Cambridge Centre for Risk Studies
**Advisory Board Research Showcase –** 13 January 2016

# Financial Catastrophe Research
# & Stress Test Scenarios
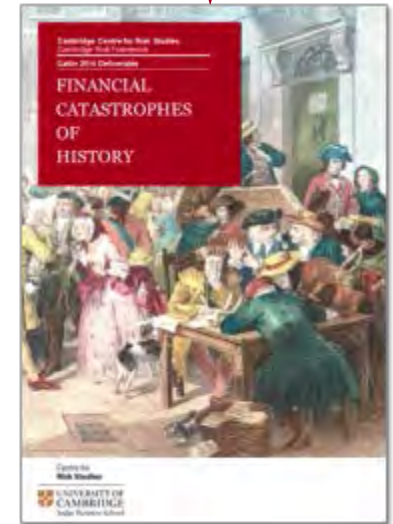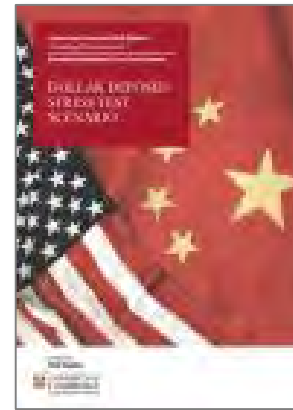
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Andy Skelton
Research Associate

# Financial Catastrophe Research

1. Catalogue of historical financial events

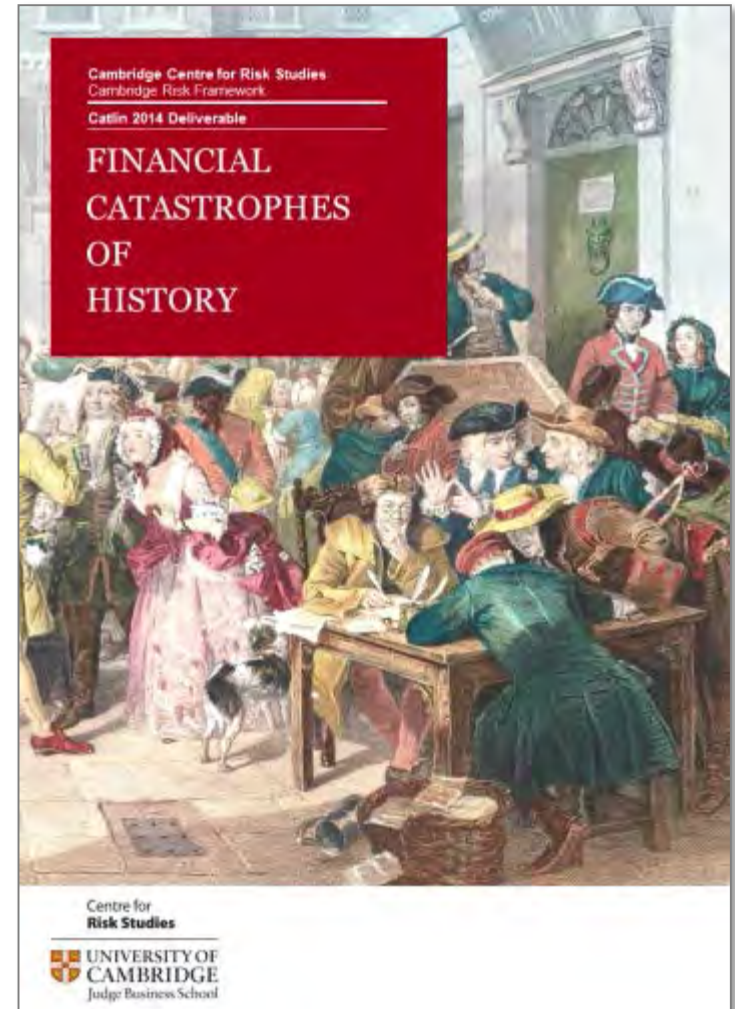2. Development of stress test scenarios

3. Understanding contagion processes
in financial networks (eg, interbank loans)
   - Network models & visualisations
   - Role of central banks in financial crises
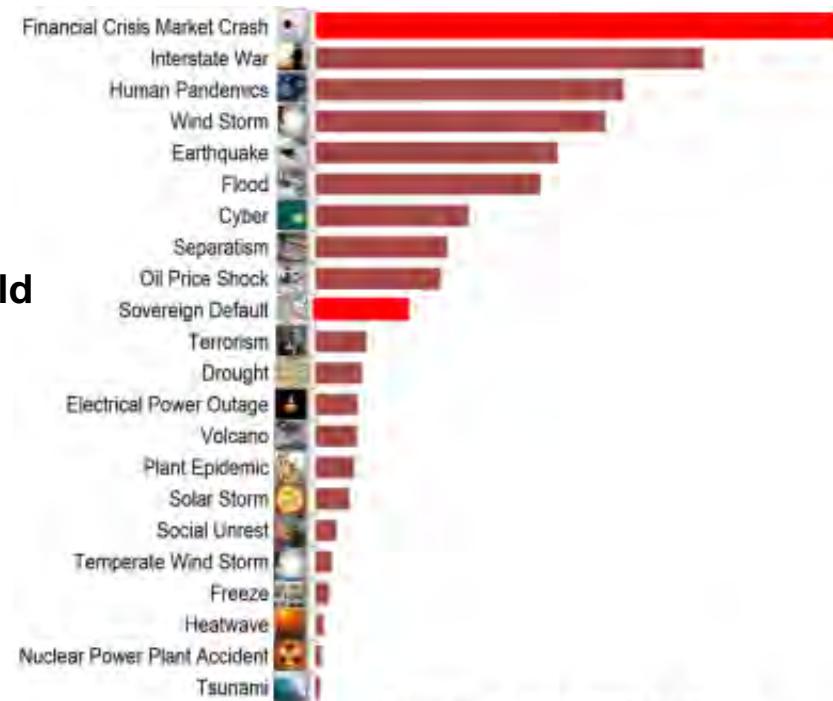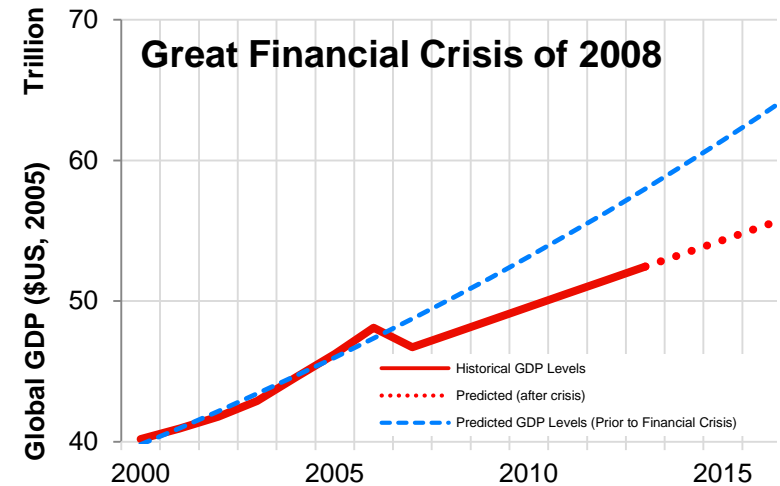   - Practitioner model – scoping exercise

