



8 December 2015

Market Risk: Understanding and Managing Tail Events

Financial Crises Research at the Cambridge Centre for Risk Studies

Centre for
Risk Studies



**UNIVERSITY OF
CAMBRIDGE**
Judge Business School

Dr Andrew Coburn

Director of Advisory Board
Centre for Risk Studies



**OXFORD
ECONOMICS**

Cambridge Centre for Risk Studies Research Themes

Research Application Areas

A. Multi-Threat Catastrophe Risk

- ‘Project Pandora’

B. Technology Catastrophe Risk

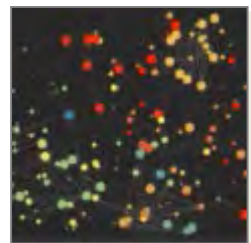
- Cyber standards and accumulation scenarios

C. Financial Catastrophe Risk

- Investment and Asset Risk Management

+ Data architecture & Methodology

- Platforms and APIs



Cambridge Financial Risk Research Team

Centre for Risk Studies Executive Team



Prof Danny Ralph
Academic Director



Dr Michelle Tuveson
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Cambridge Financial Catastrophe Research Program

- Objective: **Improve methodologies and analytics for financial risk management decision-support**
- Research has several components:



Triggers

- Understand Exogenous and Endogenous Triggers of Market Shocks
- Identify the 'Trillion Dollar' market-mover event set



Scenarios

- Develop a probabilistic event set of market tail risk scenarios
- Provide scenarios for financial stress tests



Networks

- Improve the understanding of contagion and its implications on risk
- Understand how regulators and central banks reduce risk
- Model of global financial system to understand counterparty risk and counterparty's counterparties
- Help map individual company's interconnectivity within the financial system



Response

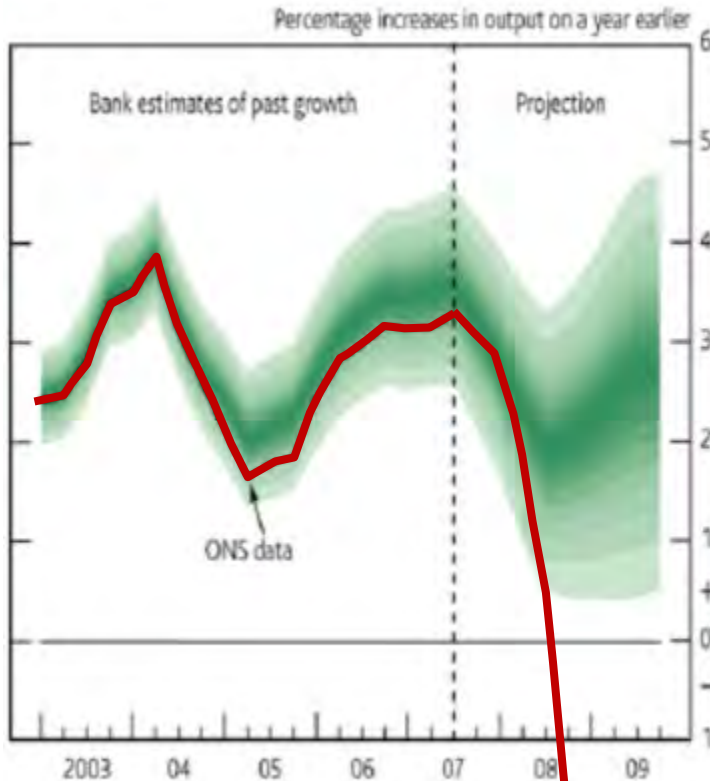
- Systemic risk monitoring with portfolio re-balancing response planning
- Having a suite of investment re-balancing strategies for full event set of crisis contingencies
- Dashboards to identify emerging systemic risk patterns

Applications of the Proposed Research

- How might this research be used by risk management professionals?
 - Investment risk managers
 - Chief Risk Officers of financial services organizations
 - Policy makers and regulators

'Normal' Financial Models Don't Work in Crises

Bank of England modelled estimates of UK GDP
November 2007



Dynamic stochastic general equilibrium (DSGE) models work well under normal conditions but not during a crisis

- “We suffered adverse 25-standard deviation events, several days in a row **according to our models.**”
 - CFO of Brevan Howard, one of the world's largest hedge funds, after it had suffered huge losses in 2008
- “**according to our models** this just could not happen”
 - Robert Merton, one of the nobel-prizewinning architects of the Black-Scholes model, 1998 on the day after Long-Term Capital lost \$4.4 Billion
- “The 1987 ‘Black Monday’ has a likelihood of 10^{-148} in traditional ‘random walk’ **mathematics.**”
 - Economist Gene Stanley, Boston University

‘Catastrophe Analytics’: ‘FinCat’

- Financial Crises are a phase change in the economic system
- Different rules and models apply during and following a financial crisis
- Non-continuous and phase-changes in dynamical systems (bifurcation theory) is known as ‘catastrophe analytics’
- We term this research our ‘Financial Catastrophe’ research programme

1. Triggers



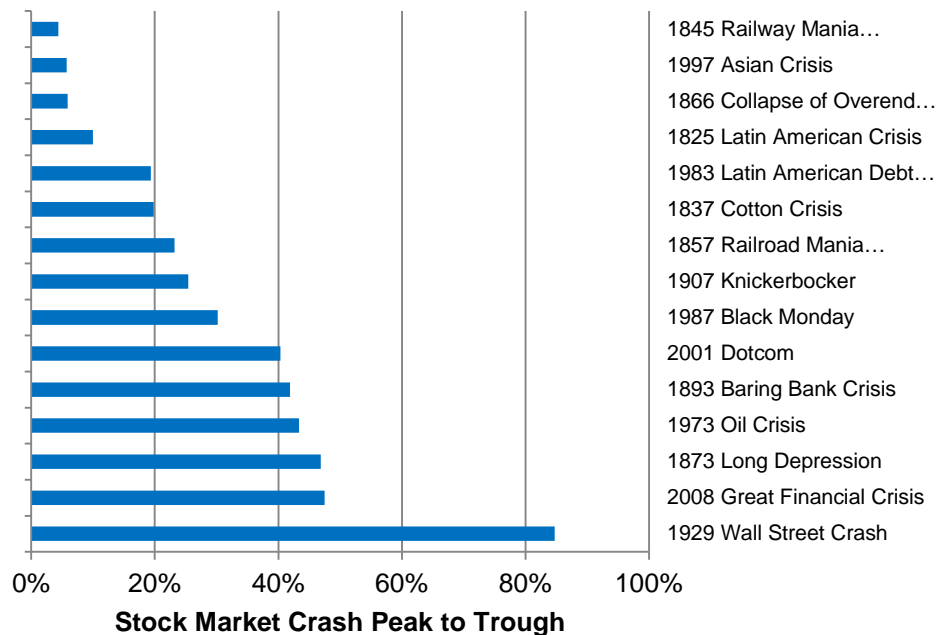
1. Triggers

- If we understand the mechanisms that trigger financial crises, and the conditions required, then we can
 - Identify scenarios that explore these
 - Create a taxonomy of causes
 - Estimate how often we can expect these to occur
 - Track causal mechanisms and monitor precursory signals
- We do this through
 - Historical precedent studies
 - Theoretical modeling of modern-day crises
 - Exhaustive evaluation of scenarios from Taxonomy of Threats

