Financial Risk and Network Theory

Seminar 9 September 2015

Financial Catastrophe Risk Modelling

Centre for Risk Studies

UNIVERSITY OF CAMBRIDGE Judge Business School

Dr Andrew Coburn

Cambridge Centre for Risk Studies

Risk journals

Agenda

1. Contagion
2. Contagion Scenarios
3. History, Crisis and Contagion
4. The Economic Burden of Contagion

Cambridge Financial Risk Research Team

Centre for Risk Studies Executive Team

Prof Danny Ralph
Academic Director

Dr Michelle Tuveson
Executive Director

Dr Andrew Coburn
Director of Advisory Board

Simon Ruffle
Director of Research & Innovation

Centre for Risk Studies Financial Risk Research Team

Dr Scott Kelly
Senior Research Associate

Dr Olaf Bochmann
Research Associate

Dr Andy Skelton
Research Associate

Dr Duncan Needham
Risk Researcher

Dr Ali Shaghaghi
Research Assistant

Dr Andrew Chaplin
Risk Researcher

Jaclyn Zhiyi Yeo
Research Assistant

Eugene Neduv
Risk Researcher

Dr Jay Jung
Risk Researcher

Tamara Evan
Editorial Associate

Jennifer Copic
Research Assistant

Siobhan Sweeney
Legal Risk Researcher

Reviewers and Advisors

Dr Louise Pryor
Senior Risk Researcher

Dr Kimmo Soramaki
CEO, FNA Ltd.

Alan Laubsch
Director, FNA Ltd.

Dr Fabio Caccioli
Risk Affliate

Dr Gordon Woo
Catastrophist, RMS Inc.

Samantha Cook
Chief Scientist, FNA

We Need a Better Understanding of Contagion

Mario Draghi: Grexit would lead to "uncharted territory"

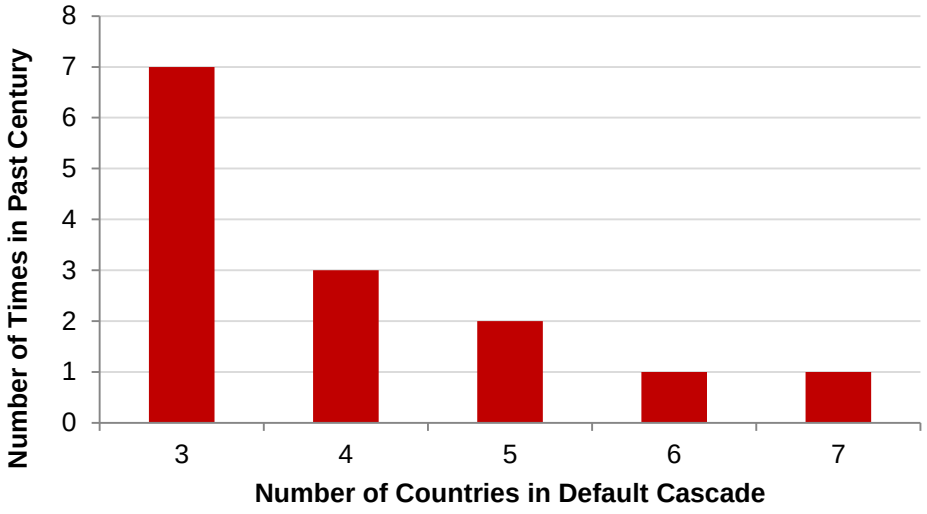
European Central Bank governor Mario Draghi said that should Greece exit the eurozone, the European Union would be entering "uncharted territory".

"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

Sovereign Defaults Happen in Waves

- 120 sovereign defaults in past 100 years
  - More than one default a year on average
- Main threat is cascades of sovereign defaults
  - Where multiple countries default under similar conditions or from follow-on consequences
  - Size of the economy defaulting is a key component
- A cascades involving 4 or more countries has occurred on average every 14 years



Correlations in Sovereign Default Cascades

- Contagion ‘spillover’ occurs if creditors to defaulting country incur so much loss that they, in turn, become insolvent
  - Trading flows between countries and intergovernmental loans show the burden that a default would cause on another country
- Borrowers (sovereign governments) and foreign lenders (investors) face frictions that interact in a vicious circle:
  - Creditors become more risk averse after any default
  - Any country default increases the cost of borrowing to other countries, particularly those with sub-optimal credit ratings
  - Foreign lenders have regulatory collateral constraints that limit their investment leverage in sovereign debt
- However - credit markets perceive little risk of contagion from spillovers following a sovereign default
  - In the 2015 Grexit crisis, Portugal sovereign debt CDS spreads imply default probability of 7.5%; Ireland around 5.3%.

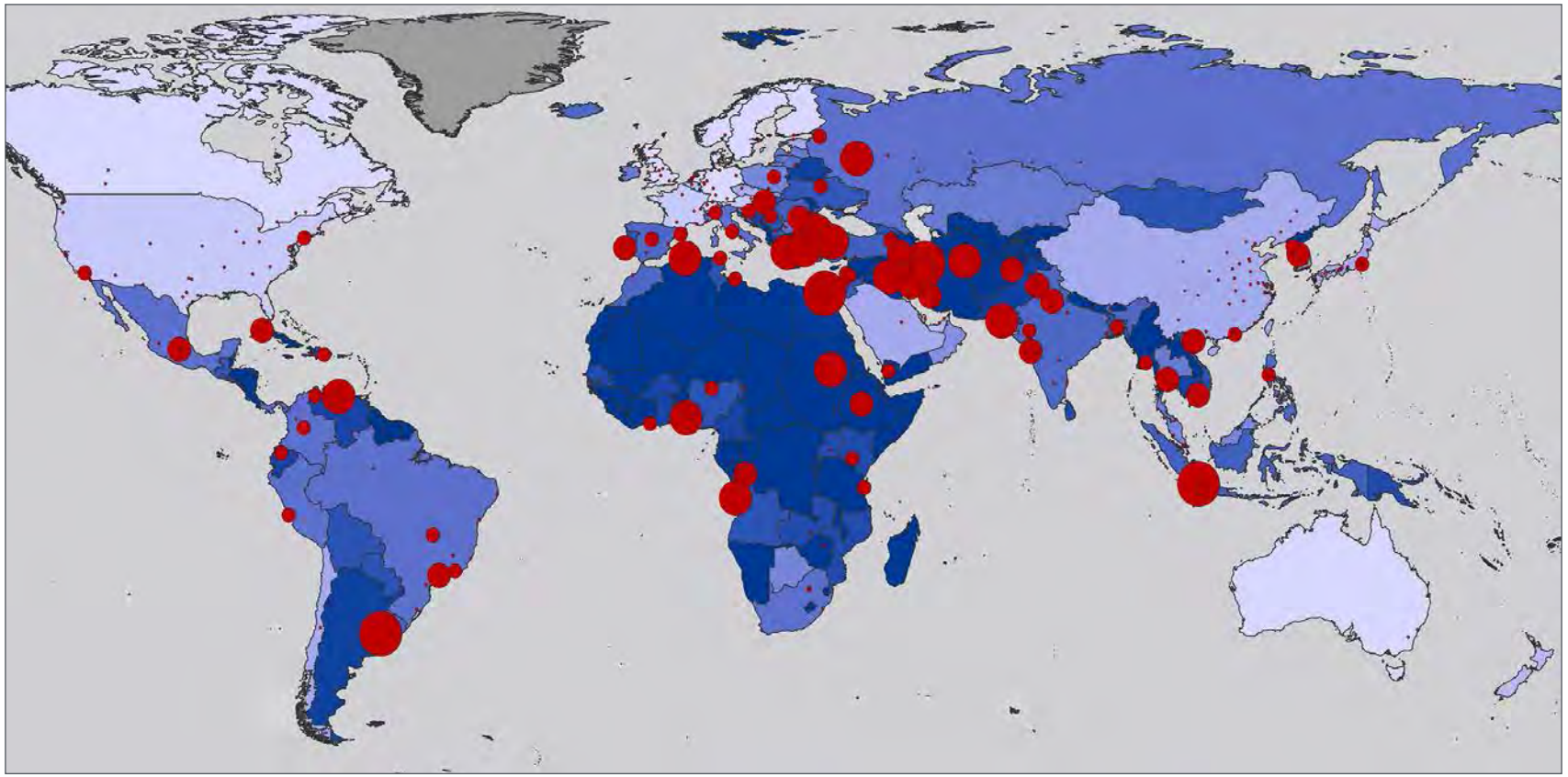
A Stress Test Scenario of Sovereign Default Contagion

Eurozone Meltdown

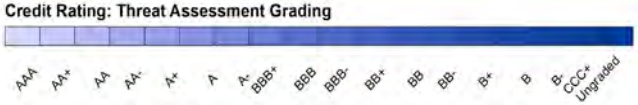
Unexpected default of Italy is followed by a number of other European countries, leading to multiple cession from the Union and causing an extensive financial crisis for investors