# Learning from History

- A key component of understanding financial crises is the study of past events
- What happened, and what drove them?
- What-If… they were to happen today?
- Technologies have changed, but human behaviour remains – crowd behaviour
- What does it tell us about the past frequency and severity of crises?
- What might the future frequency and severity of crises be?
- **12 Historical Financial Crisis**
- **Report being prepared for publication**



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Catlin 2014 Deliverable

**FINANCIAL CATASTROPHES OF HISTORY**

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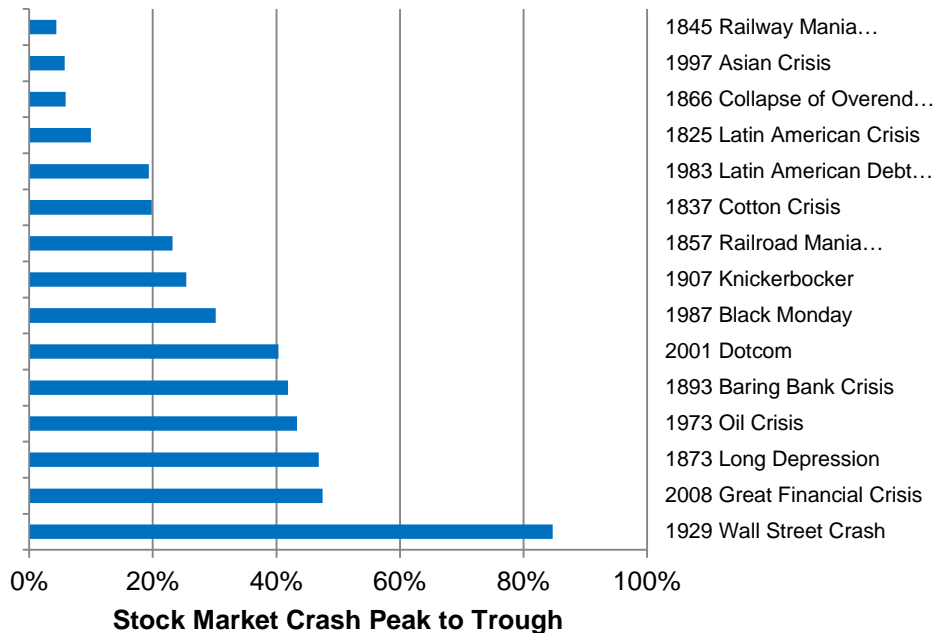
# The Economic Burden of Financial Catastrophes

- The Great Financial Crisis of 2008 destroyed an estimated **$20 Trillion** of world economic output
  - It was the most recent crisis, and the most severe, for some time
- Financial crises occur periodically, with different causes, and different severities
  - In the past generation, we have had a financial crisis **every 8 years** on average
- We estimate that the financial burden of crises averages **$0.5 Trillion** of lost economic output per year
  - This is around **1 percentage point** of global economic output
  - Without financial catastrophes global growth **could be 4% a year** instead of 3%
- Financial catastrophes are the single greatest economic risk for society
  - We need to understand them better

**Great Financial Crisis of 2008**

Trillion

Global GDP ($US, 2005)

— Historical GDP Levels
····· Predicted (after crisis)
--- Predicted GDP Levels (Prior to Financial Crisis)

2000   2005   2010   2015

Financial Crisis Market Crash
Interstate War
Human Pandemics
Wind Storm
Earthquake
Flood
Cyber
Separatism
Oil Price Shock
Sovereign Default
Terrorism
Drought
Electrical Power Outage
Volcano
Plant Epidemic
Solar Storm
Social Unrest
Temperate Wind Storm
Freeze
Heatwave
Nuclear Power Plant Accident
Tsunami

GDP@Risk from 2015 to 2025

# Historical Severities of Crashes – Past 200 Years

## US Stock Market Crashes



| | | |
|---|---|---|
| 1845 Railway Mania… | | |
| 1997 Asian Crisis | | |
| 1866 Collapse of Overend… | | |
| 1825 Latin American Crisis | | |
| 1983 Latin American Debt… | | |
| 1837 Cotton Crisis | | |
| 1857 Railroad Mania… | | |
| 1907 Knickerbocker | | |
| 1987 Black Monday | | |
| 2001 Dotcom | | |
| 1893 Baring Bank Crisis | | |
| 1973 Oil Crisis | | |
| 1873 Long Depression | | |
| 2008 Great Financial Crisis | | |
| 1929 Wall Street Crash | | |

**Stock Market Crash Peak to Trough**
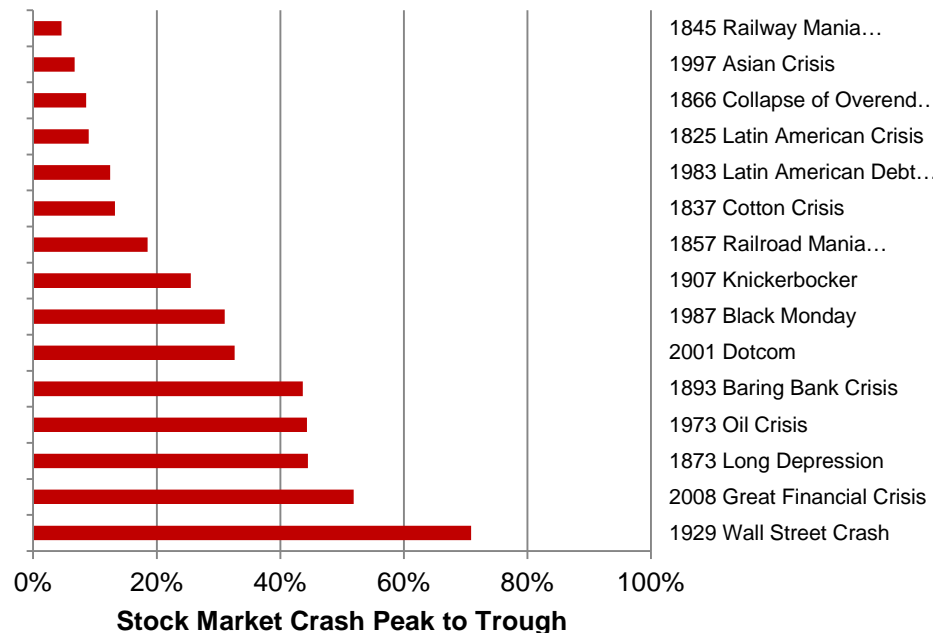
Observed, last 200 years

| Crashes Greater Than | Number of Crises | Average Interval (Yrs) |
|---|---|---|
| 10% | 12 | 16 |
| 20% | 9 | 21 |
| 40% | 6 | 32 |
| 50% | 1 | 190 |