Learning from History – Past 200 Years of Financial Crises

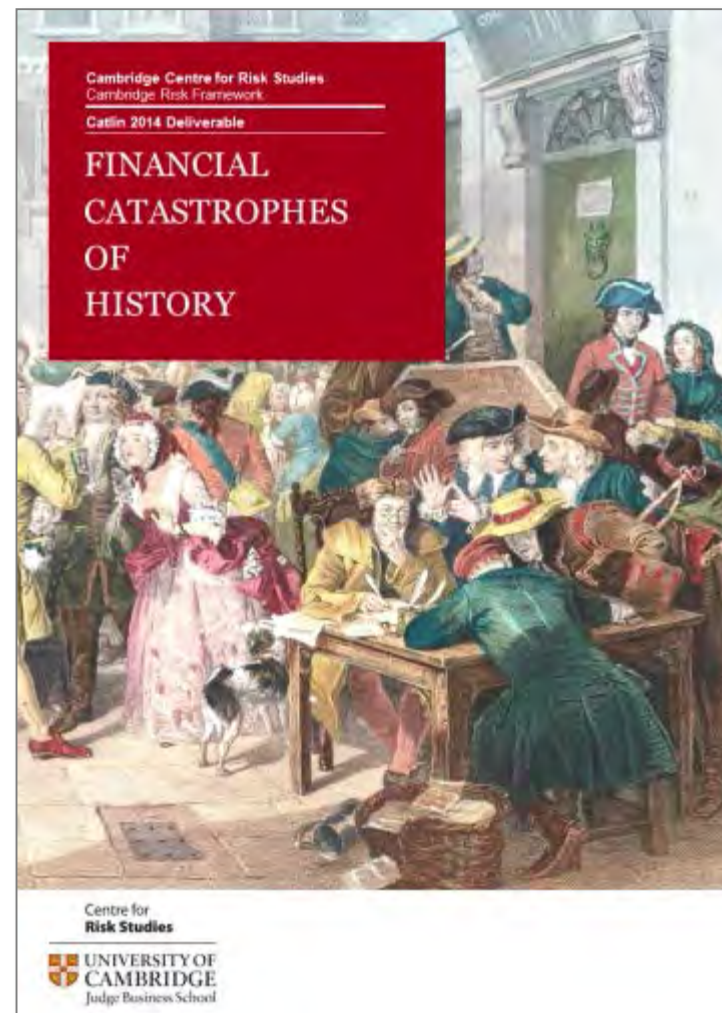


US Stock Market Crashes



Observed, last 200 years

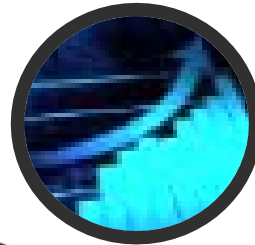
Crashes Greater Than	Number of Crises	Average Interval (Yrs)
10%	12	16
20%	9	21
40%	6	32
80%	1	190



Taxonomy of Financial Catastrophe

Complex / Technological

- ↳ Flash crash
- ↳ Black box trading
- ↳ Complex derivatives
- ↳ Cyber crash



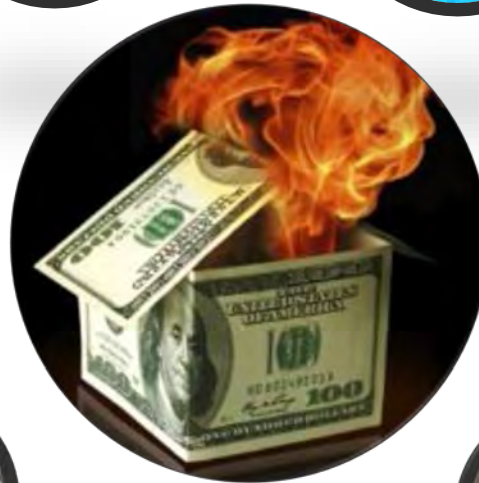
Inflation

- ↳ Cost-push inflation
- ↳ Demand-pull inflation
- ↳ Deflation



Currency Crisis

- ↳ Reserve currency
- ↳ FX shock



Banking Crisis

- ↳ Systemic failure
- ↳ Bank run
- ↳ Credit crunch



Asset Bubble

- ↳ Stock market crash
- ↳ Commodity price bubble
- ↳ Property price bubble



Illegal Activity

- ↳ Fraud
- ↳ Financial irregularity

Debt

- ↳ Sovereign Debt
- ↳ Private Debt

2. Scenarios



Cambridge Financial Stress Test Scenarios



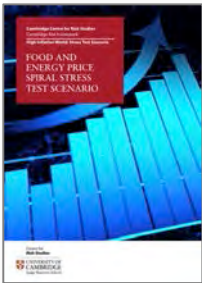
Global Property Crash

Sudden collapse of property prices in China followed by many other emerging and developed markets triggers a cascading crisis throughout the global financial system



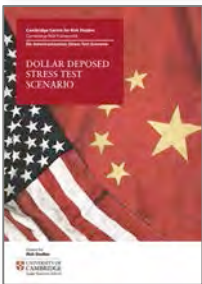
Eurozone Meltdown

Unexpected default of Italy is followed by a number of other European countries, leading to multiple cession from the Union and causing an extensive financial crisis for investors



High-Inflation World

A series of world events puts pressure on energy prices and food prices in a price increasing spiral, which becomes structural and takes many years to unwind



Dollar Deposed

US dollar loses its dominance as the default trading currency as it becomes supplanted by the Chinese Renminbi, with rapid unwinding of US Treasury positions and economic chaos

Scenario Studies Research Outputs



Taxonomy of Threats



Geopolitical Conflict
Emerging Risk Scenario



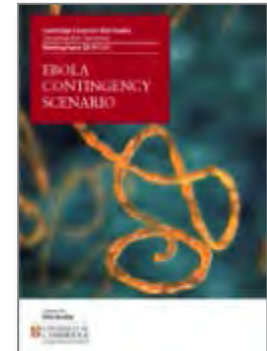
Pandemic
Emerging Risk Scenario



Cyber Catastrophe
Emerging Risk Scenario



Social Unrest
Emerging Risk Scenario



Ebola
Emerging Risk Scenario



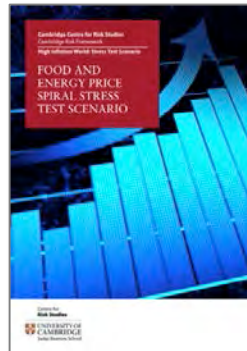
Financial Catastrophes



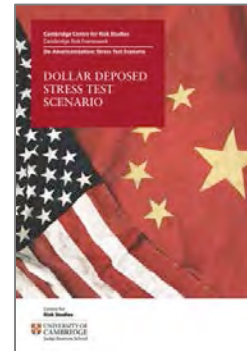
Global Property Crash
Financial Risk Scenario



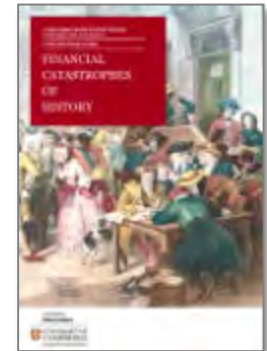
Eurozone Meltdown
Financial Risk Scenario