S1	S2	X1
Italy	Italy	Italy
Greece	Greece	Greece
Spain	Spain	Spain
Portugal	Portugal	Portugal
Ireland	Ireland	Ireland
	United Kingdom	United Kingdom
		Rest of Eurozone
Combined GDP: **$4.0 Tr**	**$6.7 Tr**	**$14.4 Tr**
% of World's GDP: 5.6%	9.0%	38.0%

World Mapping of Sovereign Default Risk



Credit Rating: Threat Assessment Grading



City - GDP@Risk ($US Bin)

Sovereign default, where a national government is unable to meet its financial obligations or honour its treasury bonds, results in devaluation of the national currency and the loss of foreign direct investment, which can have significant impact on the economic outputs of cities in that country. The published national credit rating of Standard and Poor's for June 2014 (pre-dating the Argentina default of July 2014) is used to assess the probability of national default, combined with an historical perspective of past defaults by countries from the post-1810 catalogue of Reinhart & Rogoff. The national assessment is applied to all cities in that country, to assess GDP loss and probability of the characteristic scenario of default:

SD1 Country defaults and reschedules its debt, devalues its currency substantially; Investors flee. National economy loses substantial foreign direct investment

Top 10 Cities by GDP@Risk ($US Bn)

1	ARG	**Buenos Aires**	12
2	TUR	**Istanbul**	10
3	IRN	**Tehran**	9
4	EGY	**Cairo**	8
5	IDN	**Jakarta**	7
6	VEN	**Caracas**	4
7	TUR	**Ankara**	3
8	ALG	**Algiers**	3
9	SDN	**Khartoum**	3
10	IRN	**Meshed**	3

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Stock Market Contagion: 24 Aug 2015

Shanghai

New York

London

Kuala Lumpur

Frankfurt

Mumbai

No Market Was Unaffected

China's 'Black Monday' sends markets reeling across the globe

Hundreds of billions wiped
rout sends shares tumbling

- Dow Jones index sheds 5
- S&P and Nasdaq now in
- FTSE 100 sheds £74bn
- VIX 'fear index' jumps
- Photos: Markets fall arou
- Chinese stock market tur

Americas >

Name	2 Days	Last	% Chng	Net Chng
S&P 500		1,886.61	-4.28 %	-84.28
DJI		16,000.63	-2.79 %	-459.12
NASDAQ 100		4,062.52	-3.21 %	-134.76
S&P/TSX		12,993.02	-3.57 %	-480.65
BOVESPA		43,846.87	-4.10 %	-1,872.77
MXSE IPC		40,332.77	-4.34 %	-1,831.05

Europe >

Name	2 Days	Last	% Chng	Net Chng
STXE 600		336.75	-6.79 %	-24.53
FTSE 100		5,904.29	-4.58 %	-283.36
DAX		9,507.46	-6.09 %	-617.06
CAC 40		4,303.14	-7.08 %	-327.85
FTSE MIB		20,666.59	-4.96 %	-1,079.58
SMI		8,346.27	-5.14 %	-452.30
AEX		409.44	-7.55 %	-33.43
IBEX		9,603.80	-6.50 %	-667.90
OMXS 30		1,424.64	-4.73 %	-70.71

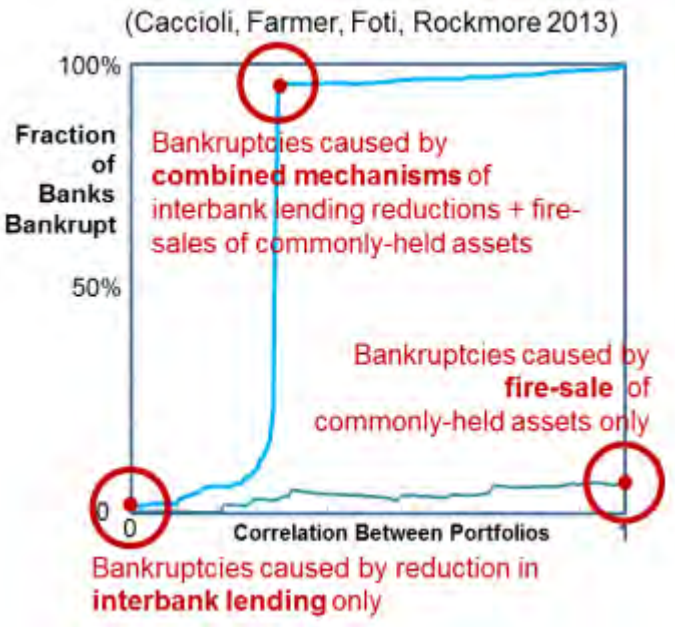
Asia >

Name	2 Days	Last	% Chng	Net Chng
NIKKEI 225		18,540.68	-4.61 %	-895.15
S&P/ASX 200		5,001.28	-4.09 %	-213.32
HANG SENG		21,251.57	-5.17 %	-1,158.05

24 August 2015

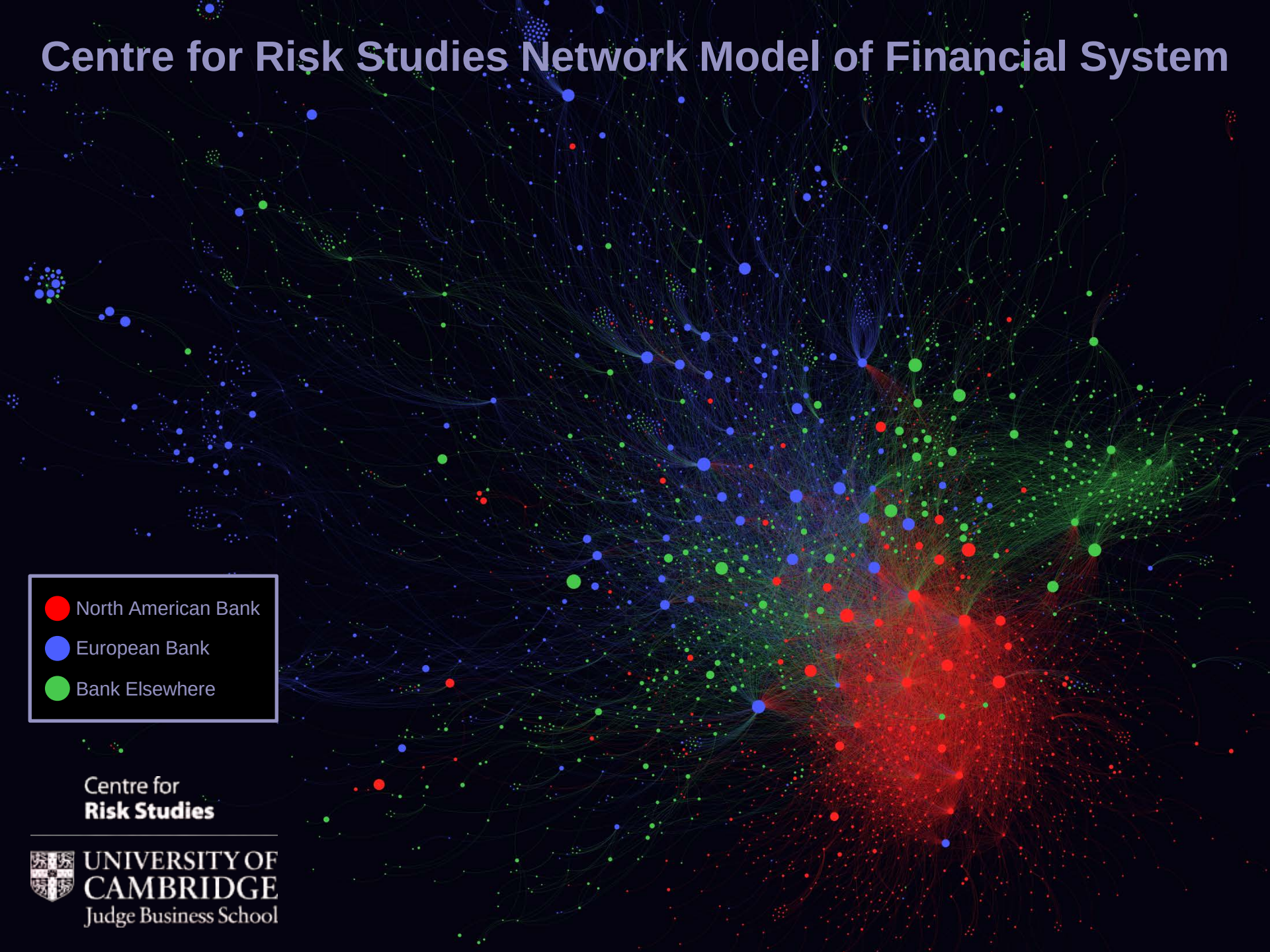
Contagion Mechanisms

- What mechanisms cause financial contagion?
  - Equity devaluation (**External Assets**)
  - Counterparty Risk (**Interbank Lending**)
  - Commonly-held asset devaluation (**Fire-Sales**)
- Interaction between these mechanisms is more important than a single mechanism on its own



