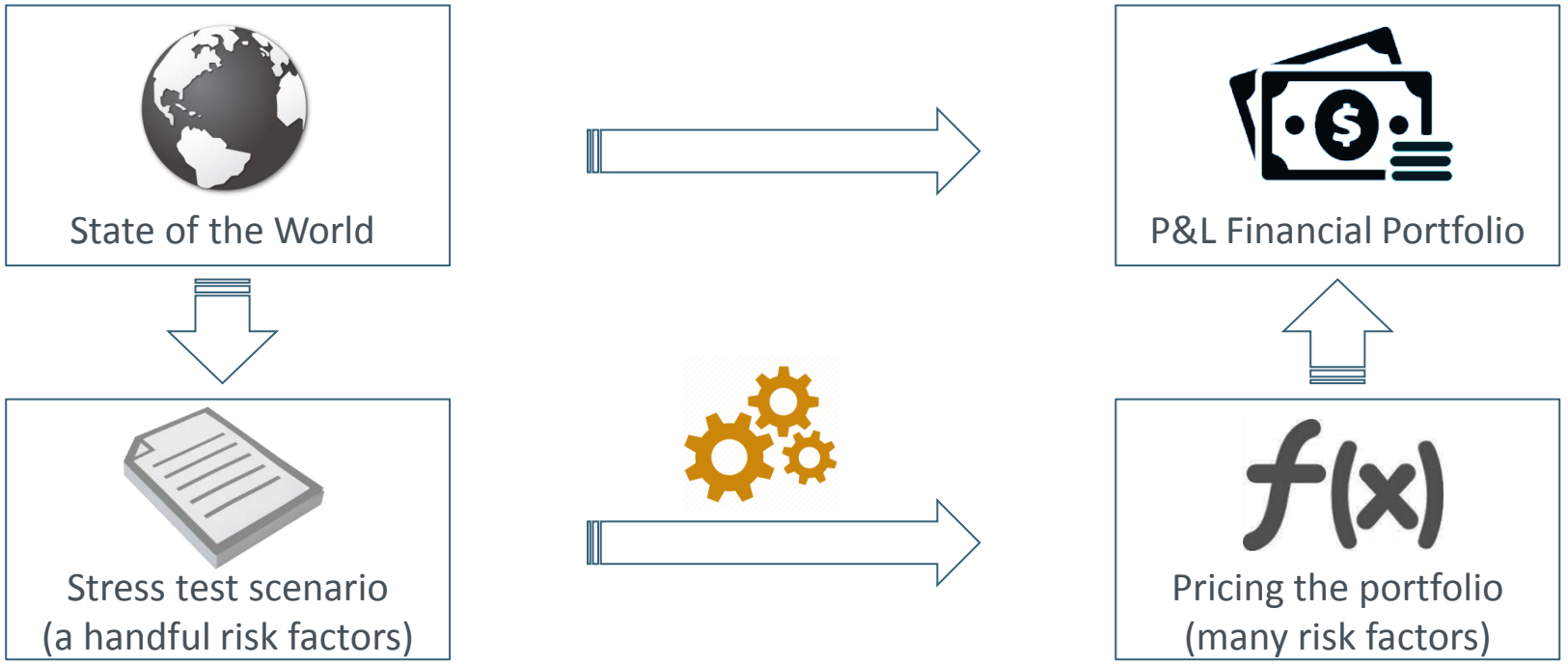
Stress Testing	VaR-Based Risk
Forward looking	Backward looking
Specific (unprecedented events)	Pro-cyclical
Subjective (blind spots)	Objective
Not backtestable	Backtestable
Model risk: propagation	Model risk: probability distribution

HALLMARK OF STRESS TESTING

- Stress Testing doesn’t mean modelling events with extremely low probability
- Stress Testing is about modelling events whose occurrence is better foreseen by expert judgment than by models
- Emphasis on the process, not an off-the-shelf solution
- ‘Stress testing is the most direct way to insert human experience into risk models’

WHAT IF?

- "**What-if?**" is the oldest question ever asked in risk management



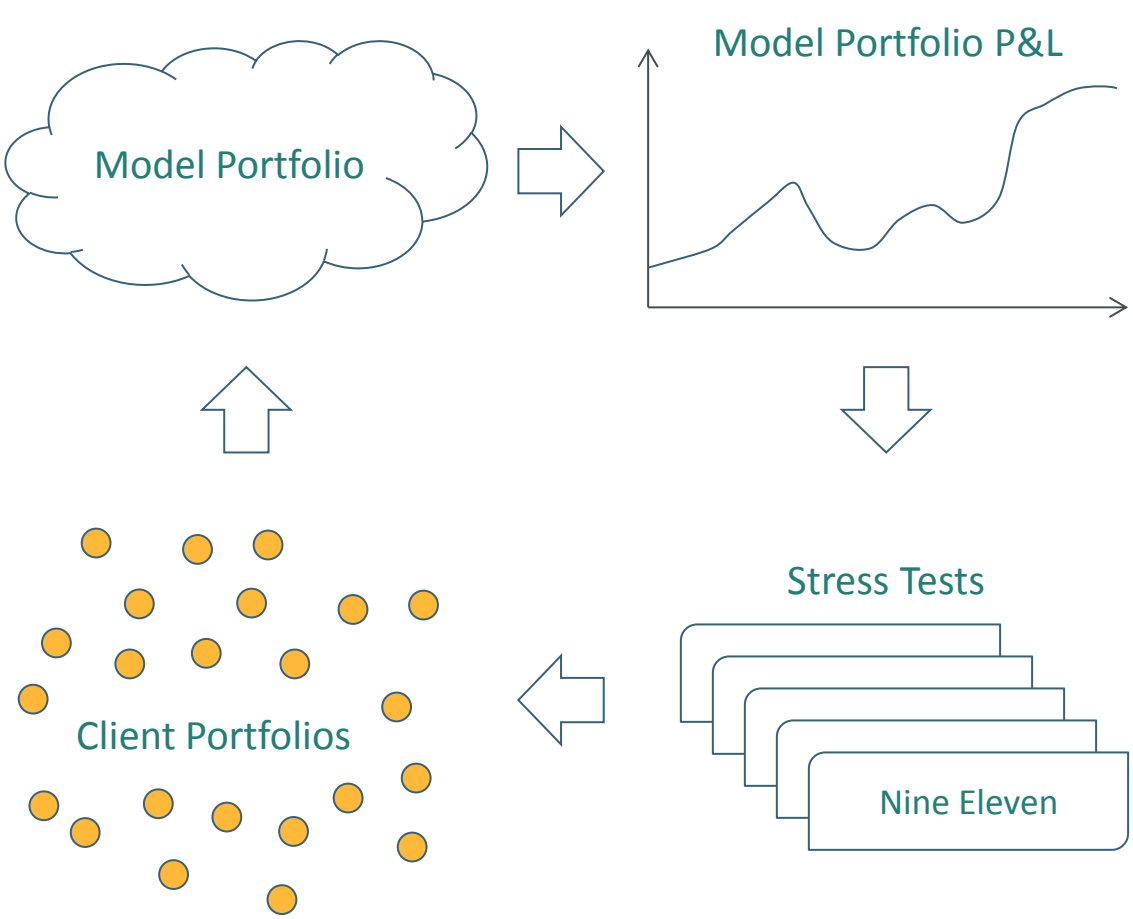
HOW TO DEFINE AND SET UP STRESS TESTS

- Scenario definition requires set of core factor shocks
  - Completeness
  - Consistency
- Propagation from few to many risk factors
  - Robustness
  - Can be done with
    - RiskManager → "Predictive stress test"
    - BarraOne → "Correlated stress test"
- Scenario definition: hypothetical vs. historical events