## UK Stock Market Crashes



| | | |
|---|---|---|
| 1845 Railway Mania… | | |
| 1997 Asian Crisis | | |
| 1866 Collapse of Overend… | | |
| 1825 Latin American Crisis | | |
| 1983 Latin American Debt… | | |
| 1837 Cotton Crisis | | |
| 1857 Railroad Mania… | | |
| 1907 Knickerbocker | | |
| 1987 Black Monday | | |
| 2001 Dotcom | | |
| 1893 Baring Bank Crisis | | |
| 1973 Oil Crisis | | |
| 1873 Long Depression | | |
| 2008 Great Financial Crisis | | |
| 1929 Wall Street Crash | | |

**Stock Market Crash Peak to Trough**

Observed, last 200 years

| Crashes Greater Than | Number of Crises | Average Interval (Yrs) |
|---|---|---|
| 10% | 11 | 17 |
| 20% | 8 | 24 |
| 40% | 5 | 38 |
| 50% | 2 | 95 |

# Modelling Historical Financial Crises
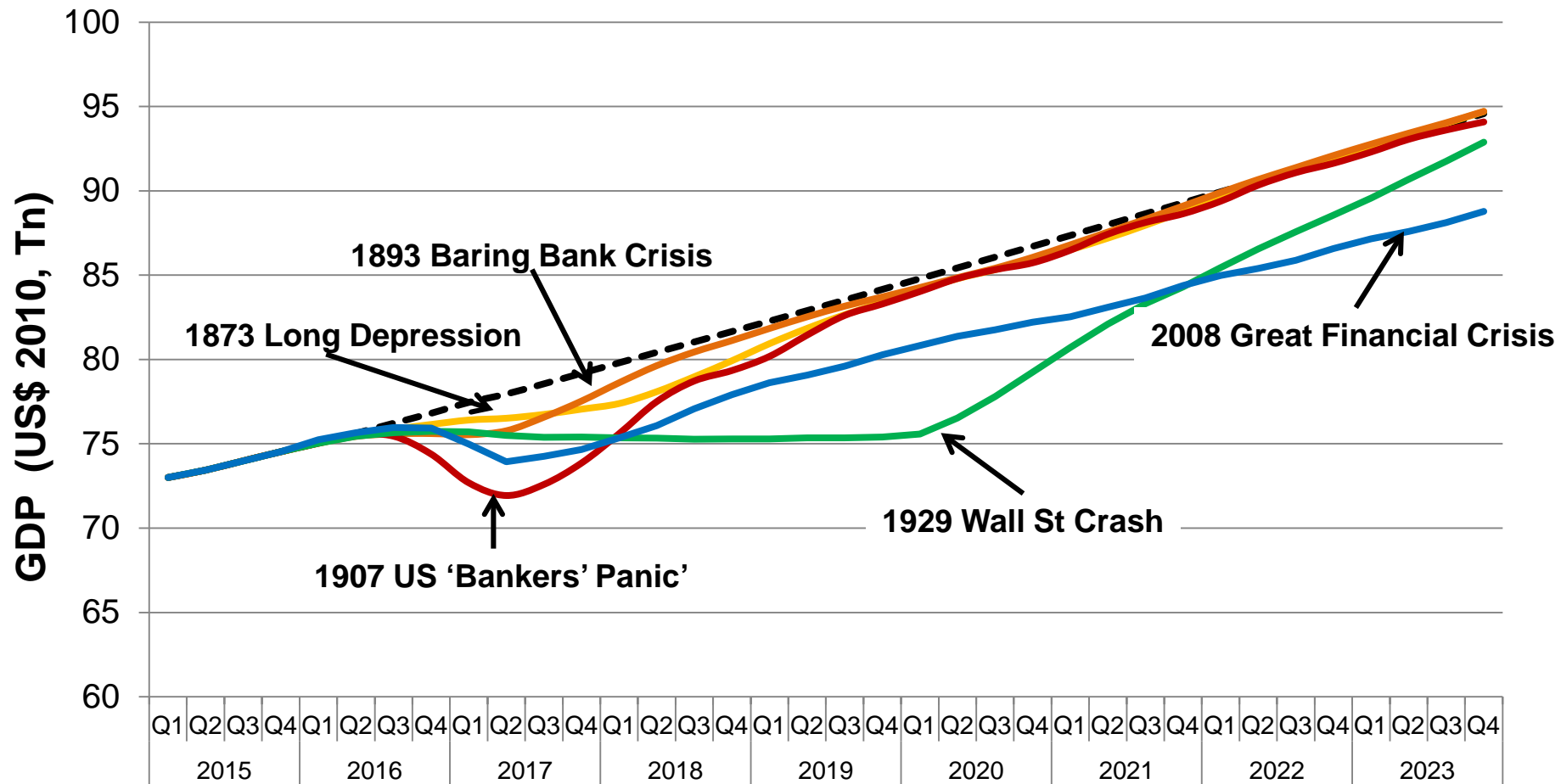
# Estimating GDP@Risk
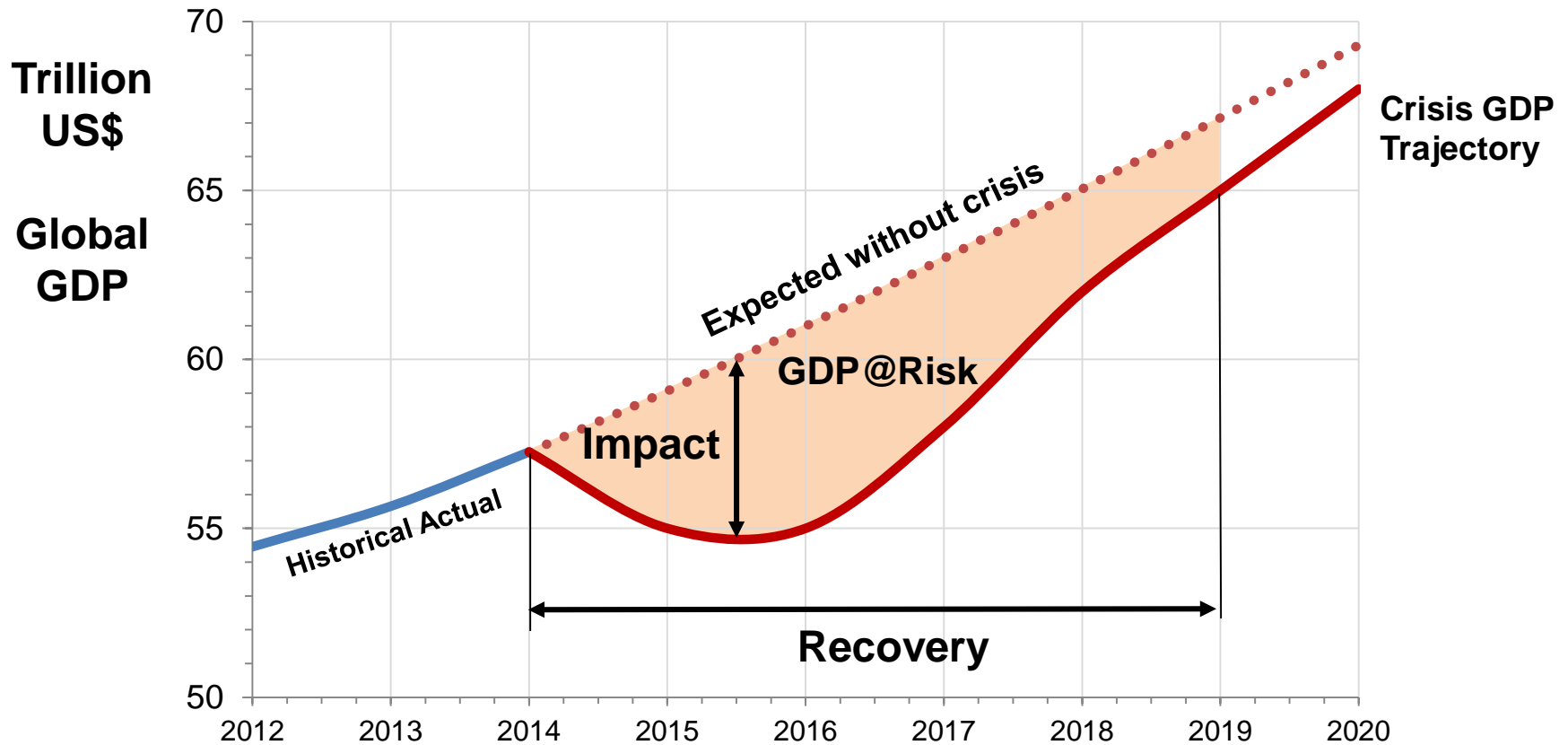