Interacting contagion mechanisms are more significant than individual mechanisms

Centre for Risk Studies Network Model of Financial System



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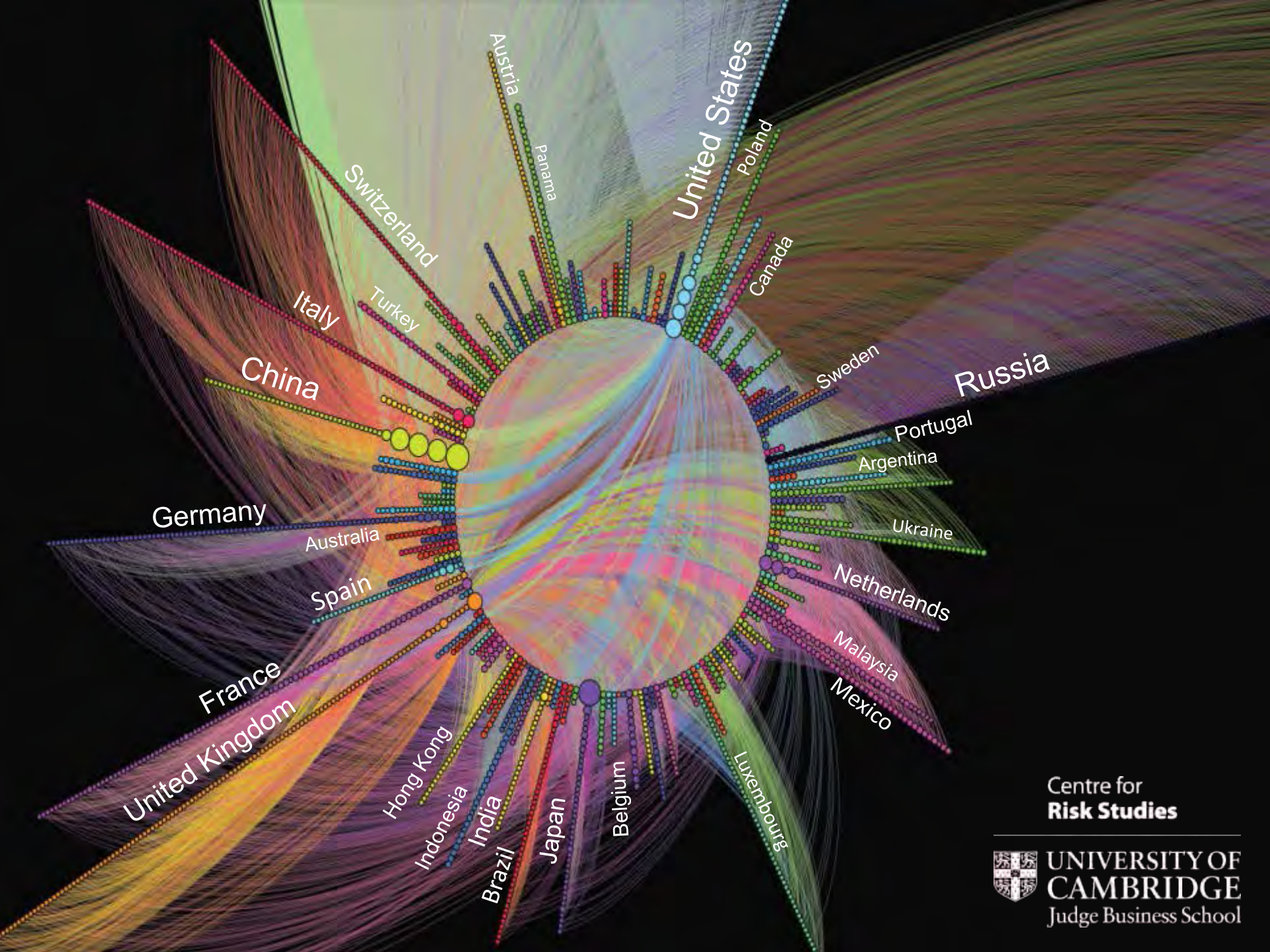

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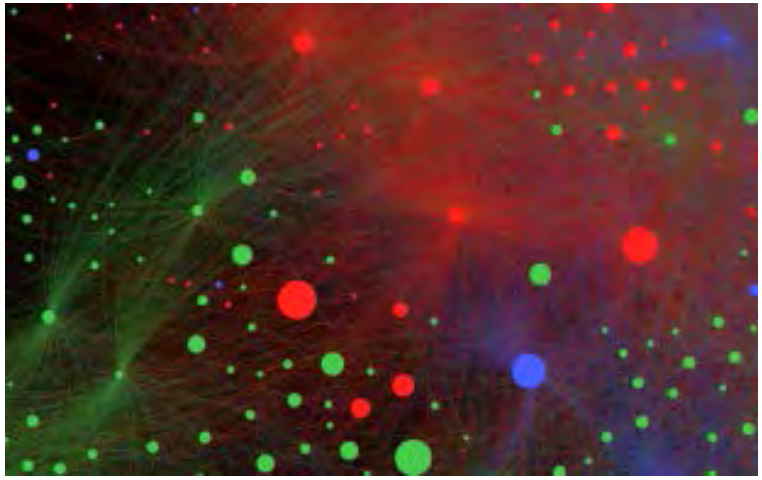
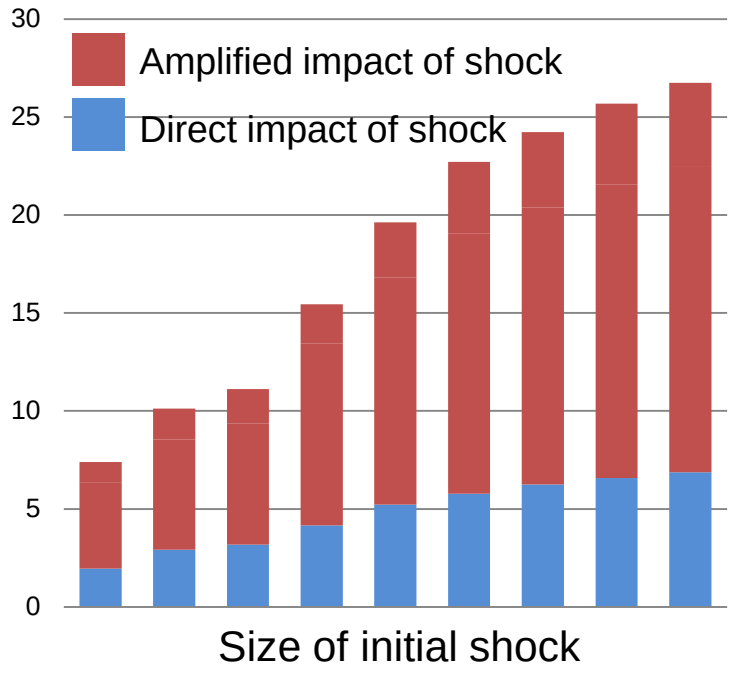
Understanding Contagion and Systemic Shock

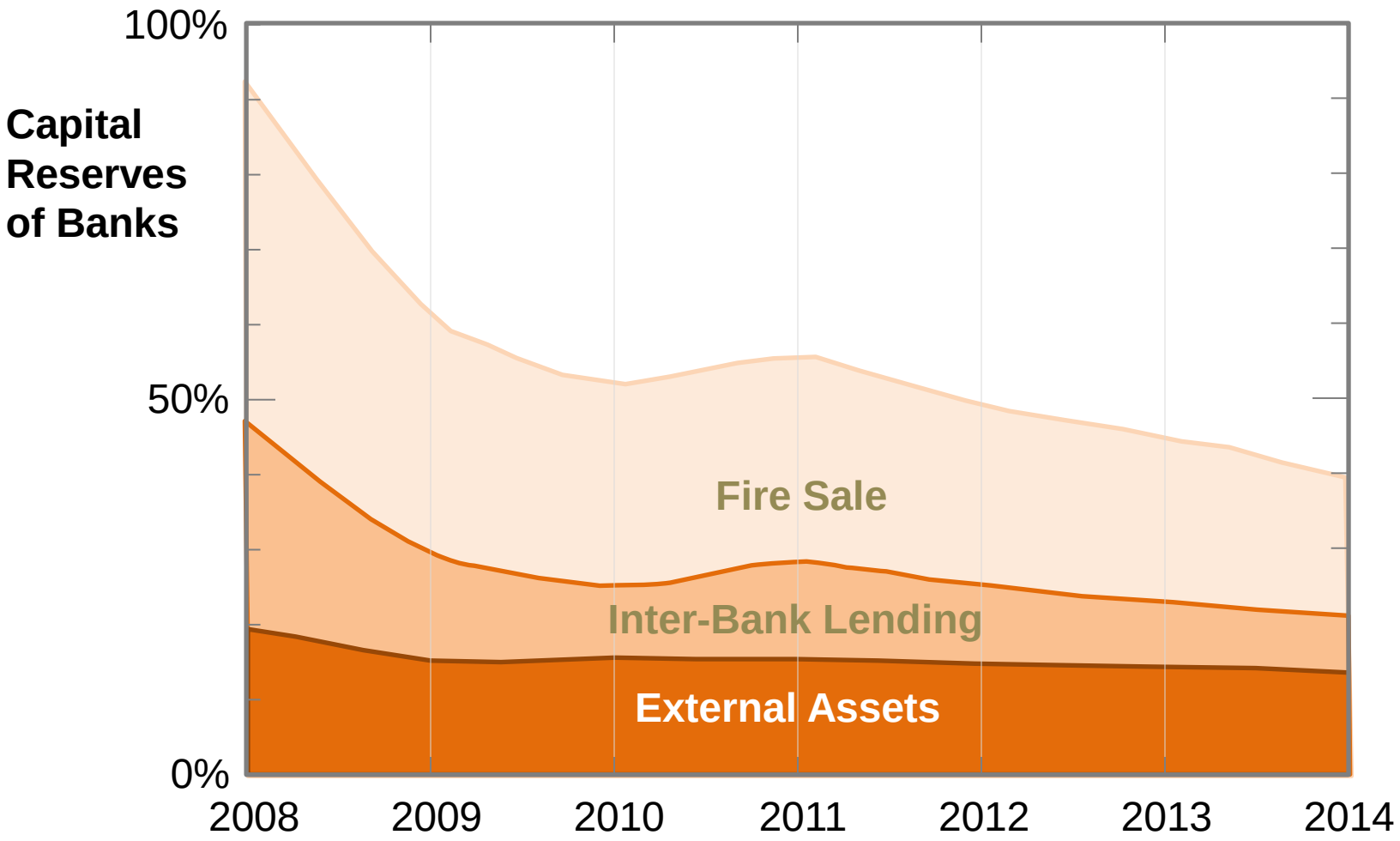
- The financial system is increasingly interconnected and integral to the economic system
  - Understanding the structure of the financial system and all its connections is vital
  - ‘Financial Cartography’
- Financial instability spreads through a variety of mechanisms
- Contagion amplifies:
  - severity 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
- Cambridge is seeking to build a practitioner model of global financial system