CONSUMPTION OF STRESS TEST RESULTS

- Critical assessment of results
  - Look at diagnostics such as error bands
  - Experiment with various risk settings
  - Drill down to asset classes and sub-portfolios
- Diagnosing the results to improve interpretation and buy into the results
- Stress test outcome should be intuitive and justifiable
- Often a next iteration is required to improve the stress test setup

A PRACTICAL CASE STUDY



- Use case
  - Many individual client portfolios
  - Design relevant and robust stress tests for all portfolios
- Methodology
  - Create model portfolio
  - Find stress periods for model portfolio
  - Set up stress tests based on P&L
  - Apply stress tests to individual portfolios

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METHODOLOGY

Subjective Input	Quantitative Assessment
1. Proxy Model Portfolio P&L with Linear Model	
Candidate set of core factors, intuitive core factor selection	Stepwise regression
2. Stress Period Definition Based on Portfolio Losses	
Peak-to-trough analysis, cross-check with VIX	Maximum loss
3. Set Up Predictive Stress Tests to Avoid Data Coverage Issues	
Core factor selection (from step 1), experiment with risk settings	
4. Diagnose Stress Test Results	
Intuitive and justifiable results	Error bands, R-squared, …

WHAT DRIVES THE PORTFOLIO RETURN?

HISTORICAL PORTFOLIO PERFORMANCE

- "When would our portfolio have been hit hard in previous crises?"
  - Our portfolio: 50% MSCI World, 10% MSCI EM, 40% Global Fixed Income (government + corporate bonds) | base currency GBP

- Problems
  1. Risk factor history is limited
  2. Scanning the history with full revaluation is computationally expensive

- Find a good set of core factors to tackle the first problem
  - Proxy portfolio return with few core factors
  - Also useful in the setup of the stress test

- Use first-order approximation to tackle the second problem

$$\Delta PV(t) \approx \sum_i \frac{\partial PV}{\partial x_i} \Delta x_i(t) = \sum_i \delta_i \Delta x_i(t),$$

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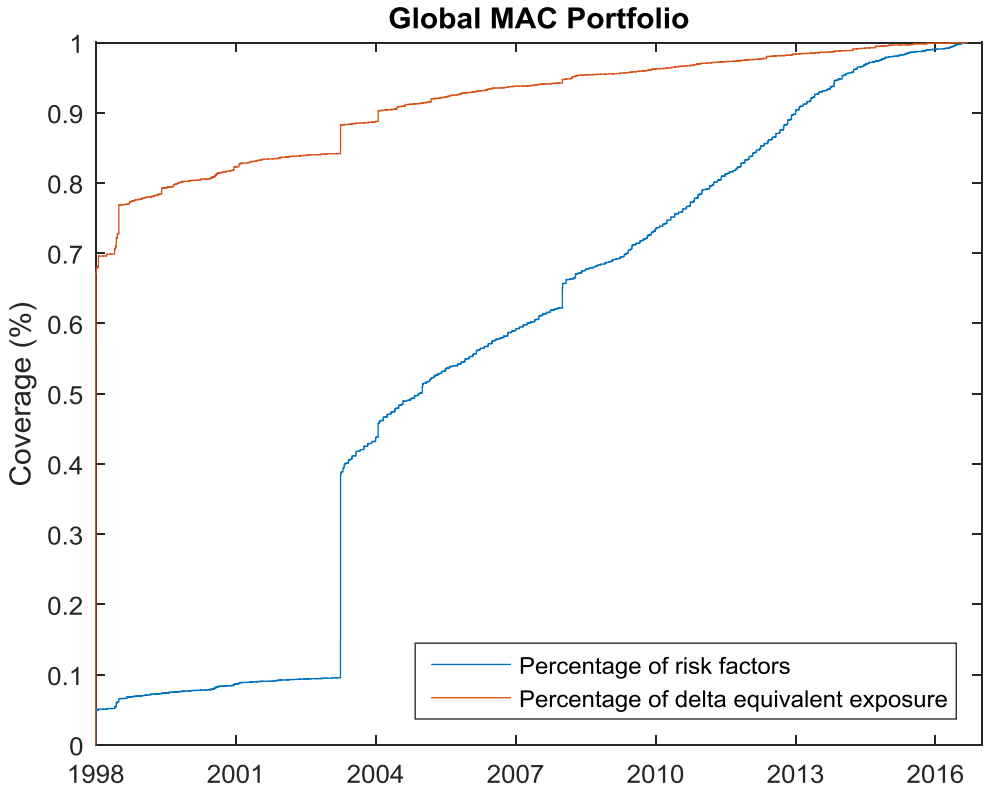
RISK FACTOR COVERAGE



- Assess historical risk factor coverage
  - Number of risk factors covered
  - Delta equivalent based coverage

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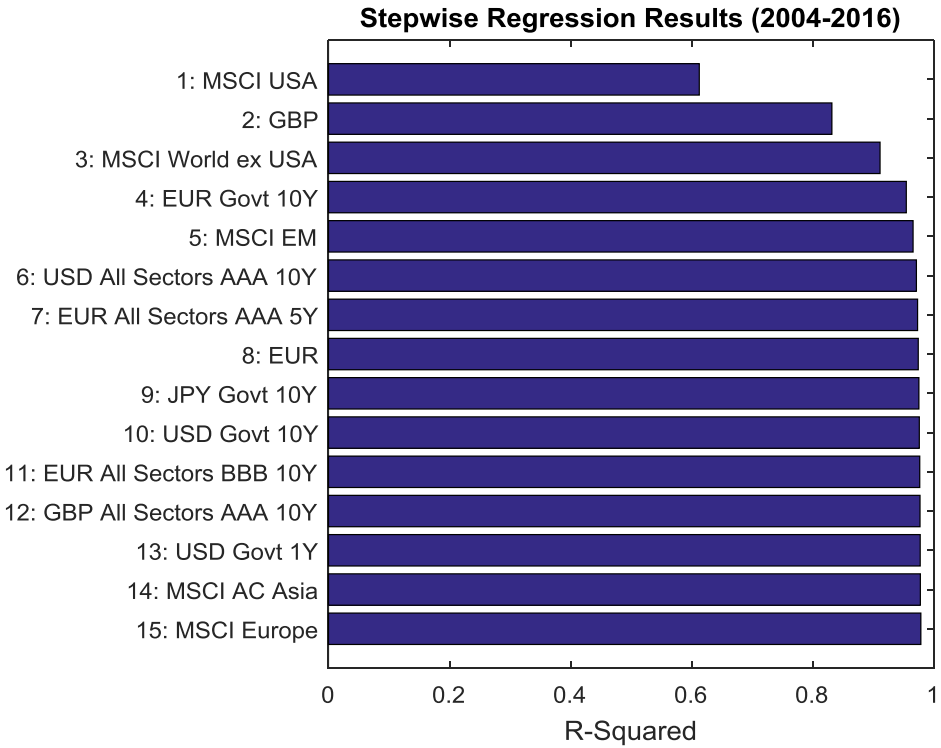
WHAT DRIVES THE PORTFOLIO RETURNS?