**GDP@Risk:** Cumulative first five year loss of global GDP, relative to expected, resulting from a catastrophe or crisis

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# GDP@Risk from Historical Events

| GDP@Risk  US$ Trillion, 2010 prices | GDP@Risk |
|---|---|
| 1893 Baring Bank Crisis | 5 |
| 1873 Long Depression | 7 |
| 1907 US 'Bankers' Panic' | 14 |
| 2008 Great Financial Crisis | 20 |
| 1929 Wall Street Crash | 30 |

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# Taxonomy of Financial Crisis

**Complex / Technological**
- ↳ Flash crash
- ↳ Black box trading
- ↳ Complex derivatives
- ↳ Cyber crash

**Inflation**
- ↳ Cost-push inflation
- ↳ Demand-pull inflation
- ↳ Deflation
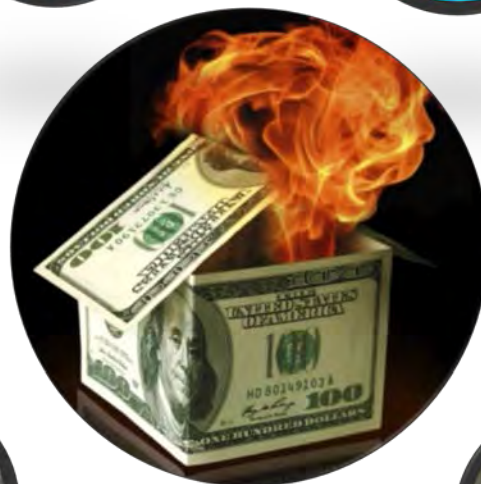
**Banking Crisis**
- ↳ Systemic failure
- ↳ Bank run
- ↳ Credit crunch

**Currency Crisis**
- ↳ Reserve currency
- ↳ FX shock

**Asset Bubble**
- ↳ Stock market crash
- ↳ Commodity price bubble
- ↳ Property price bubble

**Debt**
- ↳ Sovereign Debt
- ↳ Private Debt

**Illegal Activity**
- ↳ Fraud
- ↳ Financial irregularity

# What is a Stress Test Scenario?

- Use **narratives** that pose 'what if' questions and explore views about alternative futures.
- Help deal with **complexity** and **uncertainty**
- Release us from conditioning and existing habits that may inhibit new actions and insight
- Bring together creativity and analytics
- **Not predictions, or forecasts**
- A **coherent**, '**severe** yet **plausible'** expectation about the future
  - Sufficiently impactful to reveal vulnerabilities in a portfolio/system
  - Realistic enough to justify managerial attention or remediation

- Used to improve business resilience to shocks

# Cambridge Stress Test Scenarios



## Context

A justification and context for a 1% annual probability of occurrence worldwide based on historical precedents and expert opinion
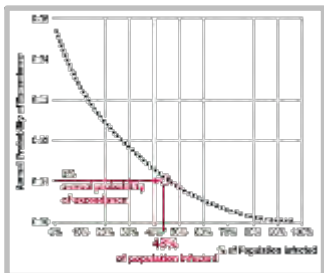
## Timeline & Footprint

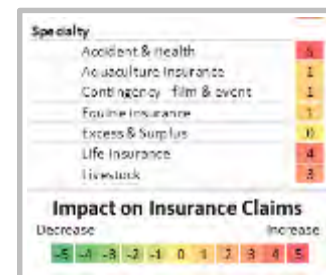**Sequencing of events in time
and space in hypothetical scenario**



## *Narrative*

*Detailed description of events
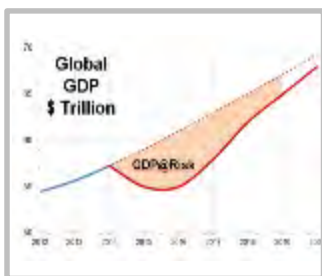3-4 variants of key assumptions for
sensitivity testing*



## *Loss Assessment*

*Metrics of underwriting loss across many
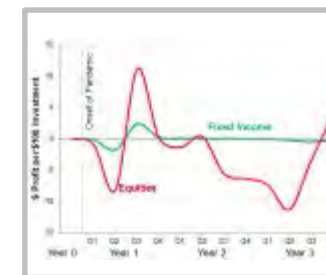different lines of insurance business*



## Macroeconomic Consequences

Quantification of effects on
many variables in the global economy



## Investment Portfolio Impact

Returns and performance over time
of a range of investment assets

# Cambridge Financial Stress Test Scenarios

## Global Property Crash

Sudden collapse of property prices in the inflated property markets and this triggers a cascading crisis throughout the global financial system

## Eurozone Meltdown

The default of Italy is followed by a number of other European countries, leading to multiple cession from the European 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
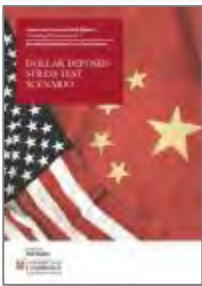
## Dollar Deposed

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

# Global Property Crash: Narrative

## 1. Shake-up

- Emerging market property prices & rental returns begin to slip
- Triggers sell-off by shrewd investors that gains momentum
- Chinese & Indian property markets begin to plummet
- International property market destabilised – most inflated markets hit first

## 2. Bubble Bursts

- Contagion flows through global financial system
- Bubble bursts in Australia, followed by NZ & Canada (all with highly inflated property markets)
- Labelled a "global collapse" & worldwide property prices plummet
- Mortgage equity markets shrink, several large European banks allowed to fail

## 3. Rock Bottom

- IMF declares a global recession
- Global cycle of negative growth – austerity measures have little effect for several years
- Low consumer confidence dampens low interest rate stimulus measures
- Triggers deflationary spirals in major economies for next 3 years, with 2 more years till recovery