Stressing the Financial System

For a shock of 0.5% asset devaluation



Olaf Bochmann: Cambridge Banking Model

Not Everyone Sees Contagion as a 'Given'

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

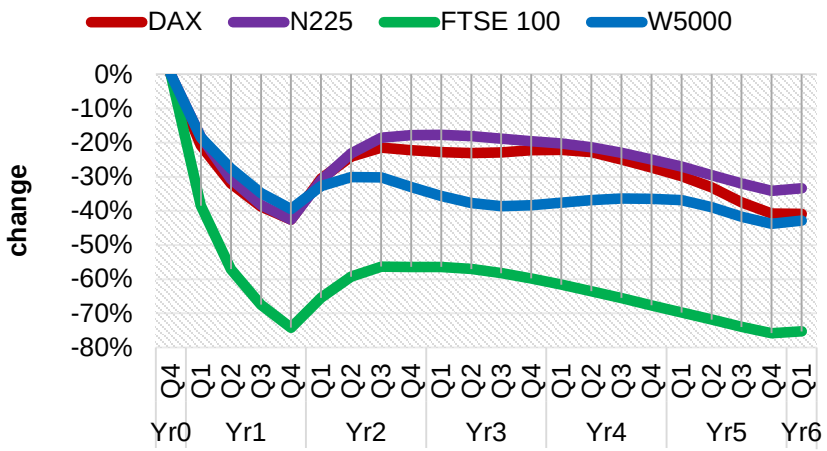
"I have some skepticism about contagion from a proposed scenario of property shock in China and the proposed Tier 1-6 markets affecting United States financial institutions…[because]

- 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

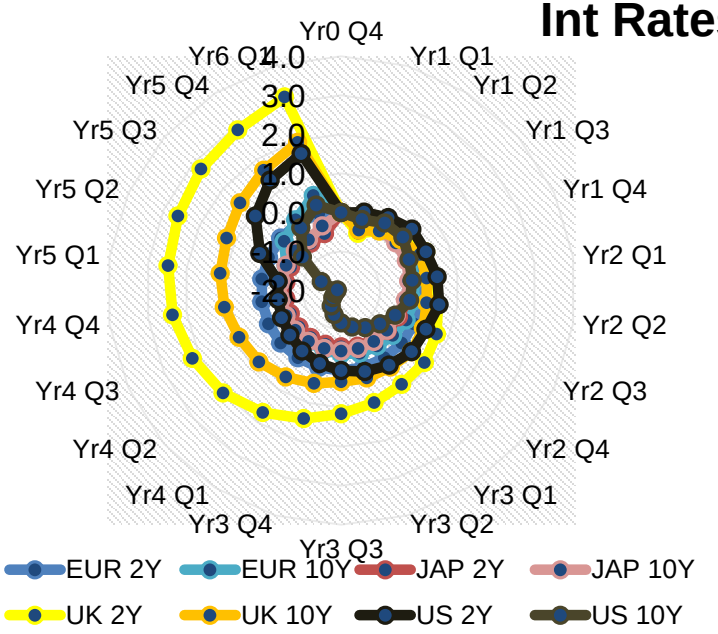
We face a challenge of explaining non-intuitive and indirect interactions of contagion mechanisms, rather than direct cross investment risks