High Inflation
Financial Risk Scenario



Dollar Dethroned
Financial Risk Scenario



Historical Crises
Financial Risk



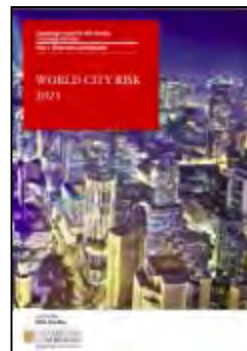
NatCat FinCats
Clash Report



Business Blackout
Lloyds Emerging Risk Report



Climate Change
Investor Sentiment Shock



World City Risk 2025
Lloyds Co-Branded Report

Available for
Download from Website:
CambridgeRiskFramework.com

21 Market Threat Models in Project Pandora

Identifying which scenarios occurring where in the world
could trigger more than a Trillion dollars of lost economic output

Finance and Trade



Market
crash



Sovereign
default



Oil price
shock

Geopolitics and Society



Interstate
Conflict



Separatism
Conflict



Terrorism



Social
Unrest

Natural Catastrophe and Climate



Earthquake



Wind
storm



Tsunami



Flood



Volcanic
eruption



Drought



Freeze



Heatwave

Technology and Space



Nuclear
accident



Power
outage



Cyber
attack



Solar
storm

Health and Humanity



Human
pandemic



Plant
epidemic

How Do You Use This?





■ Regulatory modeling

- Financial services companies are required to hold capital against extreme ('tail event') contingencies
- Banks: Basel III requires banks to assess the liquidity reserves required for a 30 day run on the bank
- Insurance Asset Managers: Solvency II requires quantification of 1-in-200 market risk capital needs
- Stress tests: picks using expert judgement of key variables to apply to see if organization passes or fails performance thresholds

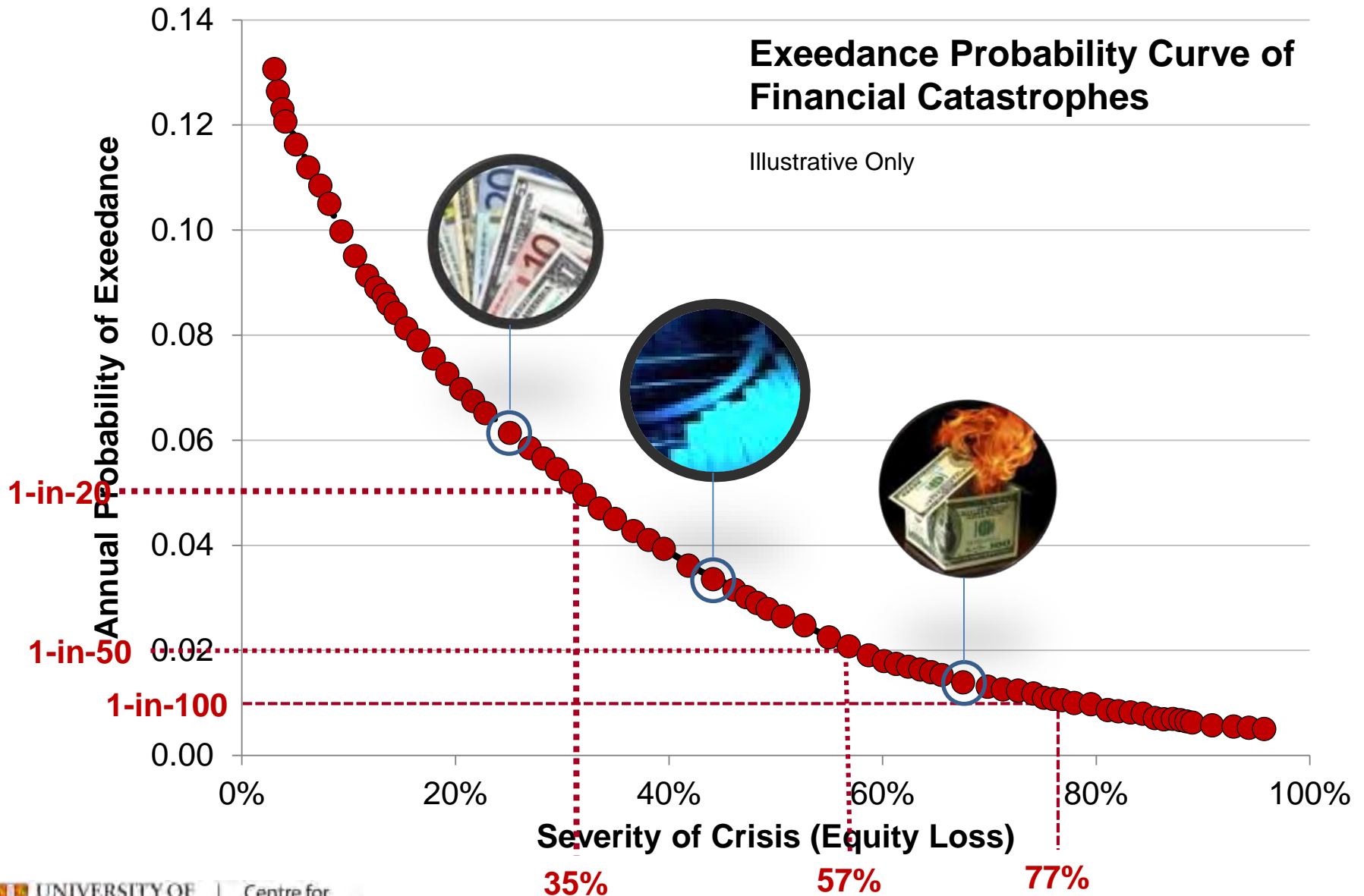
■ A probabilistic model of financial catastrophes will provide a much better assessment of risk

- Define the frequency and severity of financial crises
- Illustrate the different types of crisis and how they are likely to affect their business
- Quantify the probability of failure that is acceptable through management choice and regulatory requirement

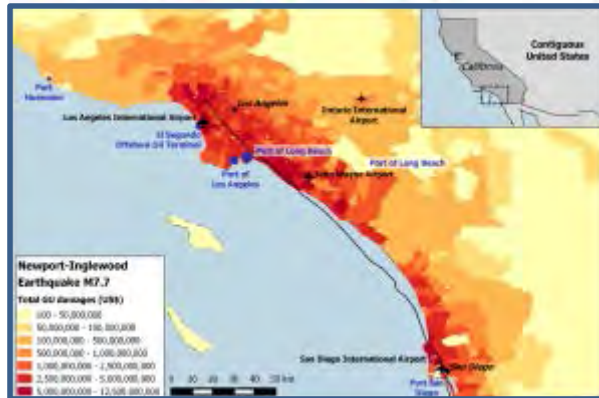
Comparing Cambridge Scenarios with US Stress Tests

		Stock Market Drop	House Price Crash	Unemployment Rate	Markets Worst Impacted
Dodd Frank Stress Test 2015		60%	25%	10%	US
 Eurozone Meltdown	S1	55%	10%	9%	Germany/UK/Euro
	S2	80%	15%	10%	
	X1	95%	20%	12%	
 Global Property Crash	S1	70%	30%	8%	China/Emerging Markets
	S2	85%	40%	9%	
	X1	90%	60%	10%	
 High Inflation World	S1	24%	30%	7%	China/Japan
	S2	30%	40%	8%	
	X1	40%	55%	9%	
 Dollar Deposed	S1	30%	15%	8%	US
	S2	45%	18%	9%	
	X1	60%	30%	10%	