# Global Property Crash: Macroeconomic losses

| Location | Baseline 5-yr GDP (US$ Tn) | S1 GDP@Risk (US$ Tn) | S1 GDP@Risk (%) | S2 GDP@Risk (US$ Tn) | S2 GDP@Risk (%) |
|---|---|---|---|---|---|
| Tier 1: China | 48.4 | 0.8 | 1.6% | 1.1 | 2.2% |
| Tier 2: Canada | 9.5 | 0.4 | 4.3% | 0.6 | 5.9% |
| Tier 3: Sweden | 2.8 | 0.1 | 3.0% | 0.1 | 4.4% |
| Tier 4: UK | 14.0 | 1.1 | 8.0% | 1.3 | 9.6% |
| Tier 5 & 6: Eurozone | 67.1 | 2.9 | 4.4% | 3.7 | 5.6% |
| Tier 7: US | 88.9 | 3.0 | 3.3% | 6.1 | 6.9% |
| Tier 8: Germany | 19.1 | 0.5 | 2.8% | 0.8 | 4.1% |
| Tier 9: Japan | 29.3 | 0.7 | 2.3% | 1.2 | 4.2% |
| World | 395.0 | 13.2 | 3.3% | 19.6 | 5.0% |
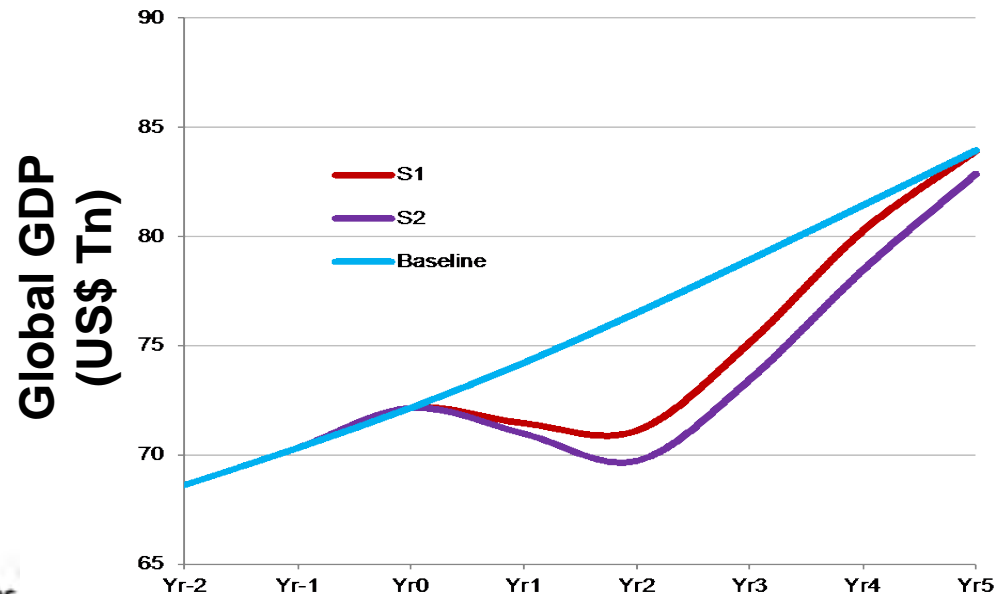
# Eurozone Meltdown: Narrative

## 1. Anti-Euro Italy

- Anti-austerity & Eurosceptic party wins snap Italian election & forms coalition with hard-line anti-European party
- EU declares that servicing of Italy's debt contingent on austerity measures
- New government offers robust rebuttal & announces extensive public welfare program

## 2. Italian Exit

- Italian exit agreed with an extensive support package
- Market value of Italian debt falls by 50%
- FI grinds to halt, foreign markets dump Eurobonds, sell-off of Italian assets
- Spanish, Portuguese & Greek long-term bond yields explode – leading to fiscal insolvency

## 3. Default Cascade

- Spain defaults and exits with comparable support package
- Markets fear Eurozone about to fall apart – confidence drops & decline in equity prices
- Portugal follows Spain, then Ireland within the week, then Greece
- Remaining members dragged into recession & stock markets fall

# Eurozone Meltdown: Macroeconomic losses

| Location | Baseline 5-Year GDP (US$ Tn) | S1 GDP @Risk (US$ Tn) | S1 GDP @Risk (%) | S2 GDP @Risk (US$ Tn) | S2 GDP @Risk (%) | X1 GDP @Risk (US$ Tn) | X1 GDP @Risk (%) |
|---|---|---|---|---|---|---|---|
| Greece | 1.3 | 0.16 | 11.6% | 0.22 | 16.3% | 0.24 | 17.9% |
| Germany | 19.1 | 0.95 | 5.0% | 0.78 | 4.1% | 0.95 | 5.0% |
| Eurozone | 67.1 | 4.17 | 6.2% | 4.72 | 7.0% | 4.91 | 7.3% |
| China | 48.4 | -0.08 | -0.2% | 0.03 | 0.1% | 0.61 | 1.3% |
| Japan | 29.3 | 0.33 | 1.1% | 0.47 | 1.6% | 0.65 | 2.2% |
| United Kingdom | 14.0 | 1.39 | 9.9% | 1.88 | 13.5% | 2.34 | 16.8% |
| United States | 88.9 | 2.72 | 3.1% | 4.62 | 5.2% | 8.62 | 9.7% |
| World | 395.0 | 11.24 | 2.8% | 16.26 | 4.1% | 23.24 | 5.9% |
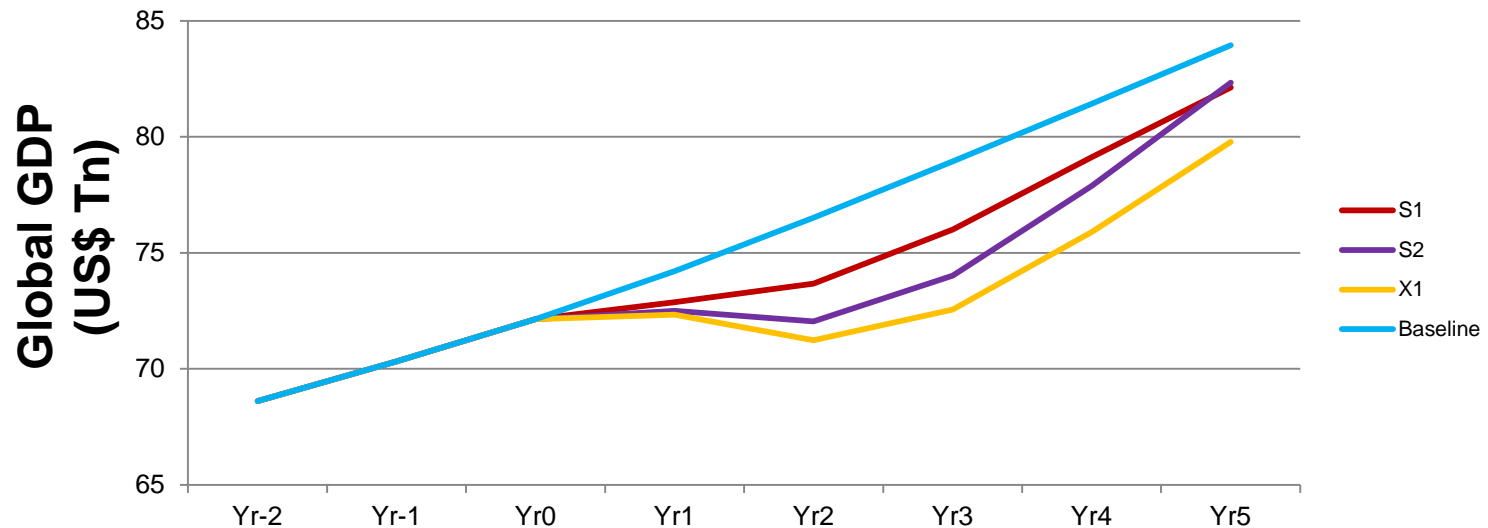
# High Inflation World: Narrative