Financial Market Impacts

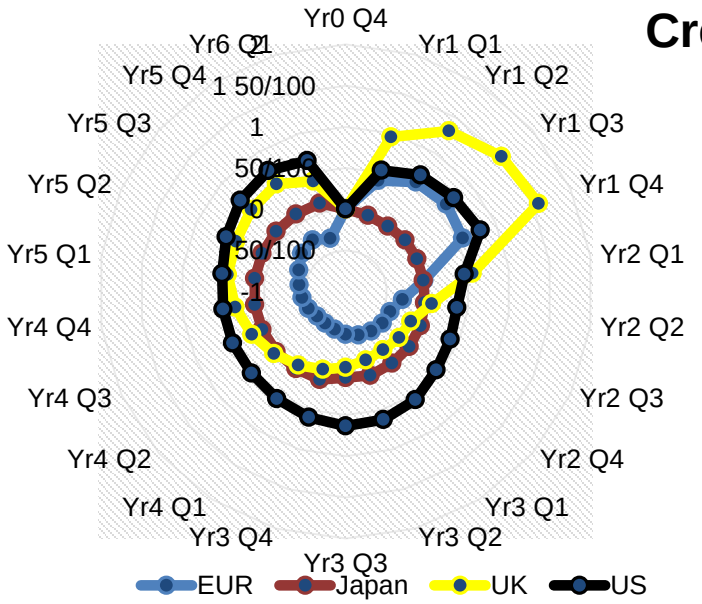
Equity



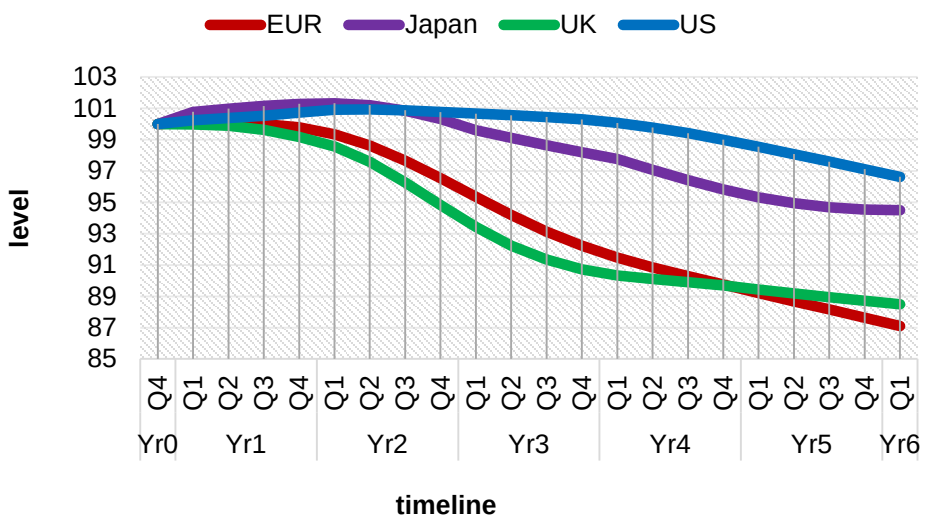
Int Rates



Credit

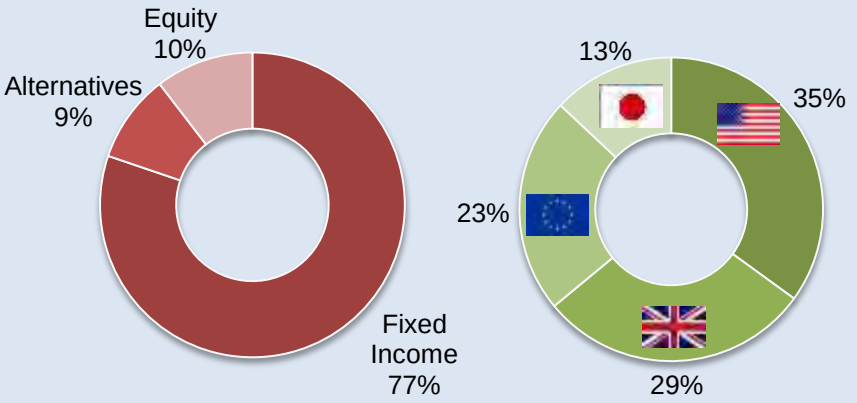


CPI

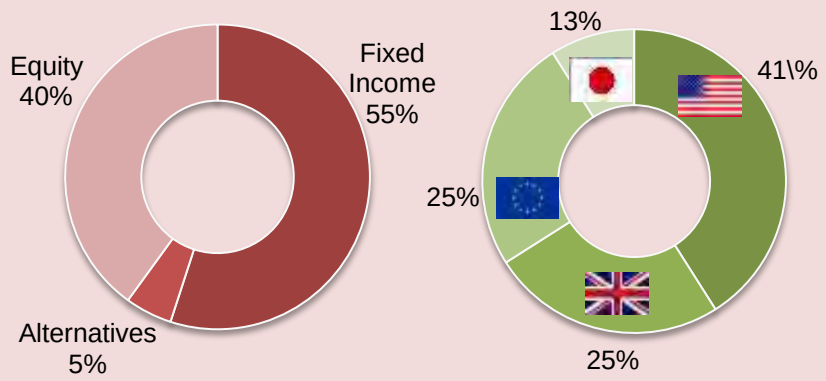


Different Investment Portfolios

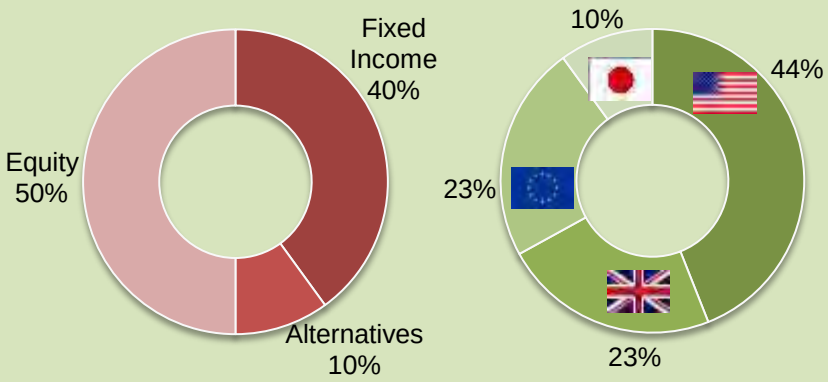
High Quality, Fixed Income



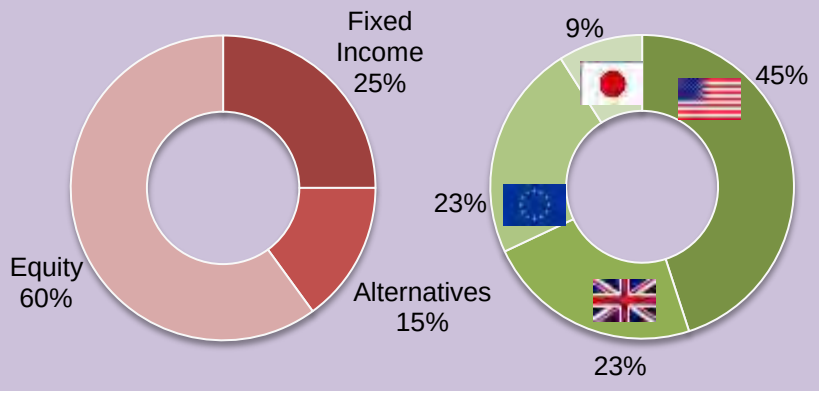
Conservative



Balanced



Aggressive



Investment Portfolio Performance in Different Scenarios

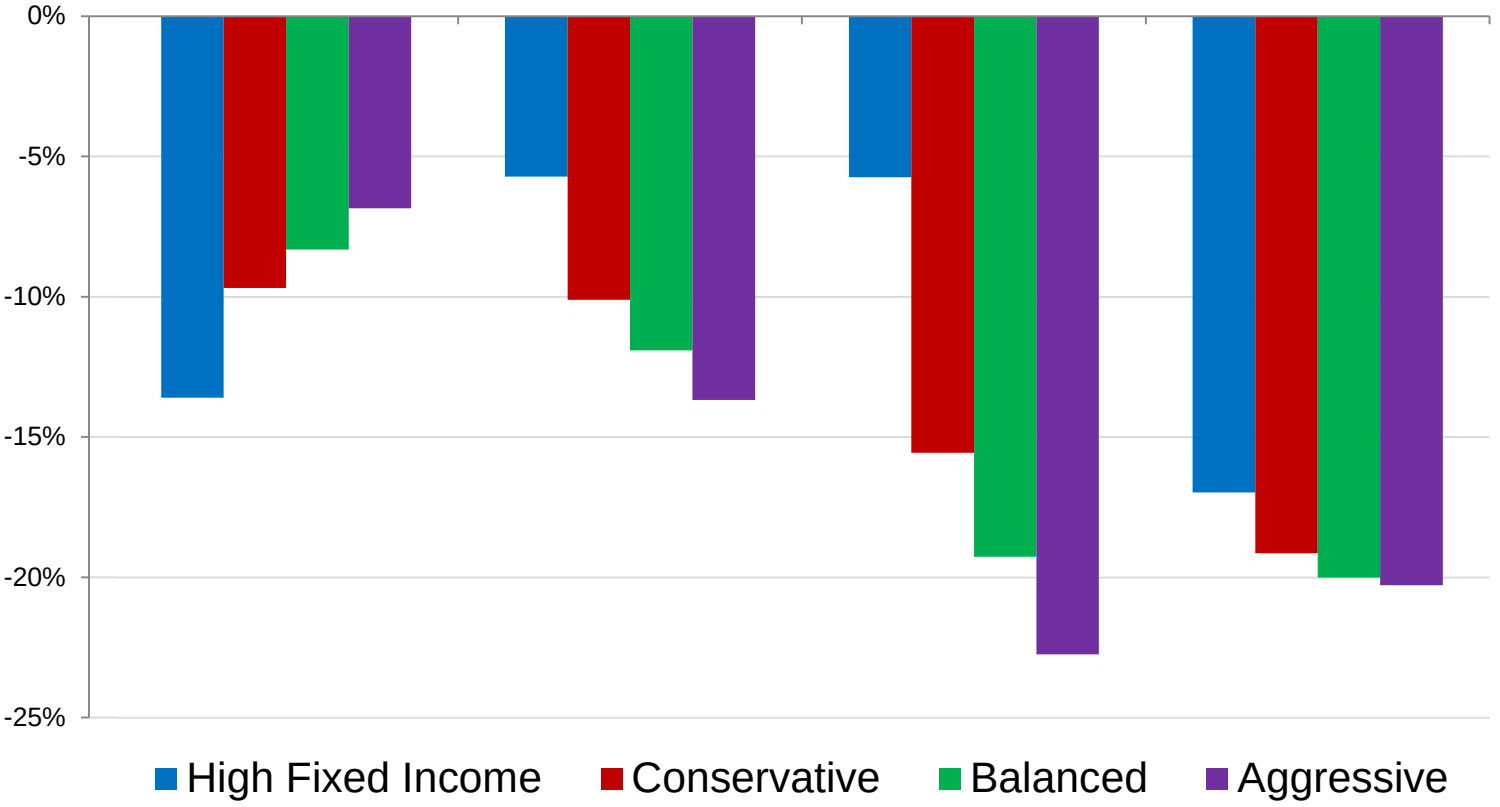
S1 Scenario Variant
Based on Max Downturn, Real USD %


High Inflation World


Eurozone Meltdown


Global Property Crash


Dollar Deposed



Global Property Crash: Correlation Analysis

Impact on the assets in a standardized investment portfolio of the hypothetical stress test scenario