What a Financial Catastrophe Model Would Look Like



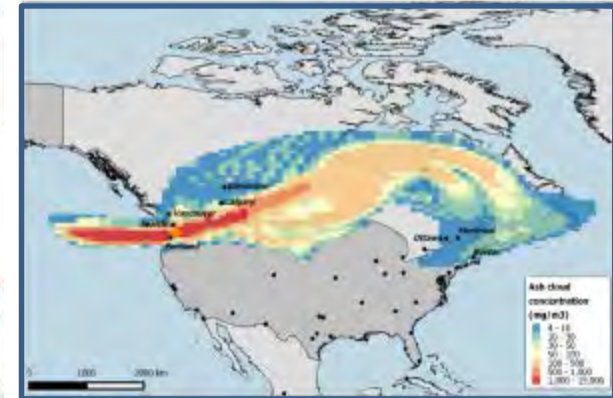
Clash: 'Trillion Dollar NatCat' Events



Earthquake M7.7 Los Angeles
GU Loss: \$863 Bn
Global GDP Loss: \$3.6 Trillion
RP: 1,100 yrs



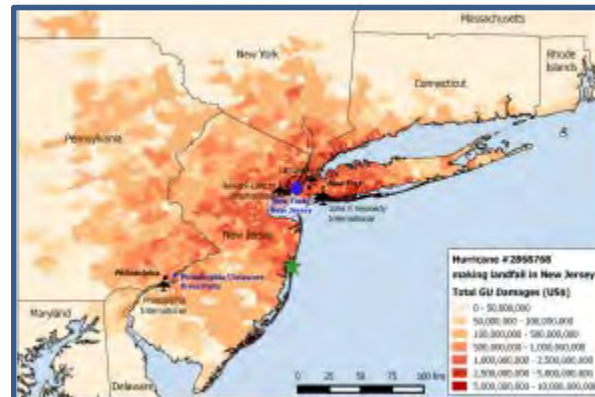
Hurricane CAT 4 Florida
GU Loss: \$1,350 Bn
Global GDP Loss: \$2.4 Trillion
RP: 1,200 yrs



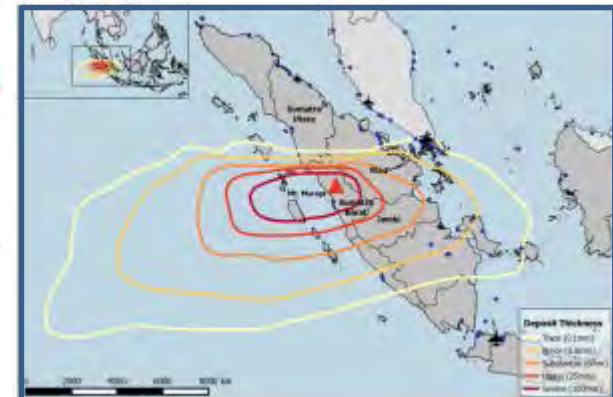
Volcano VEI VII Mt Rainer, Seattle
GU Loss: \$1,100 Bn
Global GDP Loss: \$6.3 Trillion
RP: 3,000 yrs



Earthquake M8.3 Tokyo, Japan
GU Loss: \$1,368 Bn
Global GDP Loss: \$1.6 Trillion
RP: 1,400 yrs



Hurricane CAT 4 New Jersey
GU Loss: \$1,150 Bn
Global GDP Loss: \$3.6 Trillion
RP: 1,150 yrs



Volcano VEI VII Mt Marapi, Indonesia
GU Loss: \$493 Bn
GDP Loss: \$2.5 Trillion
RP: 750 yrs

3. Networks

Centre for
Risk Studies



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Financial Risk and Networks Cambridge Conference Series



- **Annual Conference, September each year**
- In collaboration with **Journal of Network Theory in Finance**
- Many papers from key players in the field presenting cutting-edge research
- Proceedings now available online
- Attendees include
 - Regulators
 - Financial practitioners
 - Academics
- Keynotes include central banks presenting their techniques for assessing systemic risk and capital requirements in their market
- Cambridge Prize for Financial Network Visualization



We Need a Better Understanding of Contagion

Mario Draghi: Grexit would lead to "uncharted territory"

European Central Bank governor Mario Draghi said that should Greece exit the eurozone, the European Union would be entering "uncharted territory".



“Should Greece exit the Eurozone, the European Union would be entering "uncharted territory". What will the consequences on the EU be? This **we are unable to predict...**”

Mario Draghi, Governor of the European Central Bank
15 June 2015

Not Everyone Sees Contagion as a 'Given'

An email from a senior manager of a major US financial services company:

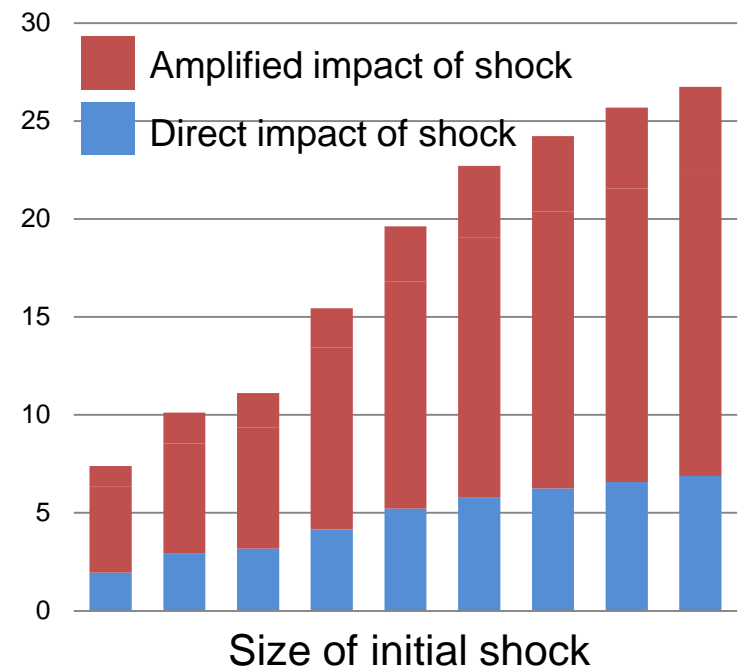
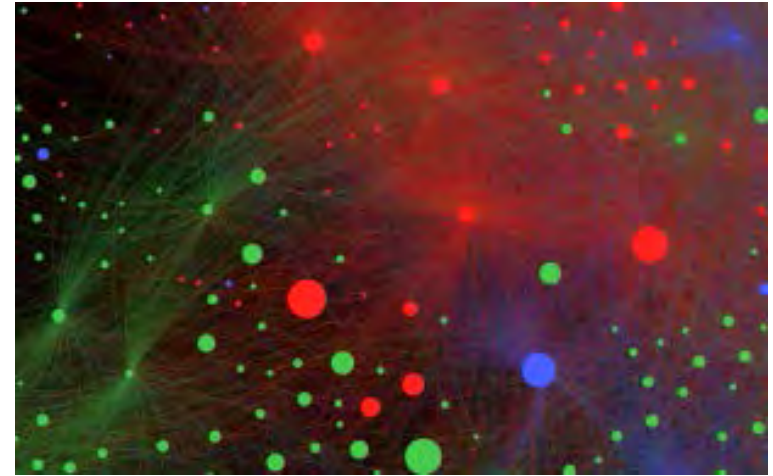
“I have some skepticism about contagion from a proposed scenario of property shock in China and the proposed Tier 1-6 markets affecting United States financial institutions...[because]