- We want to find the best set of explanatory risk factors for the portfolio P&L
- Based on period 2004-2016 (because of risk factor coverage)
- Candidate set of explanatory factors

Equity		FX	Government Yield Curves[2]	Corporate Yield Curves[2]	
MSCI World	MSCI UK	EUR/USD	USD Govt	USD All Sectors AAA	USD All Sectors BBB
MSCI World ex USA	MSCI AC Asia	GBP/USD	GBP Govt	GBP All Sectors AAA	GBP All Sectors BBB
MSCI EM	MSCI Switzerland	JPY/USD	JPY Govt	JPY All Sectors AAA	JPY All Sectors BBB
MSCI USA	MSCI Europe	CHF/USD	EUR Govt	EUR All Sectors AAA	EUR All Sectors BBB
MSCI Japan		DXY	CHF Govt	CHF All Sectors AAA	CHF All Sectors BBB

STEPWISE REGRESSION



- Stepwise linear regression to find the most explanatory factors
- Combine quantitative analysis with judgement → intuitive selection

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CANDIDATE SETS OF CORE FACTORS

- We want coverage among all relevant risk types: Equity, interest rate and currency

- We will analyze 4 potential setups

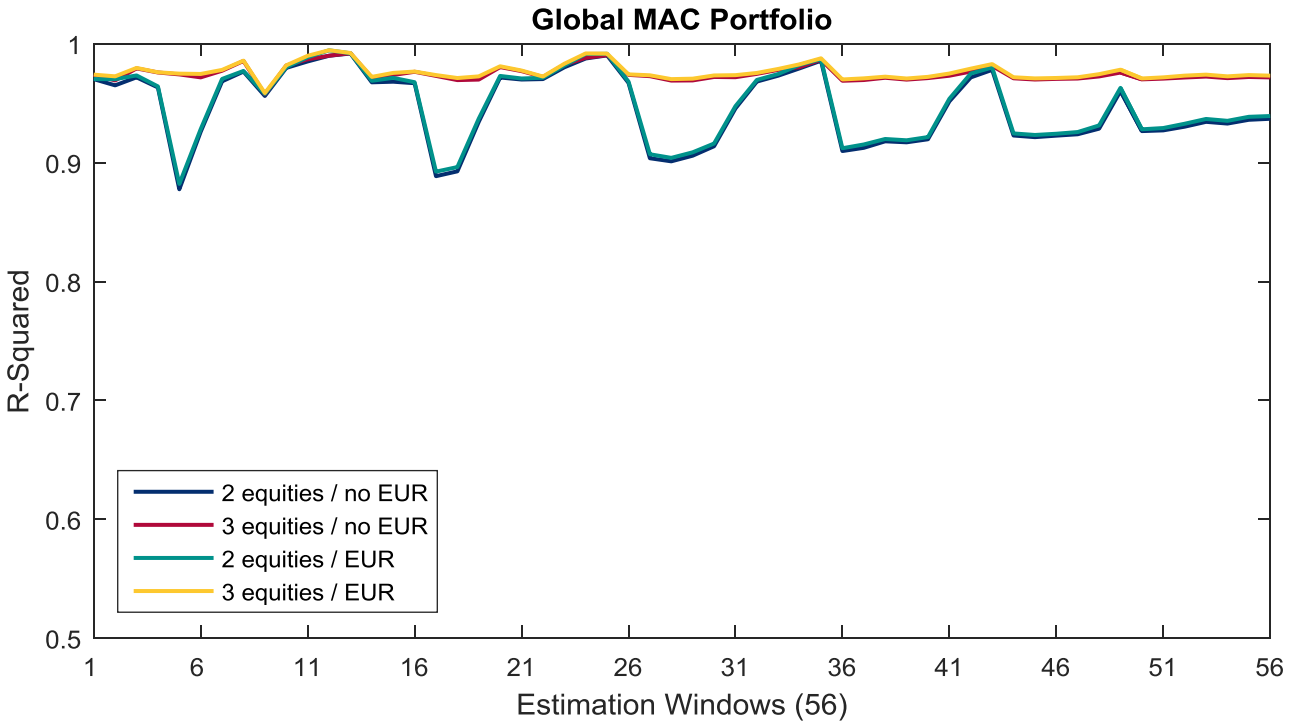
Risk Type	Risk Factor	3eqty / EUR	2eqty / EUR	3eqty / no EUR	2eqty / no EUR
Equity	MSCI World		●		●
	MSCI USA	●		●	
	MSCI World ex USA	●		●	
	MSCI EM	●	●	●	●
Interest Rate	EUR Govt 10Y	●	●	●	●
	USD All Sectors AAA 10Y	●	●	●	●
Currency	GBP/USD	●	●	●	●
	EUR/USD	●	●		

STABILITY OVER VARIOUS ESTIMATION WINDOWS

Number (see next slide)	Length	Window Start Dates	Number of Windows
1 to 13	1Y	2004 to 2016	13
14 to 25	2Y	2004 to 2015	12
26 to 35	4Y	2004 to 2013	10
36 to 43	6Y	2004 to 2011	8
44 to 49	8Y	2004 to 2009	6
50 to 53	10Y	2004 to 2007	4
54 to 55	12Y	2004 to 2005	2
56	13Y	2004	1

- Assess the stability of various setups for a variety of estimation windows
  - How stable is the explanatory power?