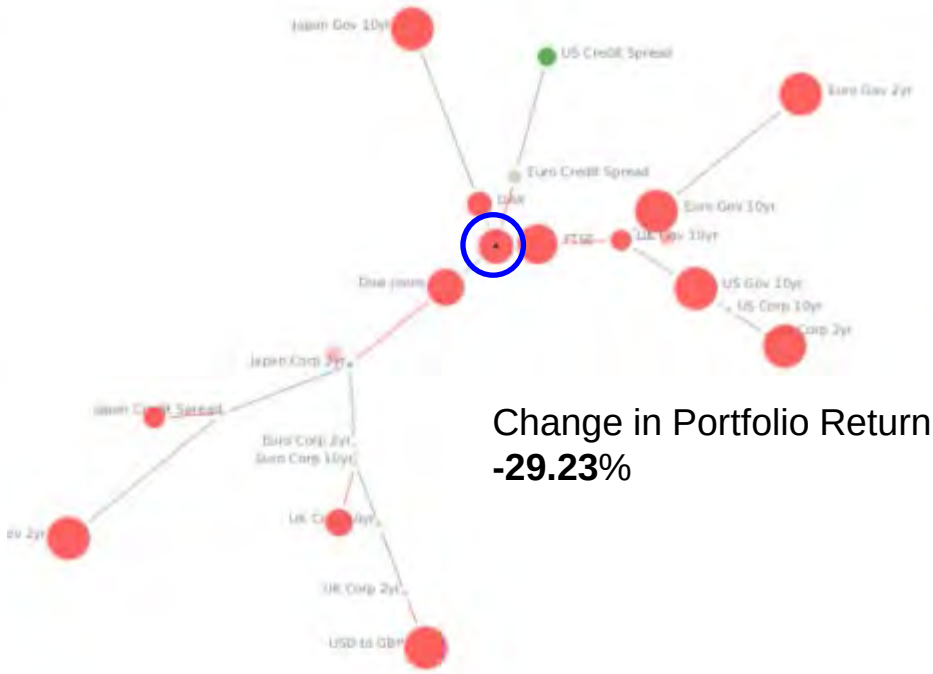
Asset Correlation Structure

FNA

Before Shock

Standard Portfolio

Portfolio After Crisis



Change in Portfolio Return:
-29.23%

Cambridge Financial Stress Test Scenarios

Global Property Crash

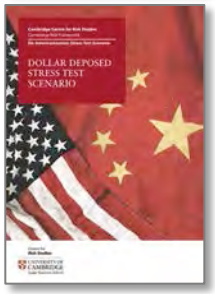
Sudden collapse of property prices in China followed by many other emerging and developed markets triggers a cascading crisis throughout the global financial system

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

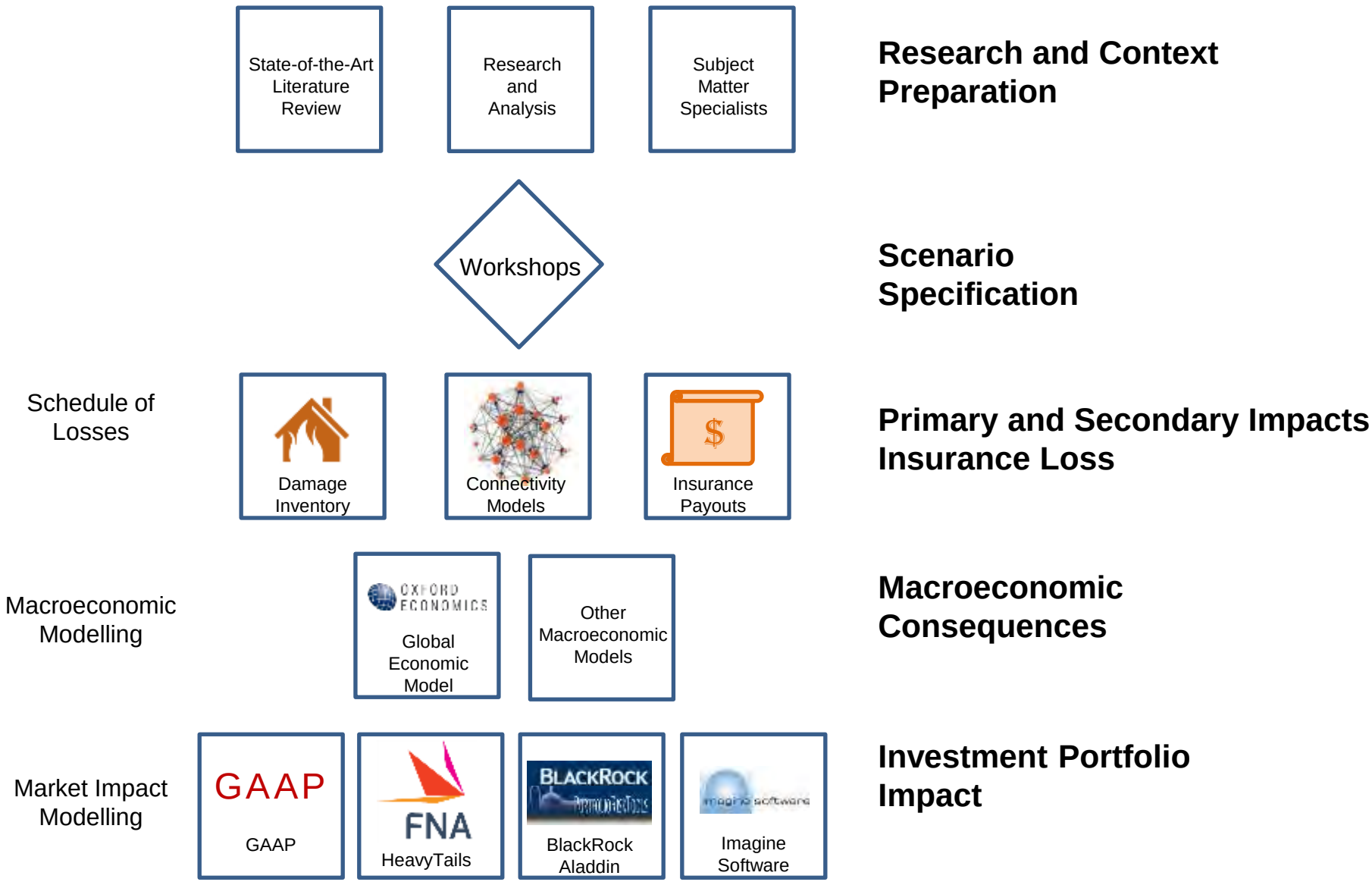


Dollar Deposed

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

Review Copies Available

Cambridge Scenario Development Process

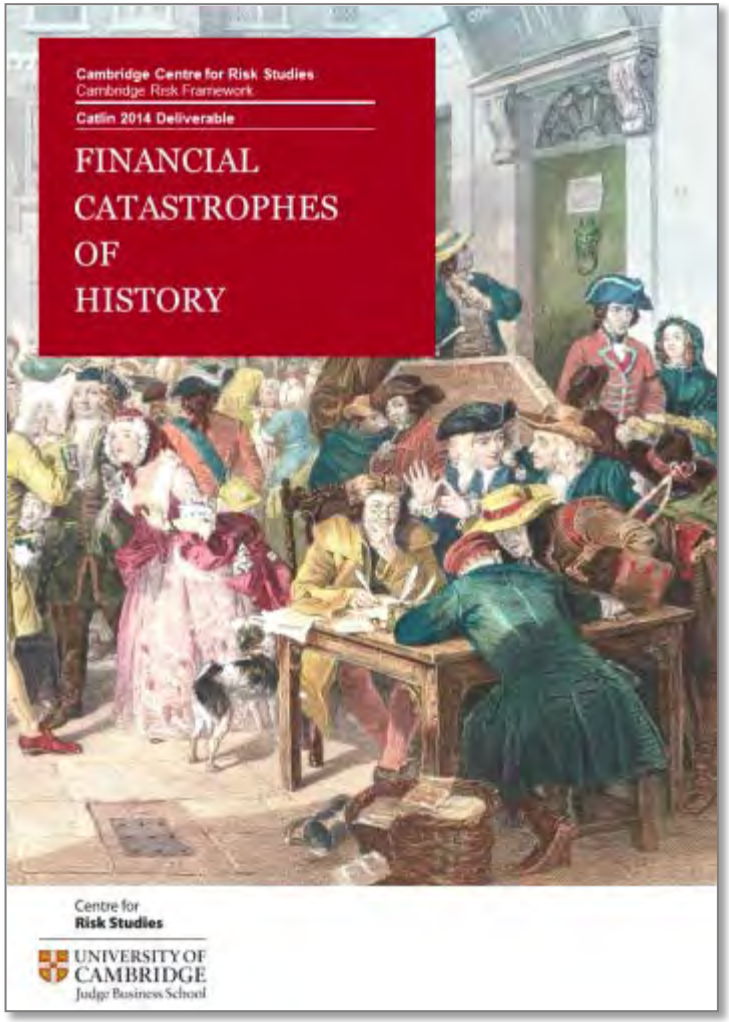


Comparing Cambridge Scenarios with US Stress Tests

		Stock Market Drop	House Price Crash	Unemploy-ment 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%	

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
- What does it tell us about the past frequency and severity of crises?
- What might the future frequency and severity of crises be?