- US banks and investors have not lent heavily to real estate in the Tier 1-6 countries
- US real estate market is currently valued more in line with long-term averages

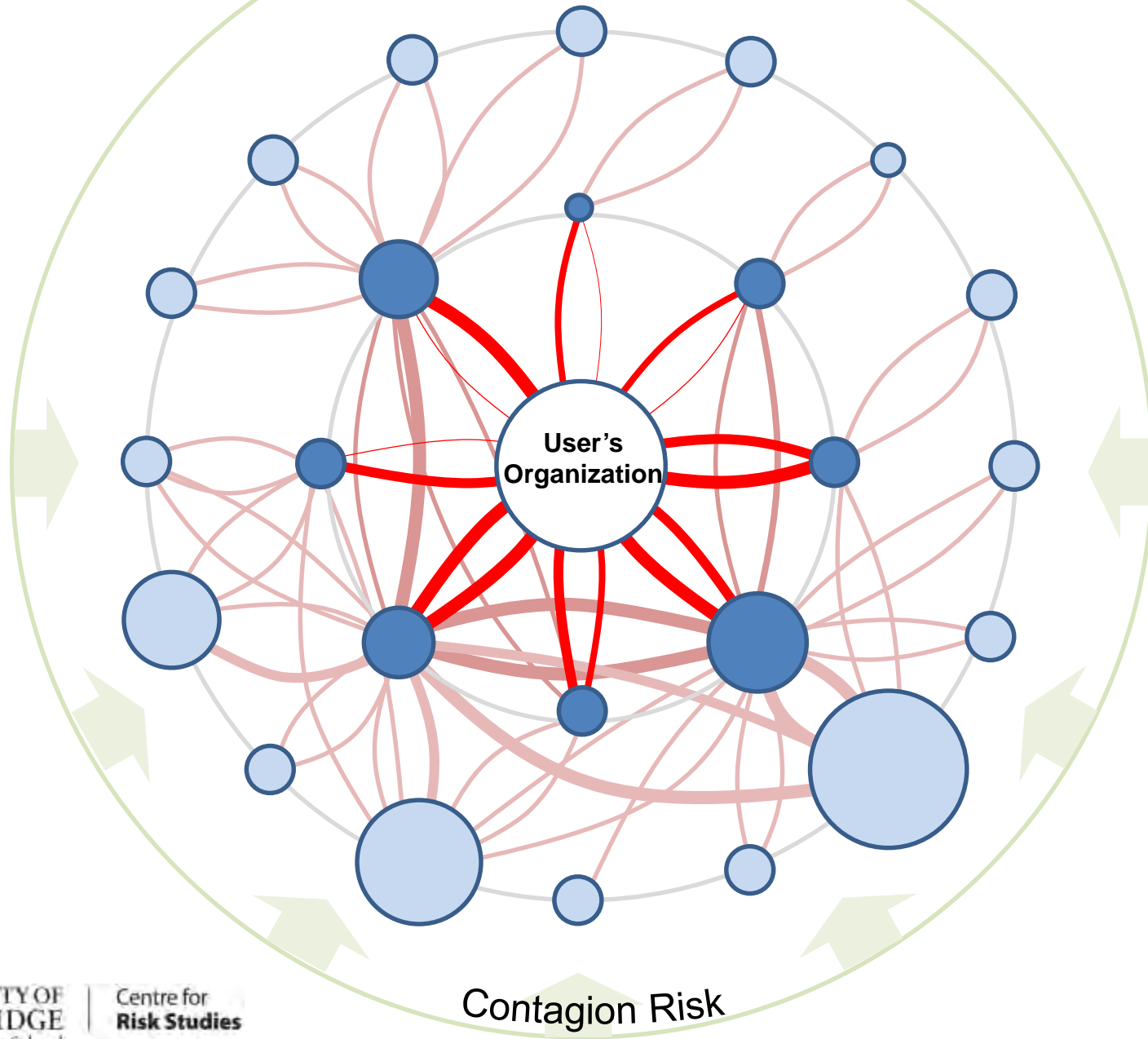
We face a challenge of explaining non-intuitive and indirect interactions of contagion mechanisms, rather than direct cross investment risks

Understanding Contagion and Systemic Shock

- The financial system is increasingly interconnected and integral to the economic system
 - Understanding the structure of the financial system and all its connections is vital
 - ‘Financial Cartography’
- Financial instability spreads through a variety of mechanisms
- Contagion amplifies:
 - severity of the shock impact
 - extent of who is affected
- It is behavioural
 - issues of trust, perception, and self-interest drive the collapse
 - Can we model ‘confidence’?
- This is a key research field
 - Working with the community of researchers on networks in finance



Counterparty Risk and Financial Interconnectivity



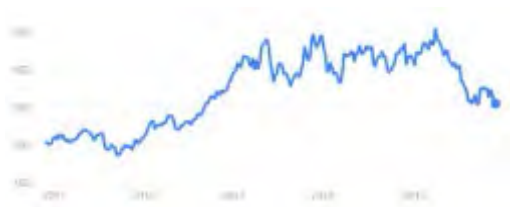
4. Response



4. Response

“There’s nothing you can do in a crisis. Everyone’s in the same boat. You just hold on and hope, and wait for sentiment to turn...”

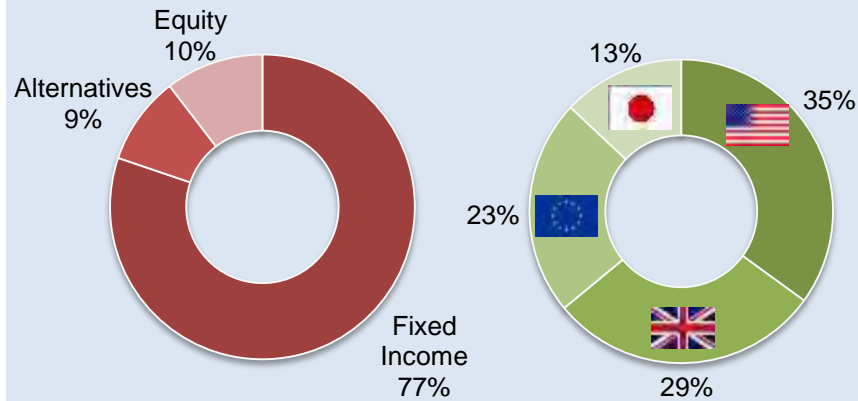
– Martin Gilbert, Chief Executive, Aberdeen Asset Management



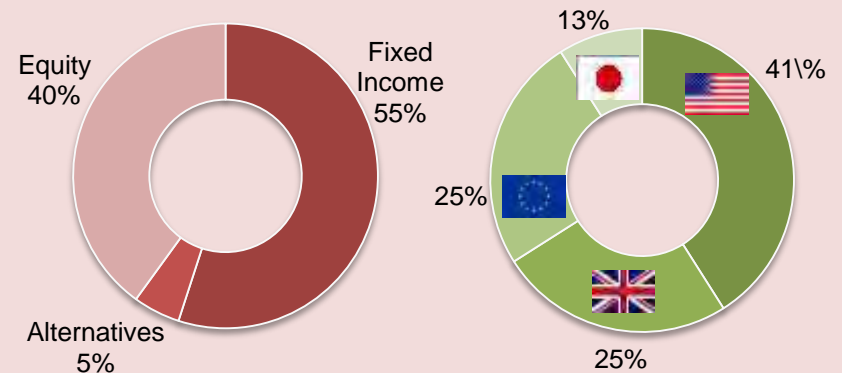
- Is this true?
- Most investors have a strategy for rebalancing their portfolios in a crisis
 - Many of these strategies are the same: a ‘flight to quality’
 - This may not always be the best strategy
- What is the optimal strategy for minimizing the impact of an unfolding scenario?