STABILITY OVER VARIOUS ESTIMATION WINDOWS



- The setup with three equity factors (World ex USA, USA and EM) dominates
- Impact of adding the euro as core factor is negligible

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FINAL SET OF CORE FACTORS

Risk Type	Core Factor	First Observation
Equity	MSCI USA	1998/01/01
	MSCI World ex USA	1998/01/01
	MSCI EM	1998/01/01
Interest Rate	EUR Govt 10Y	1998/01/01
	USD All Sectors AAA 10Y	2003/04/01
Currency	GBP/USD	1998/01/01

- We select a parsimonious set of core factors
- Risk factor coverage as far back as possible

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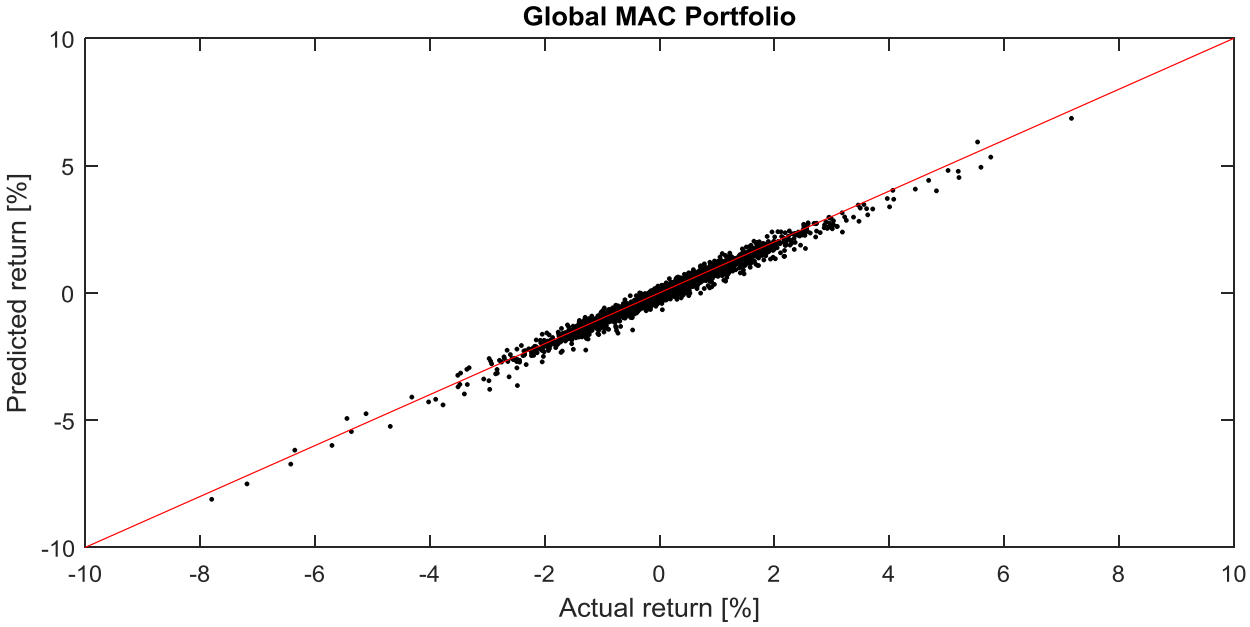
REGRESSION RESULTS



Core Factor	Beta	T-Stat
MSCI EM	0.07	36.06
MSCI USA	0.26	107.57
MSCI World ex USA	0.17	51.88
EUR Govt 10Y	-1.54	-31.12
USD All Sectors AAA 10Y	-1.00	-25.59
GBP	-0.52	-187.23

- Intuitive regression betas with significant t-stats

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STRESS PERIOD IDENTIFICATION

METHODOLOGY

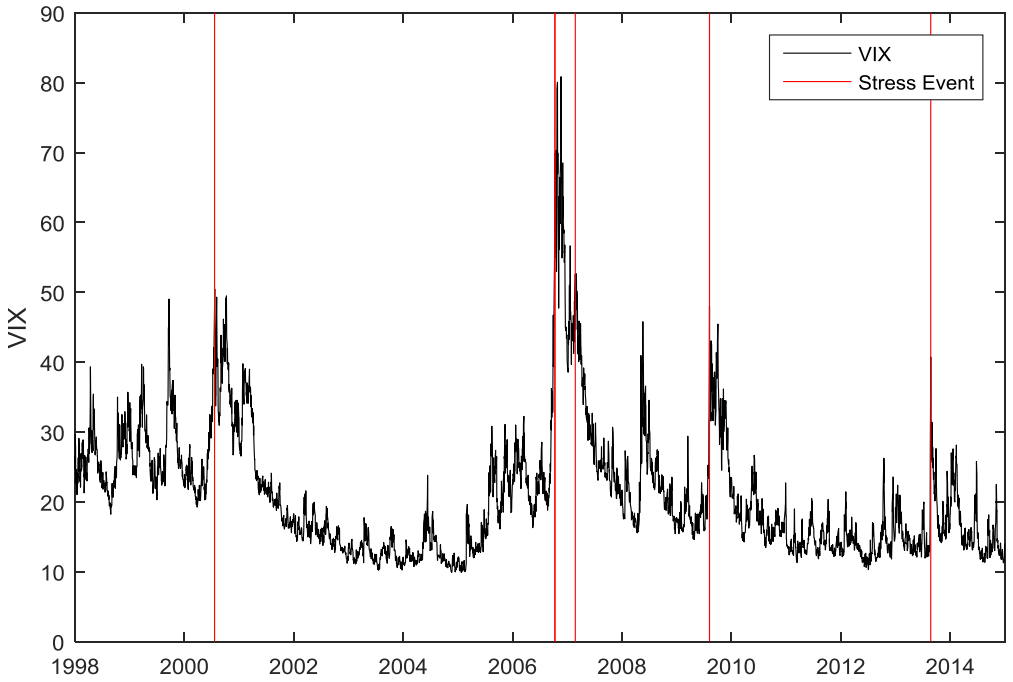
- Subjective judgement backed by quantitative analysis based on two tools
- Maximum portfolio loss
  - Specific to portfolio
  - Based on weekly losses
- Market volatility (VIX)
  - Market-wide measure
  - Level of market turbulence

MAXIMUM PORTFOLIO LOSS

Date Range	P&L (%)	Description
2008, Oct 3-10	-8%	Great Financial Crisis: Fall 2008
2011, Aug 1- 8	-6%	European Sovereign Debt Crisis
2009, Feb 16 - 23	-5%	Great Financial Crisis: Spring 2009
2015, Aug 17 - 24	-5%	China Crisis
2002, Jul 15 - 22	-4%	Dotcom Bubble