## 1. Weather troubles

- Extreme weather across northern hemisphere
- Ecological crisis – US, Europe & China see 70% decline in bee colonies
- Droughts lead to shortages in maize & cattle feed grains
- Prices increase for certain food groups

## 2. Oil troubles

- Militant separatist group seize control of Strait of Hormuz & 20% of world's crude exports
- Shipments of crude through the Strait restricted leading to surge in the price of oil
- Food prices escalate – millions go without food
- Cost-push spiral emerges worldwide

## 3. Worldwide Inflation

- Global food basket shrinks & world inflation rates approach double figures
- Consumer Price Inflation (CPI) spikes
- Demand for higher wages stimulates an unemployment spiral, exacerbating growth of inflation
- Central banks gradually adjust rates & prices begin to stabilise

# High Inflation World: Macroeconomic Losses

| Scenarios | Baseline | S1 | | S2 | | X1 | |
|---|---|---|---|---|---|---|---|
| Locations | 5-year GDP | GDP@Risk (US$, Tn) | GDP@Risk (%) | GDP@Risk (US$, Tn) | GDP@Risk (%) | GDP@Risk (US$, Tn) | GDP@Risk (%) |
| China | 48.4 | 1.1 | 2.9% | 2.0 | 3.9% | 2.7 | 4.6% |
| Germany | 19.1 | 0.1 | 1.1% | 0.2 | 1.5% | 0.5 | 1.7% |
| Japan | 29.3 | 0.3 | 1.3% | 0.4 | 1.8% | 0.7 | 2.1% |
| United Kingdom | 14.0 | 0.2 | 1.5% | 0.3 | 2.2% | 0.4 | 2.7% |
| United States | 88.9 | 1.6 | 2.4% | 2.5 | 3.1% | 3.4 | 3.6% |
| **World** | **395.0** | **4.9** | **1.7%** | **8.0** | **2.2%** | **10.9** | **2.6%** |
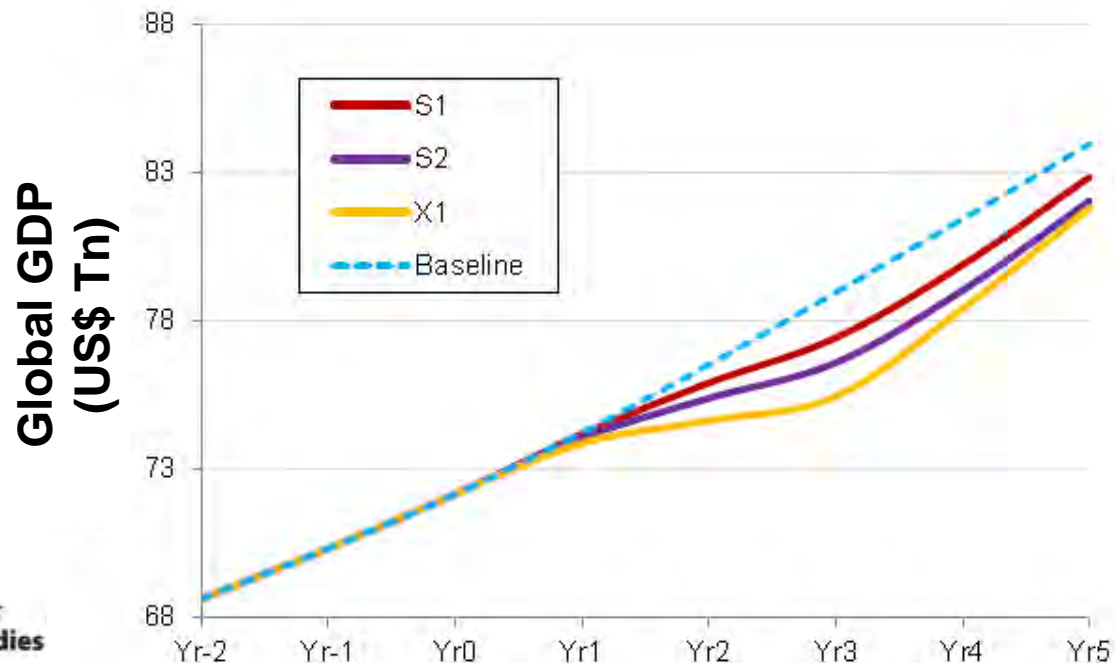
# Dollar Deposed: Narrative

**1. Trouble Brewing**

- Reduced global liquidity of the USD
- China's growth continues – increased int. trade, FDI & confidence in RMB trade
- China begins massive industrial development plan, funded by domestic bond market
- Business development predicted to follow

**2. Dollar Dumped**

- China's economy continues to accelerate
- Large scale infrastructure & commodity commitments (funded by US treasuries) drives USD down
- Forces flotation of RMB – de facto 'dump' of US bonds
- RMB gains credibility as reserve currency
- US rating downgraded – panic ensues

**3. Rise of the RMB**

- Smart money favours growth prospects in China
- US interest rate raised but faith in USD lost
- US falls into recession
- Flight to quality seen as investors move out of US into China, boosting FDI
- China's interest rate reduced as RMB gains strength in global markets