Different Investment Portfolios

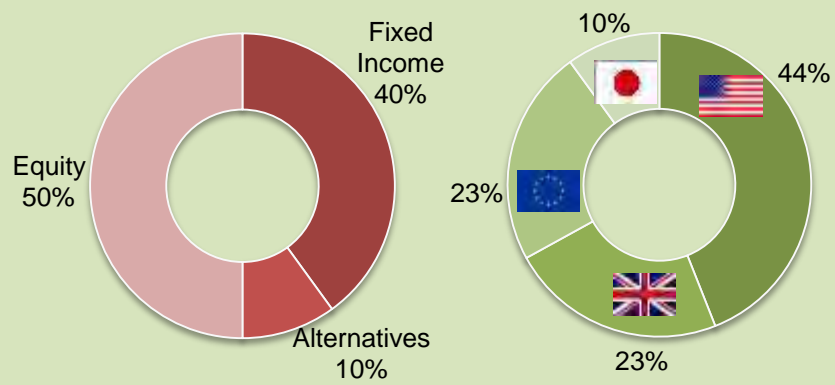
High Quality, Fixed Income



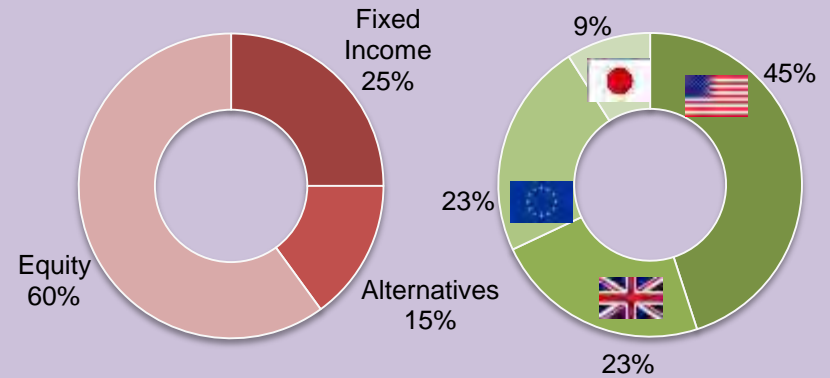
Conservative



Balanced

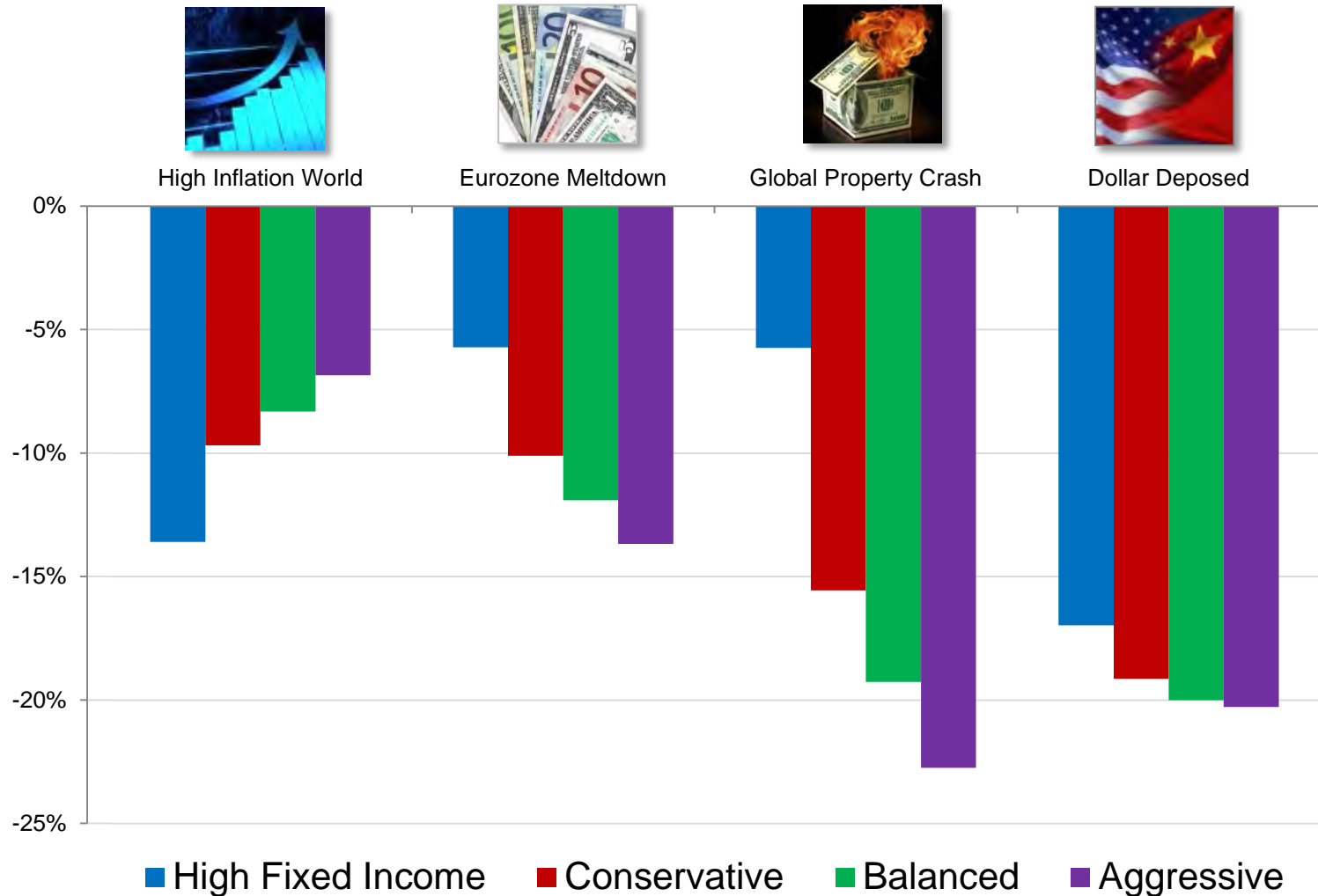


Aggressive





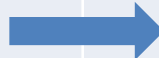



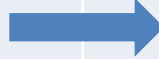