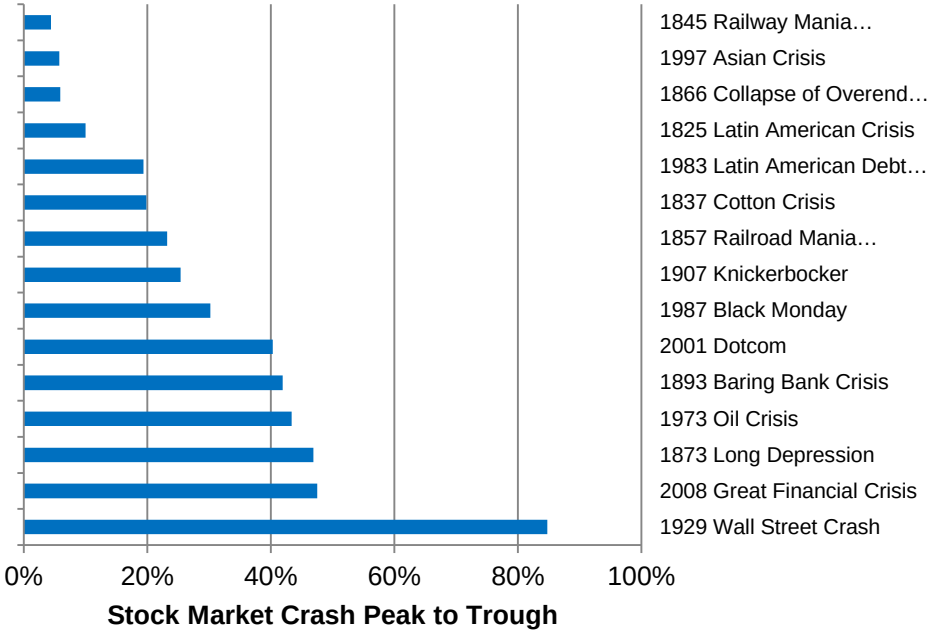
Publication in preparation

Historical Catalogue of Financial Crises

1. 1720s Crises (South Sea, Mississippi
2. **1825 UK Country Bank Crisis**
3. 1857 Panic (USA)
4. 1866 Collapse of Overend and Gu
5. 1873 Crisis (USA)
6. 1890 Baring Crisis
7. **1907 US 'Bankers' Panic'**
8. 1914 Financial Crisis
9. 1931-33 and the Great Depressio
10. Early 1980s Latin American Debt
11. 1997-99 Asia crisis,
12. **2008 Global Financial Crisis**