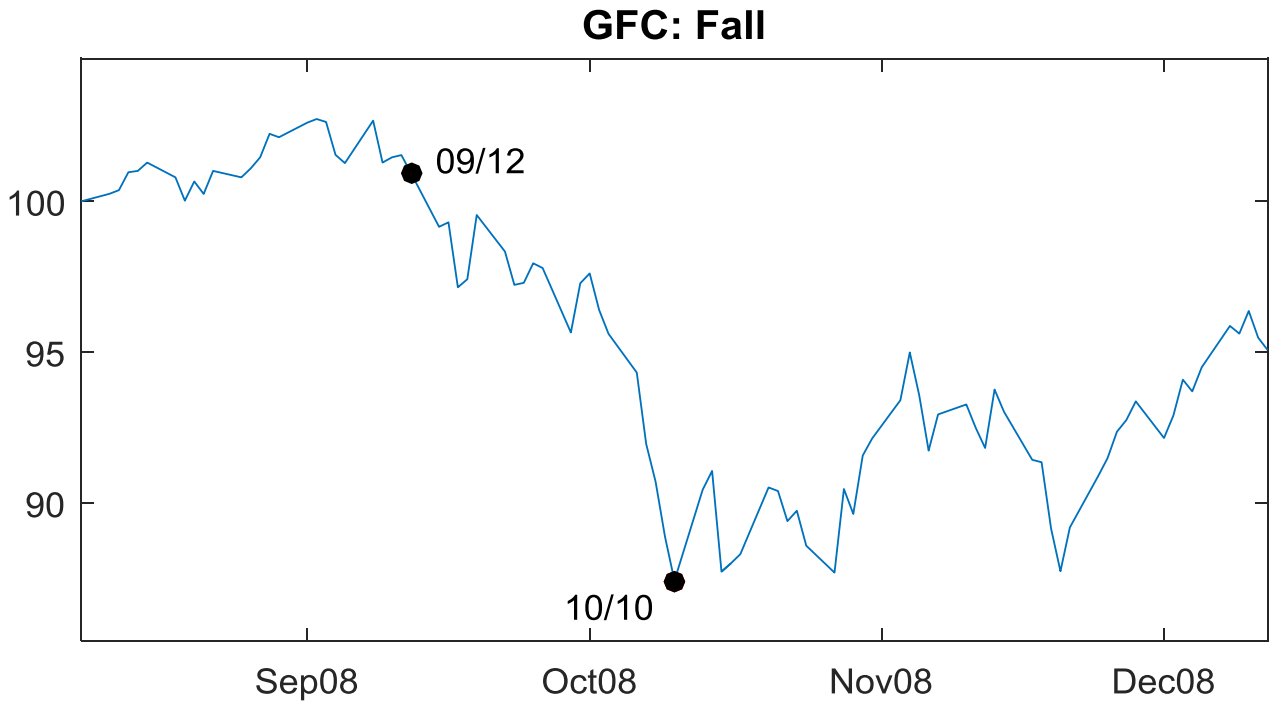
- Losses are not very severe
  - Linear approximation smoothed, but
  - Comparison on a relative basis
  - Stress test shocks will be more severe

MARKET VOLATILITY



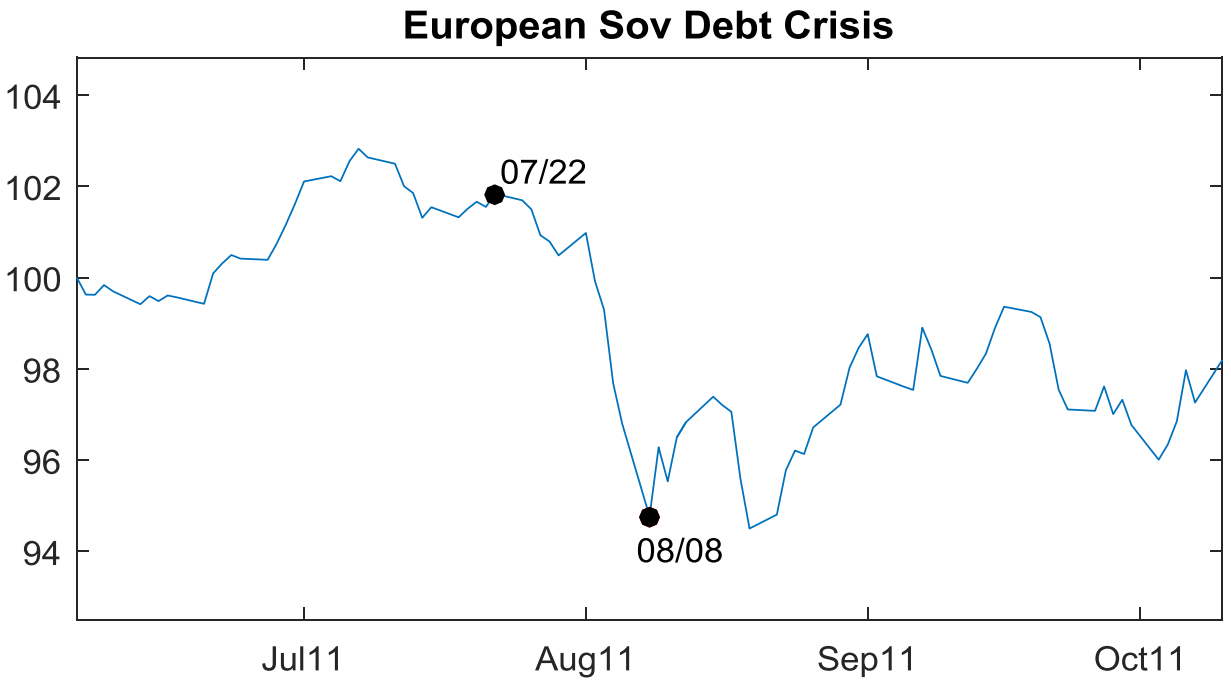
- The maximum losses coincide with market-wide distress
  - Intuitive selection of stress periods
  - Find stress windows around the selected dates (not all weekly stress periods)

GFC: FALL 2008



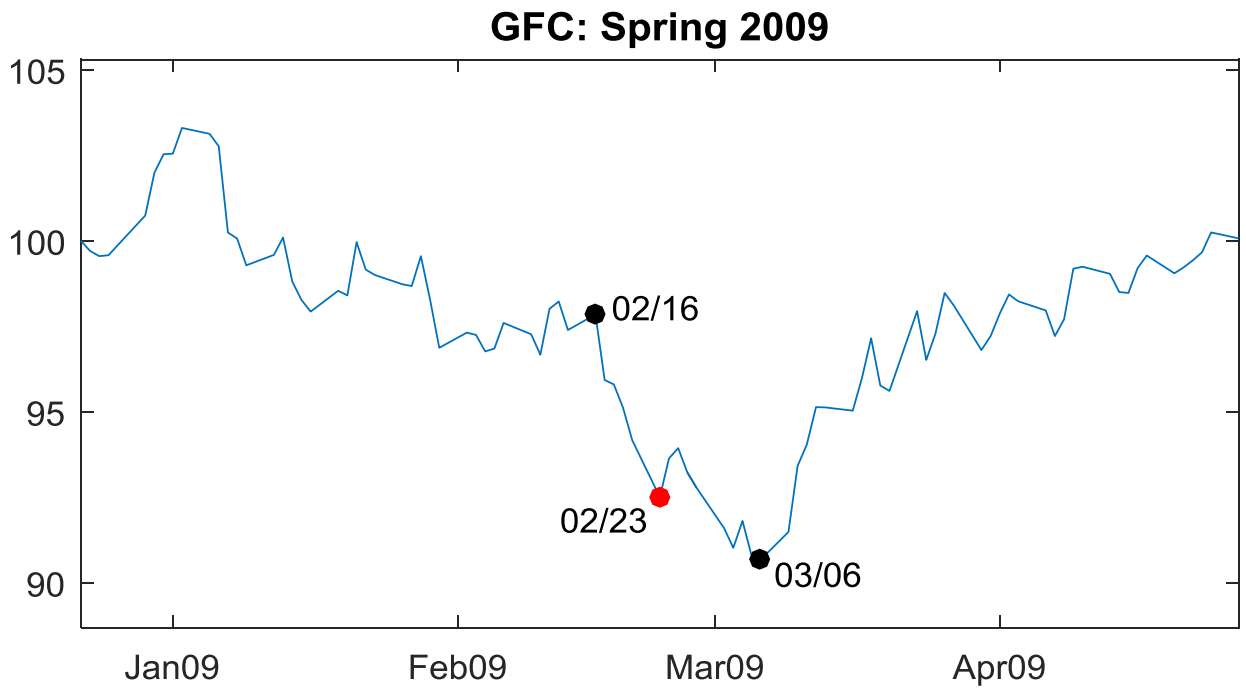
- Start date is the business day prior to Lehman collapse, end day is local minimum