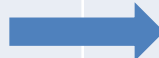



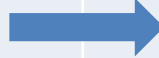


Investment Portfolio Performance in Different Scenarios

S1 Scenario Variant
Based on Max Downturn, Real USD %

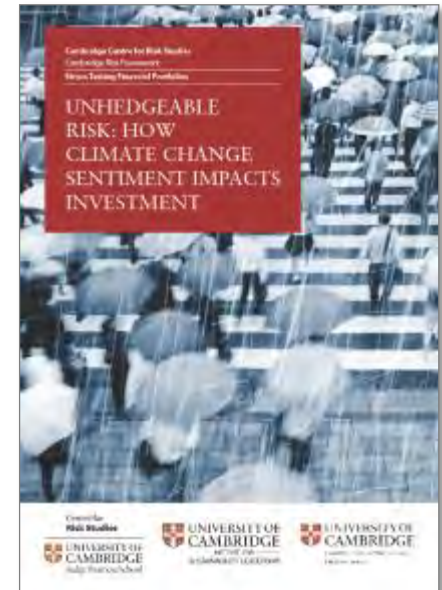
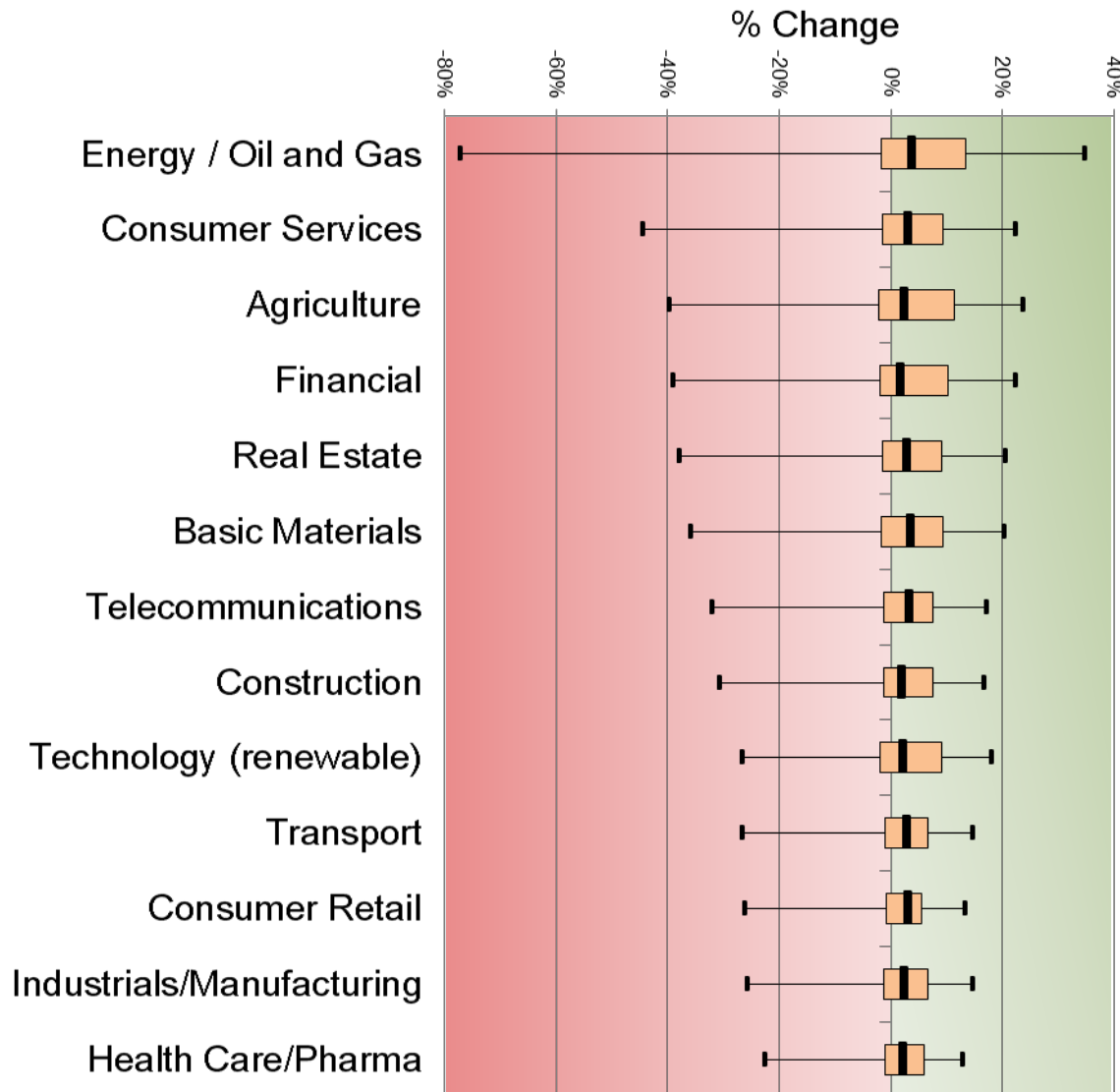