# Dollar Deposed: Macroeconomic Losses

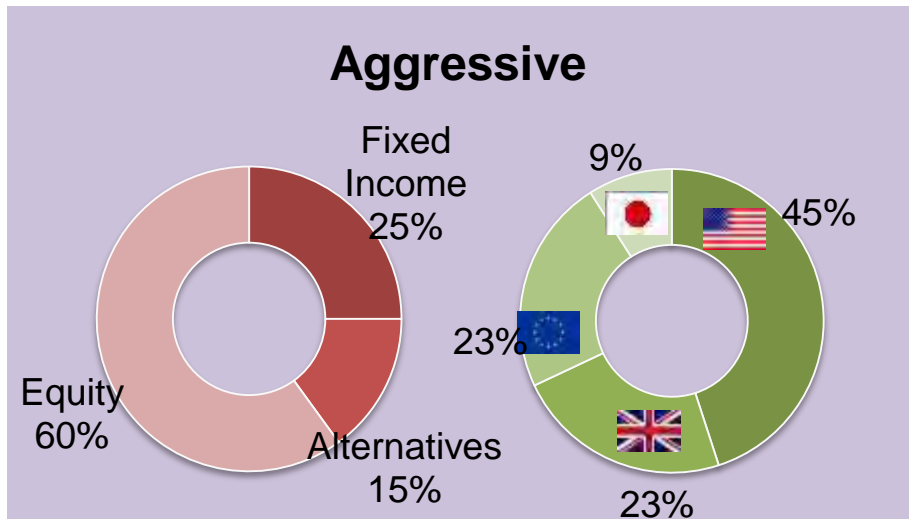| Location | 5-Year GDP (US$ Tn) | S1 | | S2 | | X1 | |
|---|---|---|---|---|---|---|---|
| | | GDP@Risk (US$ Tn) | GDP@Risk (%) | GDP@Risk (US$ Tn) | GDP@Risk (%) | GDP@Risk (US$ Tn) | GDP@Risk (%) |
| China | 48.4 | -0.4 | -0.8% | -0.9 | -1.8% | -1.5 | -3.1% |
| Germany | 19.1 | 0.0 | 0.1% | 0.0 | -0.2% | -0.2 | -1.1% |
| Japan | 29.3 | 0.2 | 0.8% | 0.2 | 0.6% | -0.2 | -0.8% |
| UK | 14.0 | 0.0 | 0.1% | 0.0 | 0.0% | -0.1 | -0.8% |
| US | 88.9 | 1.5 | 1.7% | 2.1 | 2.4% | 2.3 | 2.6% |
| World | 395.0 | 1.9 | 0.5% | 1.6 | 0.4% | -1.6 | -0.4% |
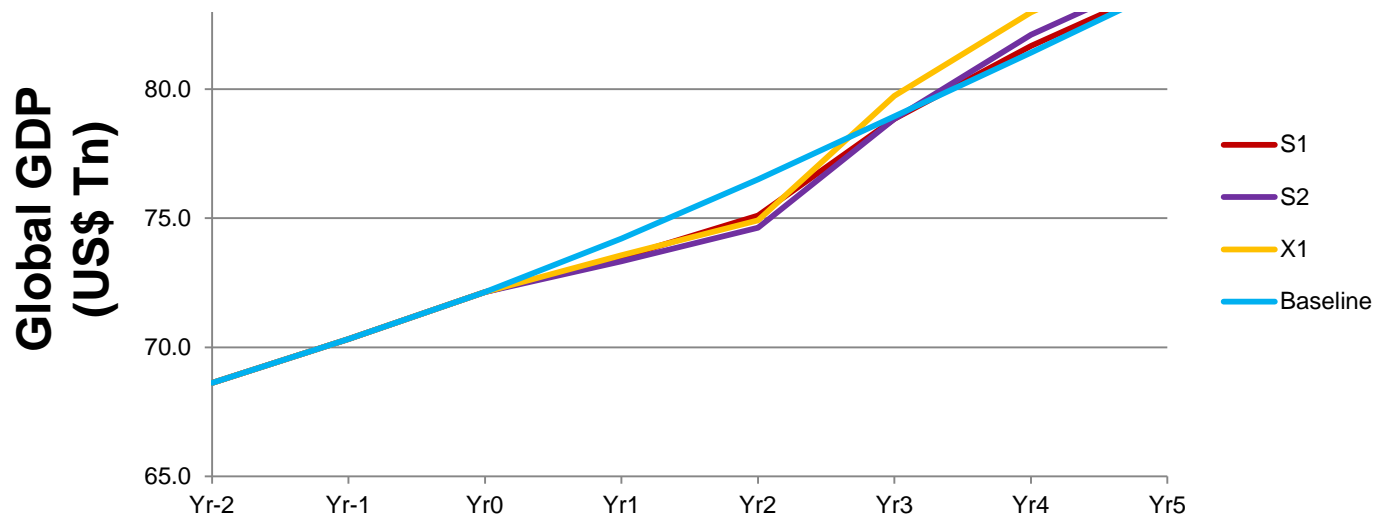
# Historical Events & Scenarios: GDP@Risk

| GDP@Risk  US$ Trillion, 2010 prices | GDP@Risk |
|---|---|
| 1893 Baring Bank Crisis | 5 |
| 1873 Long Depression | 7 |
| 1907 US 'Bankers' Panic' | 14 |
| 2007 Great Financial Crisis | 20 |
| 1929 Wall Street Crash | 30 |
| CRS Dollar Deposed | 2 |
| CRS High Inflation World | 5-11 |
| CRS Eurozone Meltdown | 11-23 |
| CRS Global Property Crash | 13-30 |

# Cambridge Scenarios: GDP@Risk

| GDP@Risk US$ Trillion | S1 | S2 | X1 |
|---|---|---|---|
| **Geopolitical Conflict**<br>**China-Japan Conflict** | **17** | 27 | 32 |
| **Asset Bubble Shock**<br>**Global Property Crash** | **13** | 20 | 30 |
| **Pandemic**<br>**Sao Paolo Virus** | **7** | 10 | 23 |
| **Sovereign Default Shock**<br>**Eurozone Meltdown** | **11** | 16 | 23 |
| **Food and energy price spiral**<br>**High Inflation World** | **5** | 8 | 11 |
| **Cyber Catastrophe**<br>**Sybil Logic Bomb** | **5** | 7 | 15 |
| **Social Unrest**<br>**Millennial Uprising** | **2** | 5 | 8 |
| **De-Americanisation of Financial System**<br>**Dollar Deposed** | **2** | 2 | -2 |

# Comparing Different Investment Portfolios



High Quality, Fixed Income
- Equity 10%
- Alternatives 9%
- Fixed Income 77%
- 13%
- 35%
- 23%
- 29%

Conservative
- Equity 40%
- Fixed Income 55%
- Alternatives 5%
- 9%
- 41%
- 25%
- 25%

Balanced
- Fixed Income 40%
- Equity 50%
- Alternatives 10%
- 10%
- 44%
- 23%
- 23%