EUROPEAN SOVEREIGN DEBT CRISIS



- After the bailout plan agreed on July 21 we saw slight portfolio gains, but then markets believed that the bailout plan was far from sufficient and markets crashed

GFC: SPRING 2009



- No natural trigger event, we use the local peak-to-trough as the stress period

CHINA HARD LANDING

- Start date is the business day prior to the Yuan devaluation, end date is the local minimum

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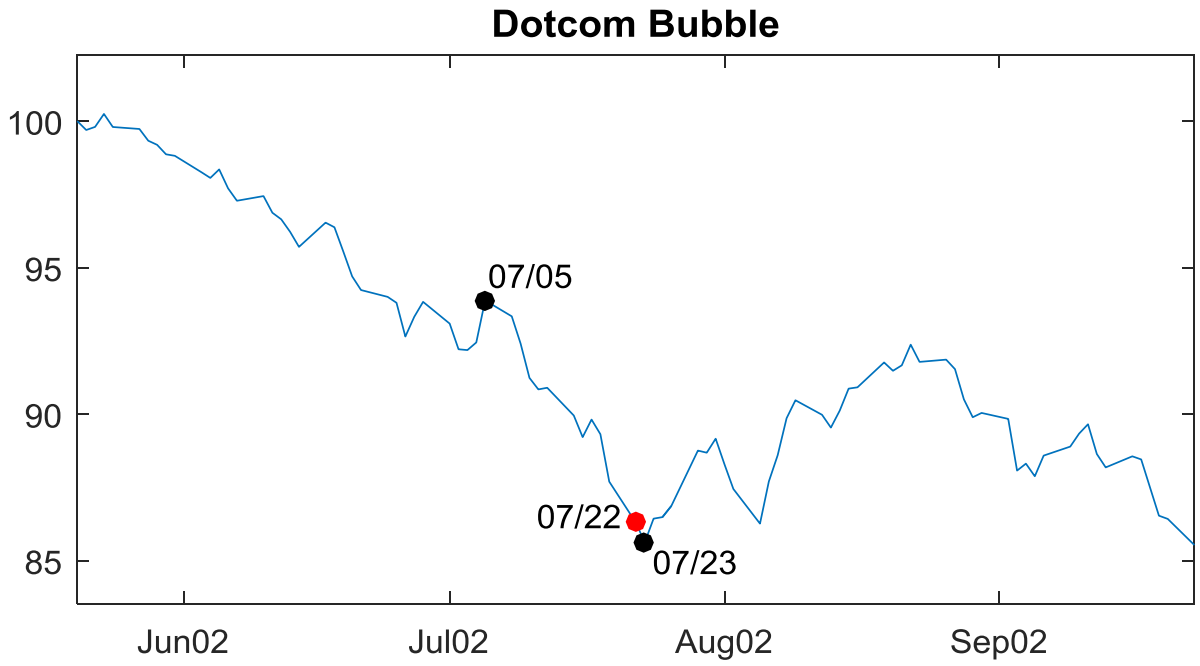
DOTCOM BUBBLE



- Markets went down over long periods of time. We select the local peak-to-trough around the selected date

STRESS TEST DEFINITIONS

	MSCI EM	MSCI USA	MSCI World ex USA	EUR Govt 10Y	USD All Sectors AAA 10Y	GBP
Dotcom Bubble	-4.9	-19.0	-13.2	-0.2	0.0	2.8
GFC: Fall 2008	-30.8	-28.4	-29.7	-0.1	0.4	-4.7
GFC: Spring 2009	-10.8	-17.1	-15.0	-0.1	-0.2	-0.6
European Sov Debt Crisis	-14.1	-16.9	-15.1	-0.5	-0.5	0.0
China Hard Landing	-13.1	-10.0	-10.0	-0.1	-0.2	1.2

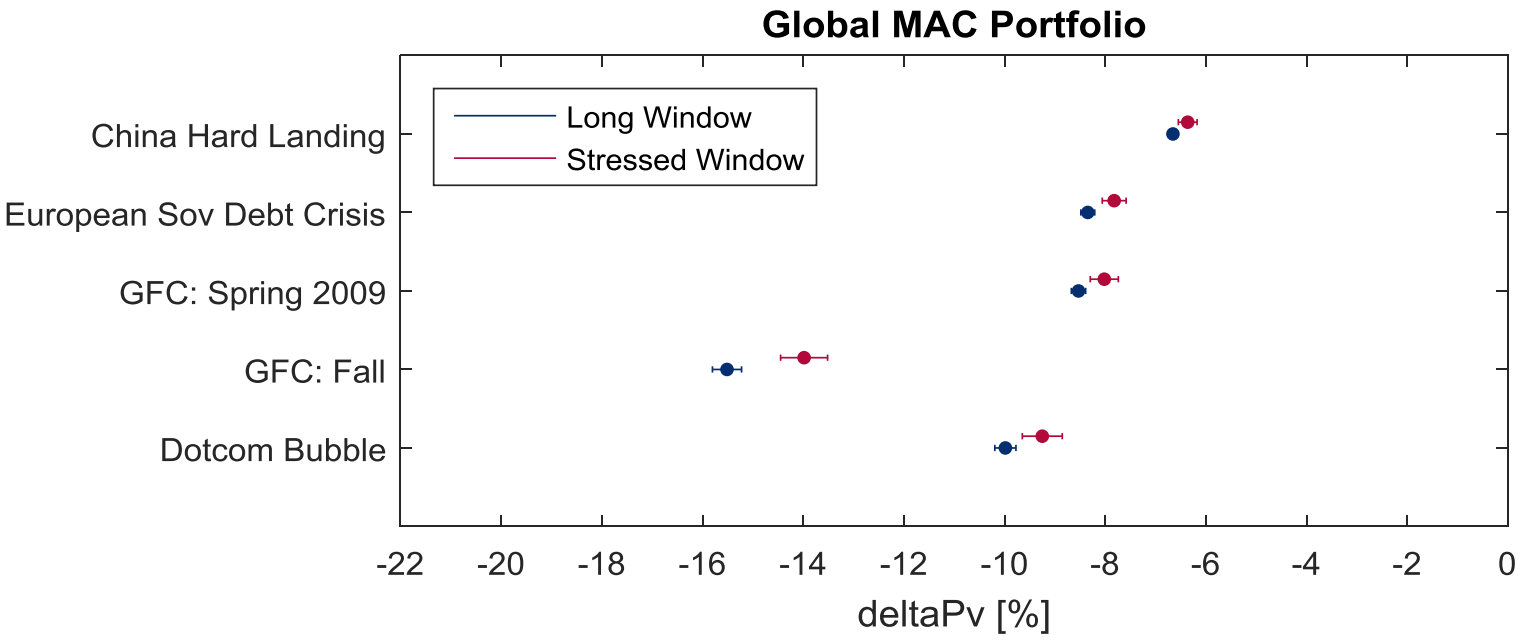
- Interest rates and FX can go both directions (e.g. flight to quality effects)