Rebalancing a Fixed Income Bond Portfolio

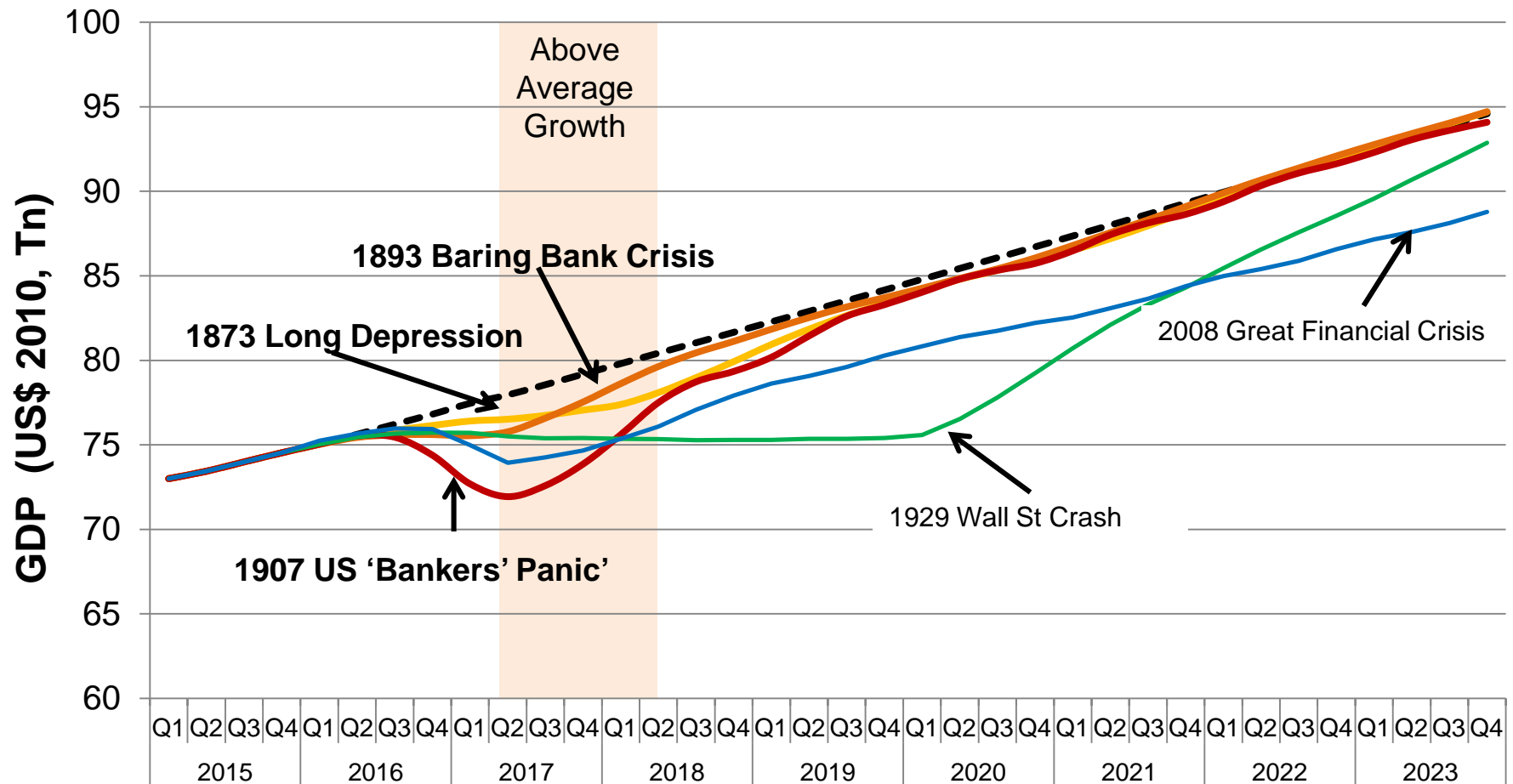
Cumulative Returns, Real USD %

	Worst Equity Performance	Best Equity Performance
 Asset Bubble Shock Global Property Crash	 	
 Sovereign Default Shock Eurozone Meltdown	 	 
 Food and Energy Price Spiral High Inflation World	 	
 De-Americanisation of Financial System Dollar Deposed	 	 

Scenario Impacts on Different Sectors of the Economy



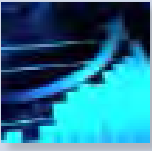



Recovery Periods Provide Faster Growth Opportunities



■ Can we improve modeled predictions of recovery timing?

Leading Indicators for Different Crisis Types

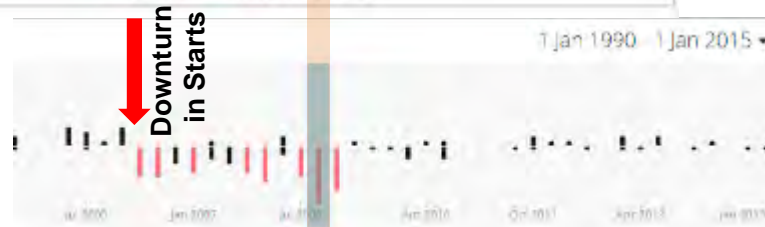
	Illustrative Scenario	Financial Crisis Type	Early warning indicators	Case Study	Lead time
	Global Property Crash	Asset Bubble: Property	Property construction stats: <ul style="list-style-type: none"> • New homes completed; • Property price index; • Ratio of income to prices; • Rental to house price; 	2008 Sub-Prime Crisis	9-12 months
	Eurozone Meltdown	Sovereign Default	<ul style="list-style-type: none"> • Government bond prices • Correlation metrics • Outlier count 	Greece 2008-2012	9-12 months
	High Inflation World	Inflation spiral	<ul style="list-style-type: none"> • Velocity of circulation • Debt to GDP • Money Supply • Input prices • Commodities/oil • Food 	Inflation tracking	3-12 months
	Dollar Deposed	Currency Crisis	<ul style="list-style-type: none"> • Debt to GDP • Trade balance statistics • Domestic Investment • Treasury values • Currency relativities 	US \$ vs China Renminbi	3-12 months

Market Data as Leading Indicator of 2008 Crash

Stock Market

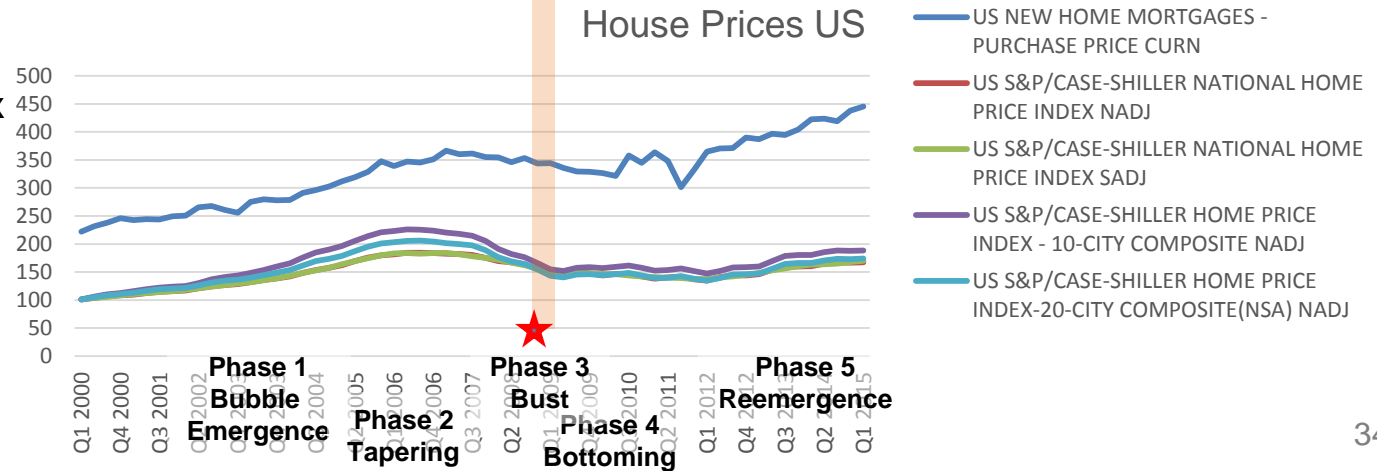


House Starts Statistics Index



Drastic slowdown
In House Construction
Precedes Home Prices
Fall by almost 2 years

House Price Index



Rebalancing Strategies for Managing Crises

- How many rebalancing strategies might we need, to cover all eventualities?
- We propose to develop an event set of a wide range of systemic risk scenarios (several thousands)
 - and the **portfolio rebalancing strategies** that minimize the impact of each of these scenarios on portfolio yields
 - There are many variations of mitigation and hedging strategies for best results
- These rebalancing strategies can be implemented during the crisis as the characteristics of the crisis emerge
- This will enable an investment management team to develop rules and best-practice for monitoring systemic risk
 - Including when to trigger a rebalancing strategy
- We propose to develop
 - a dashboard for monitoring signals of systemic risk
 - a suite of portfolio rebalancing strategies for thousands of potential crises of many different types
 - a best-practice guide for implementing mitigation measures

Systemic Risk Monitoring

- From monitoring the financial markets over the past three years (using the FNA Correlation Analytics application) there have been at least four systemic events with serious significance for investment portfolios
 - Gold and commodities crash April 2013
 - Energy markets oil price shock Nov 2014
 - Shanghai stock market correction and commodities crash August 2015
 - Swiss Franc devaluation Jan 2015
- For case studies of these see
 - ‘Early Warning - Gold: Gold crash of April 2013’ and ‘Energy Meltdown’ on <http://www.fna.fi/heavytails>
- Systemic events occur with a regularity that would make routine daily monitoring of systemic threats a valuable process



HeavyTails Early Warning - Energy

Energy meltdown

What precipitated the global energy collapse? We focus on the tipping point in energy markets in 2014, which cascaded into a Subprime Energy Bubble bust with major systemic risk implications going forward.



■ Financial catastrophes are the single greatest risk to economic output in our threat universe

- Everyone should care about them, not just banks and regulators

■ The tools for practitioners to understand and manage financial catastrophes are currently inadequate

- The Centre for Risk Studies is assisting in the development of better analytics for financial catastrophe risk management

■ The financial services industry can do better

- Applying research outputs and making new tools available will improve risk management practice and improve our financial stability

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