Aggressive
- Fixed Income 25%
- Equity 60%
- Alternatives 15%
- 9%
- 45%
- 23%
- 23%
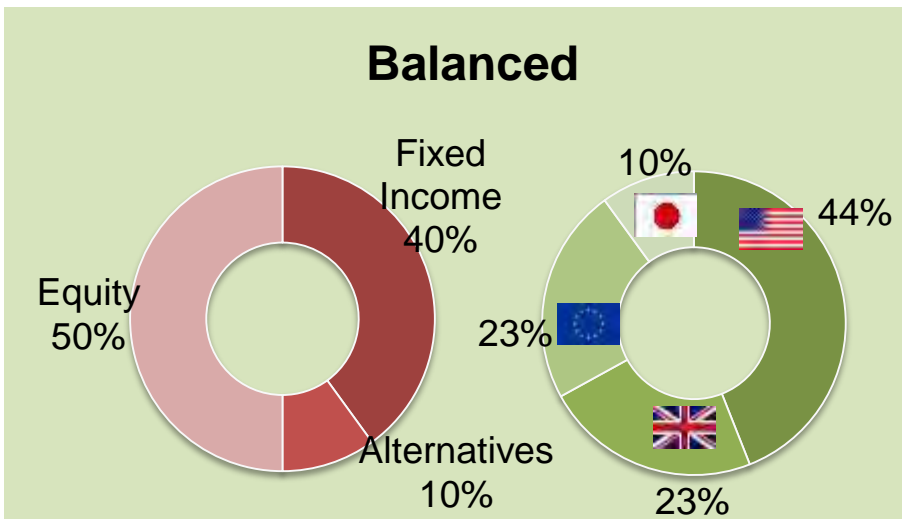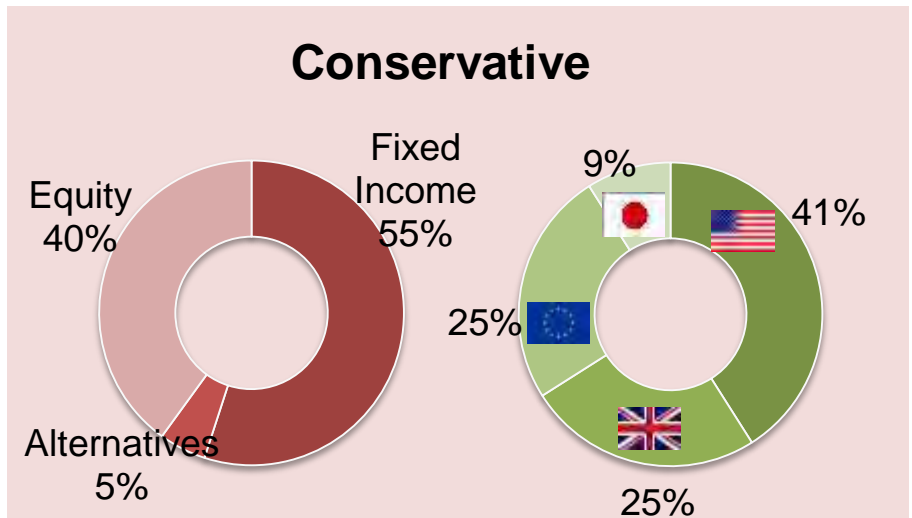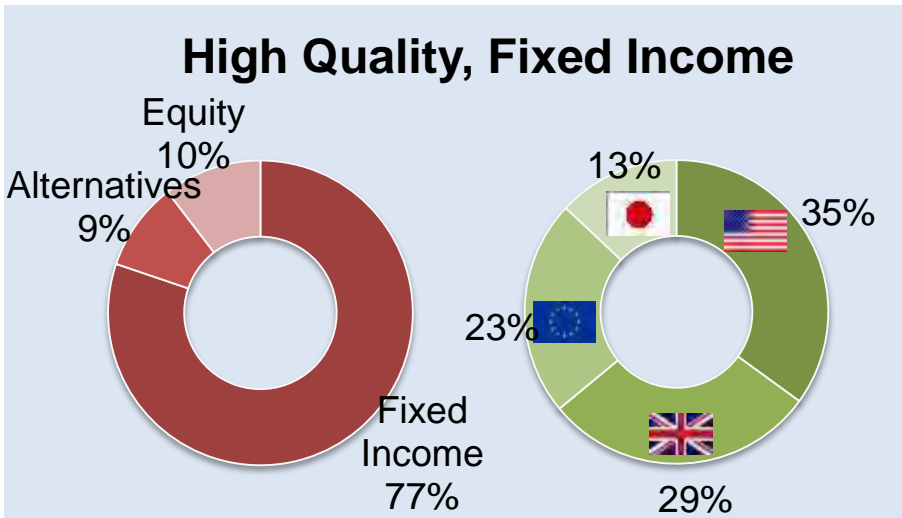
# Maximum Downturn in Portfolios across 4 Financial Catastrophe Scenarios



**Global Property Crash**     **Eurozone Meltdown**     **High Inflation**     **Dollar Deposed**

Legend: ■ High-Quality Fixed Income ■ Conservative ■ Balanced ■ Aggressive
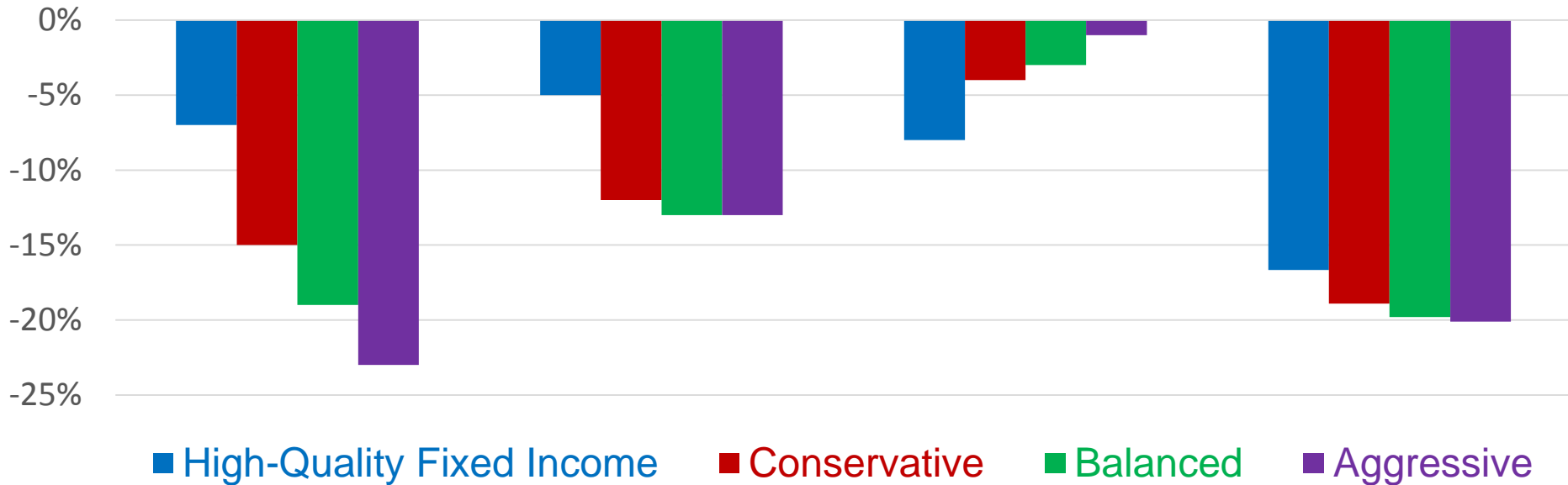
S1 variant of each scenario

# Future Research: Towards a Probabilistic FinCat Model

- Two problems:
  - Regulators: How to set capital requirements to buffer future events that haven't been seen before, but can be imagined?
  - Financial institutions: How to find an optimal rebalancing plan when faced with a catalogue of what-ifs?
- Probabilistic Graphical Models (PGMs) could be used to help give a quantitative probability dimension to scenario narratives and in a logically coherent manner[1]
  - Modular approach
  - Intuitive visual interface transparent to all (not a black box model)
- Systematic generation of shock scenarios[2]
  - Middle ground between traditional stress testing & reverse stress testing
  - Reduces danger of 'blind spots' in stress testing
- Early warning systems leading to real-time probabilities, dynamic capital measures and portfolio rebalancing plans

1. eg, Rebonato, R., & Denev, A. (2014). Portfolio Management under Stress. Cambridge Books.
2. eg, Mark D. Flood & George G. Korenko (2015) Systematic scenario selection: stress testing and the nature of uncertainty, Quant. Fin., 15:1, 43-59

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