PREDICTIVE STRESS TEST QUALITY

STRESS TEST RESULTS

- Stress test prediction and standard error (error bands) for
  - Full portfolio
  - Drilldown sub-portfolios
  - Small portfolios consisting of 20 assets
    - 50 pure equity
    - 50 pure FI
    - 50 mixed equity/FI
- We experiment with two potential risk settings
  - Long stable correlation window (5 year period: 2012-2016)
  - Stressed period risk setting, based on the correlation matrix during the great financial crisis (2 year period: 2009-2010)

FULL PORTFOLIO



- Portfolio P&L and error bands
  - Error bands are small
  - Long window leads to larger losses (more risk factor coverage)
    - Consider proxies

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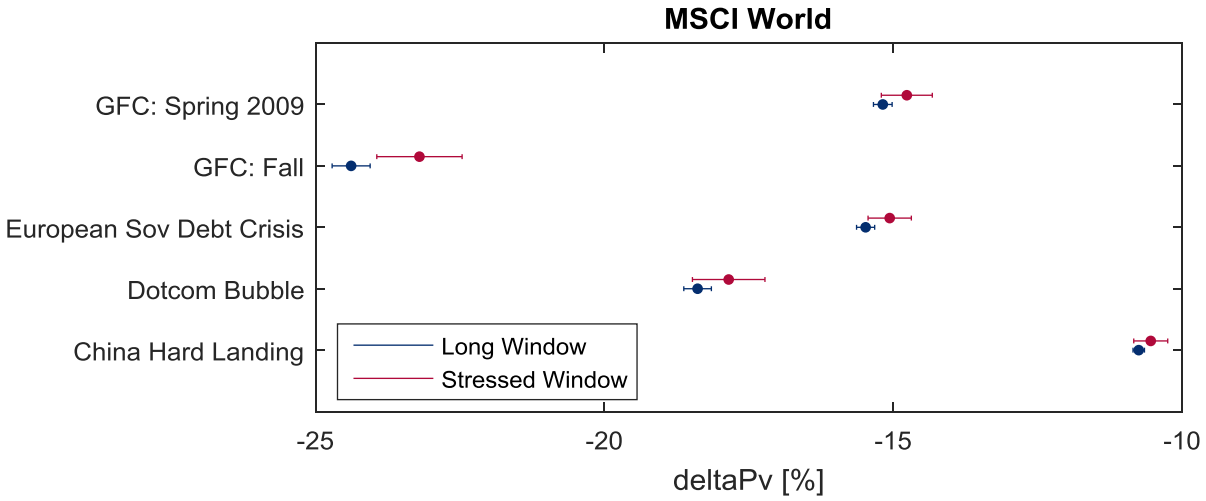
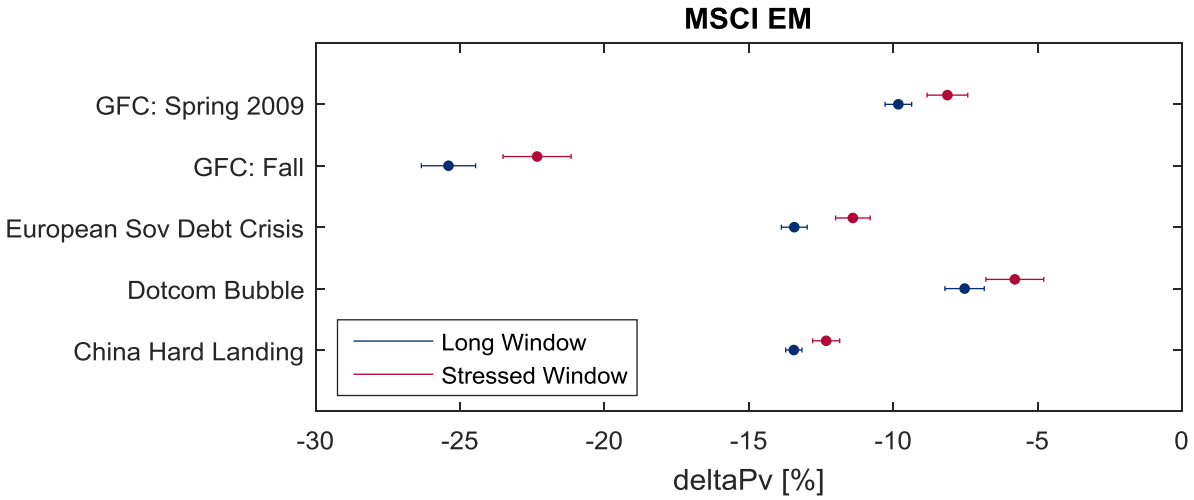
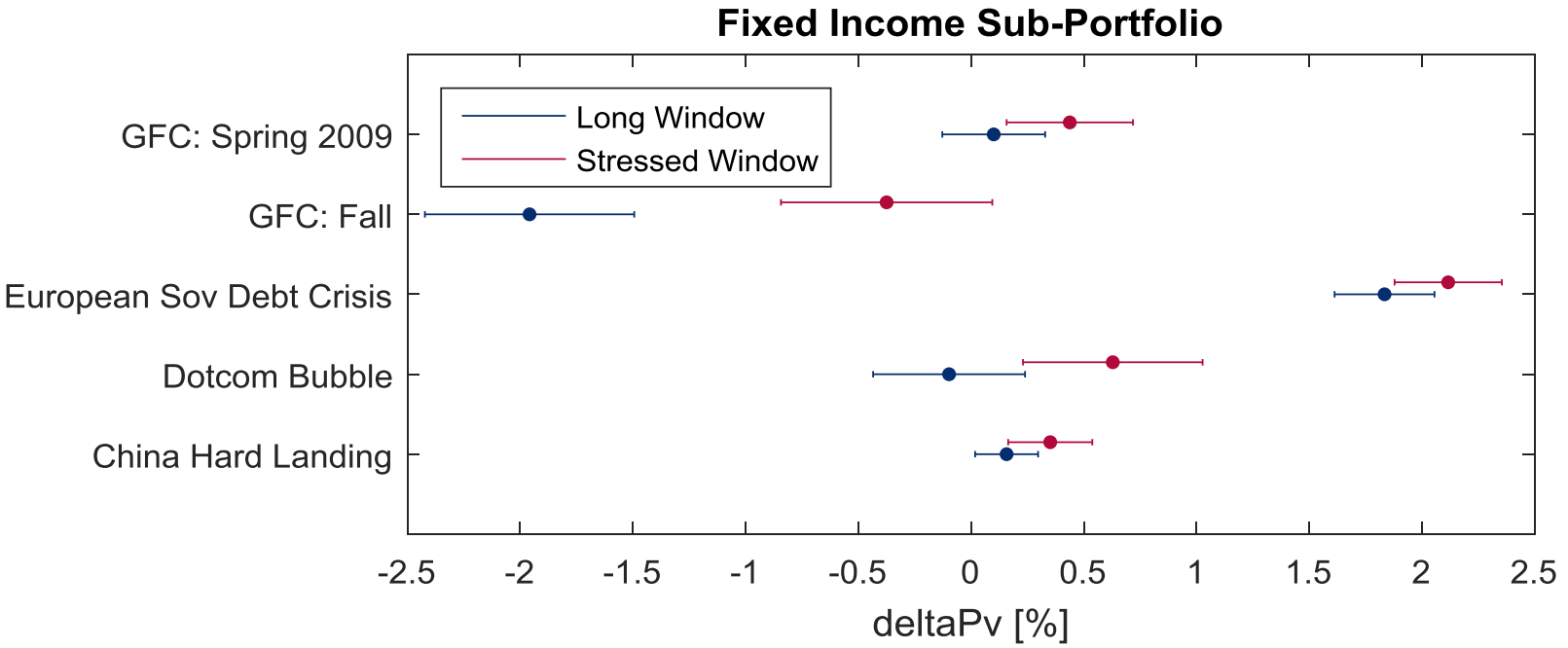
EQUITY SUB-PORTFOLIOS





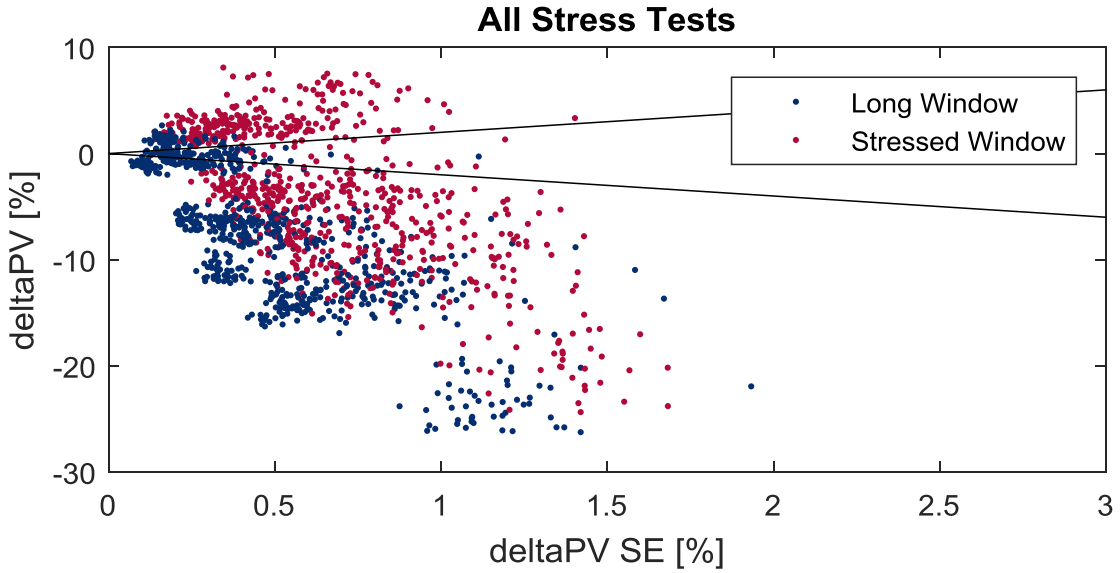
- Larger losses under long window
- Larger uncertainty for stressed window

FIXED INCOME SUB-PORTFOLIO



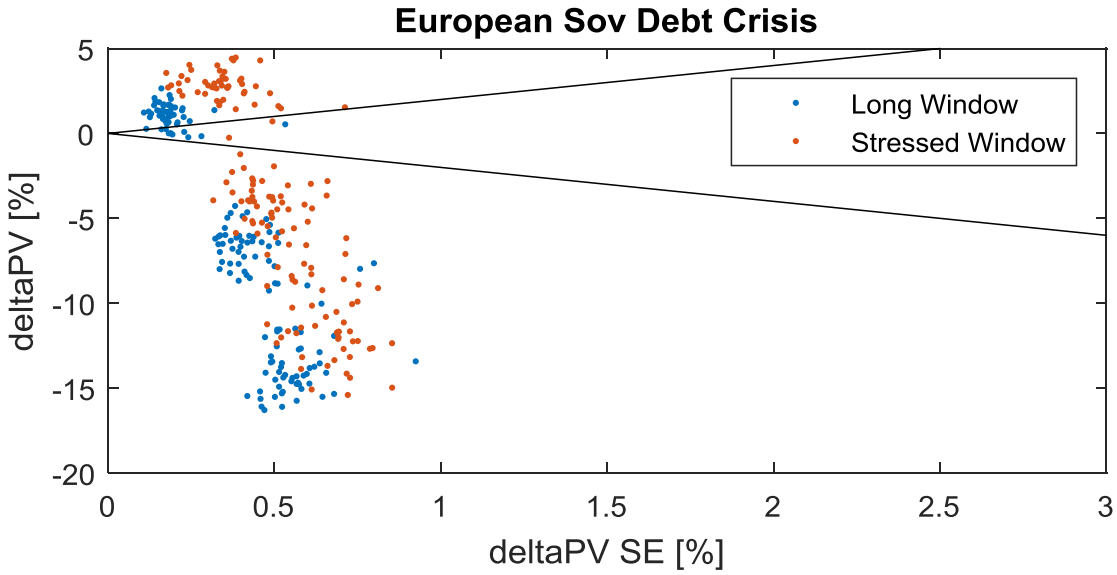
- Losses more severe for the long term window

SMALL PORTFOLIOS: ALL STRESS TESTS



- Plot portfolio P&L (vertical axis) and prediction error (horizontal axis) of each portfolio P&L prediction
- P&Ls which fall within the “cone” are not significant

SMALL PORTFOLIOS: EUROPEAN SOV DEBT CRISIS



- Three clusters for different portfolio types (equity vs. fixed income)
- Impact of the estimation window
  - Larger prediction error for stressed window
  - Worse stress test results for the long term window

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CONCLUSION

CONCLUSION

- Stress testing is complementary to VaR-based risk measures
  - Forward-looking and event specific
  - Not off-the-shelf but subjective inputs required
  - Inject human experience into risk models
- Subjective choices can be backed by data driven analysis
  - Portfolio-specific stress tests based on maximum historical losses
  - Diagnostics to gain confidence in the stress test setup, find weaknesses and potentially improve the stress test
- Case study shows that a good stress test setup can (should) be a mix of “science” and “art”
  - Data-driven backing improves the acceptance by the stakeholders

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