Historical Severities of Crashes – Past 200 Years

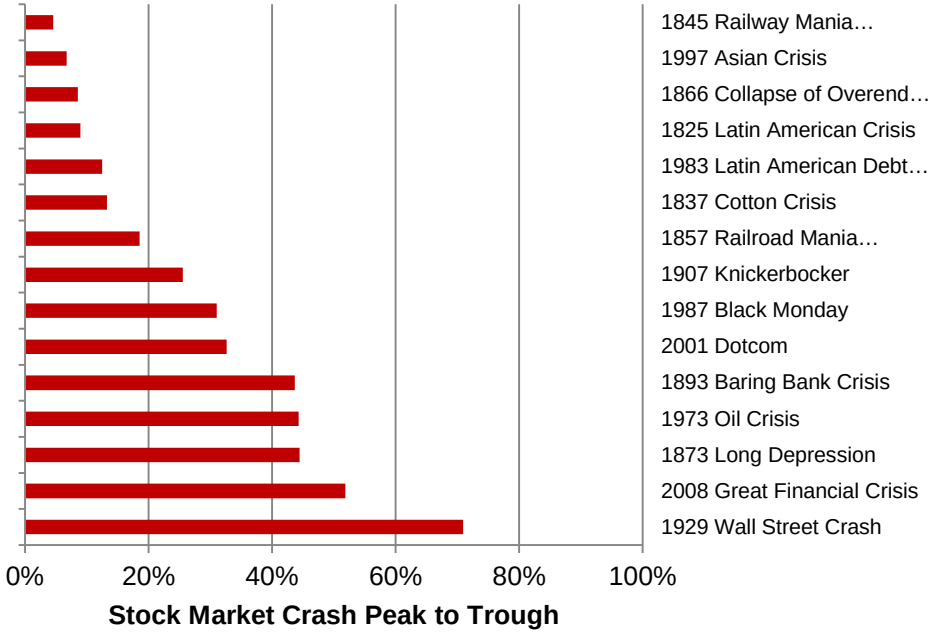
US Stock Market Crashes



Observed, last 200 years

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

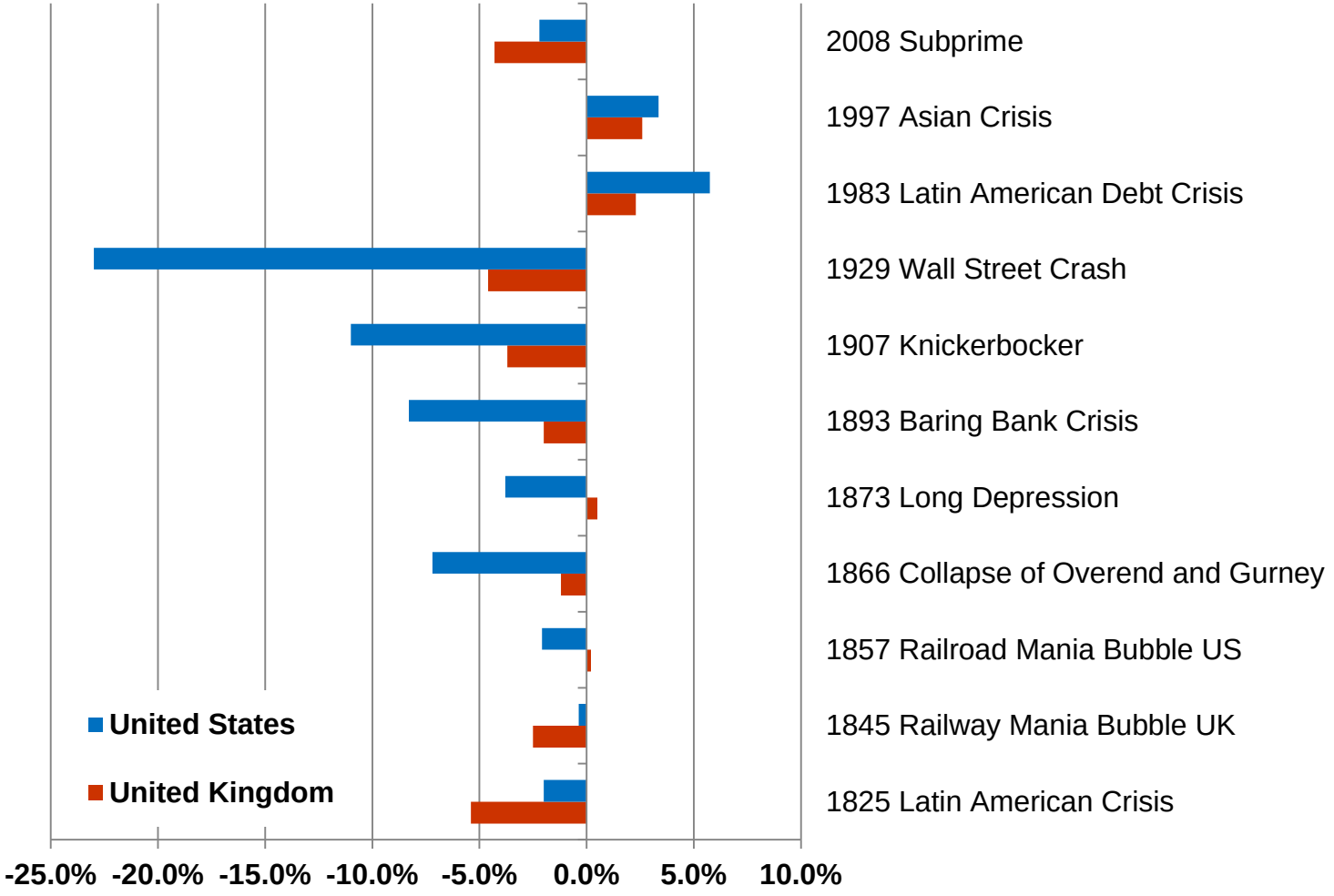
UK Stock Market Crashes



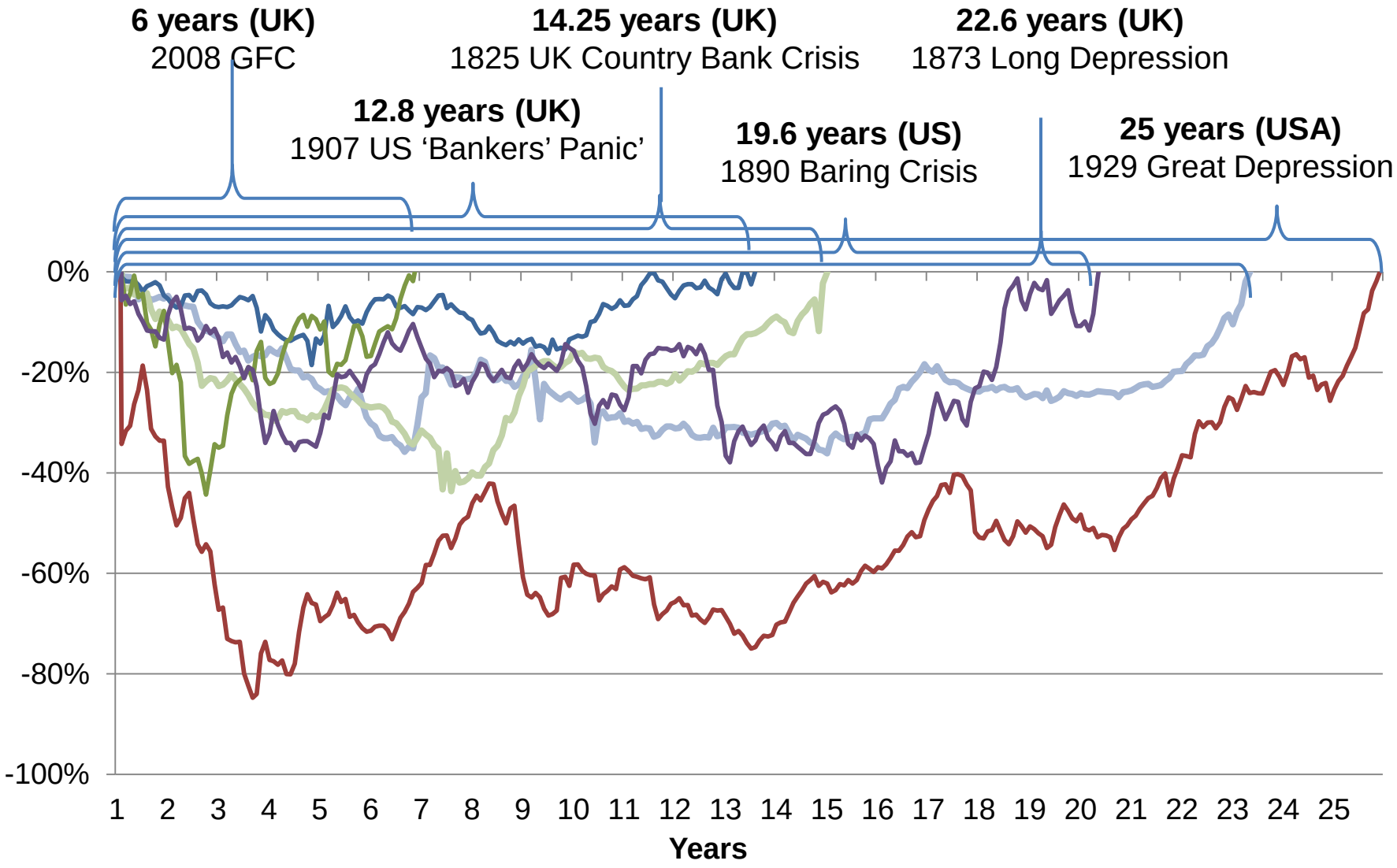
Observed, last 200 years

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

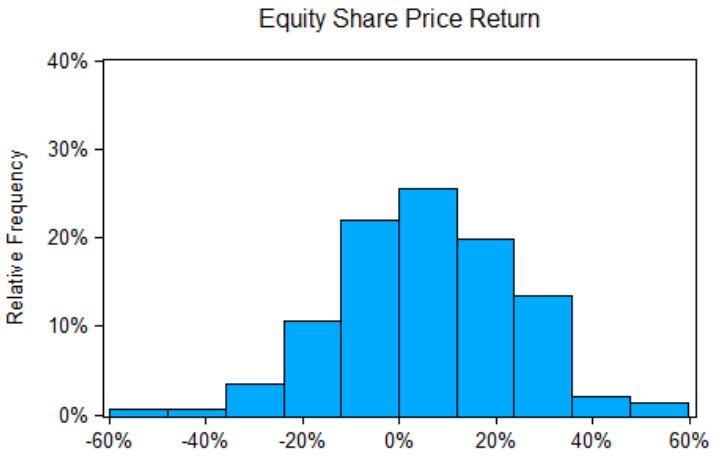
GDP Growth Rates



Duration of Economic Impact from Crises

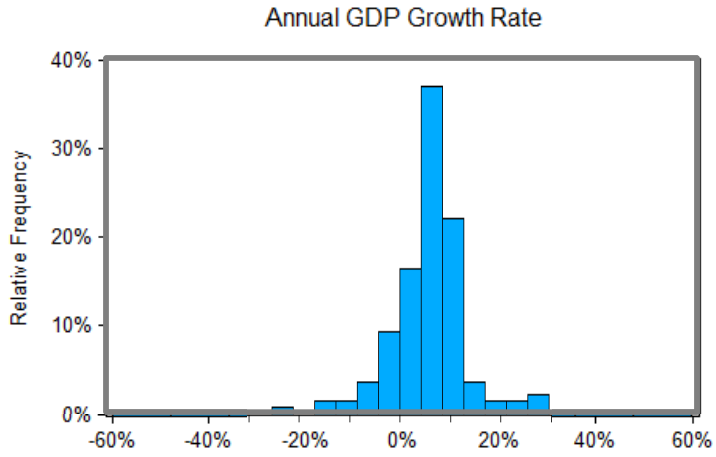


Markets are More Volatile than Economy



Stock Returns Value at Risk (1800 - 2010)

	1%	5%	Mean
US Equity VaR	-35.7%	-23.6%	5.7%
UK Equity VaR	-19.9%	-12.8%	4.6%



GDP Growth at Risk (1800 - 2010)

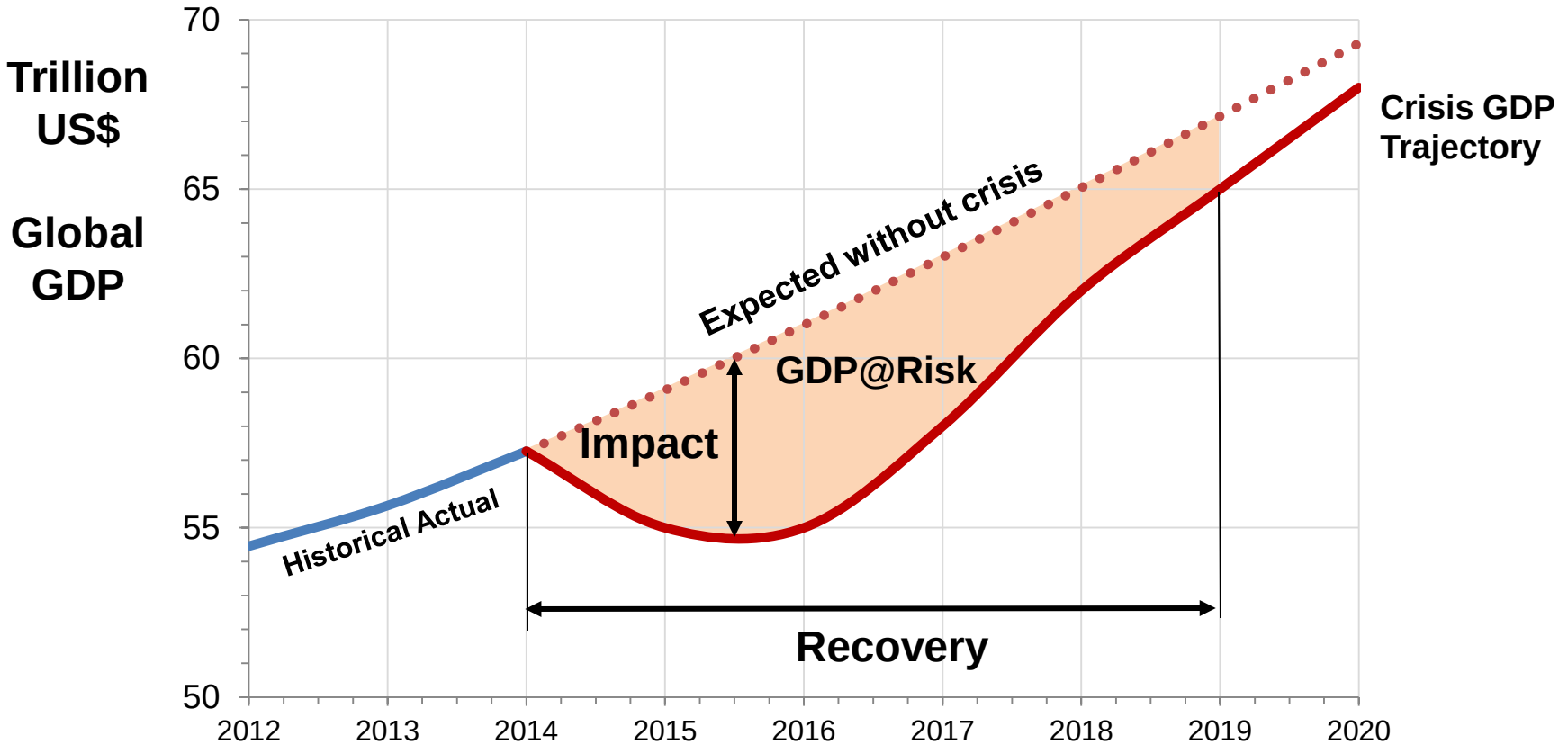
	1%	5%	Mean
US GDP at Risk	-12.7%	-7.4%	5.3%
UK GDP at Risk	-5.1%	-3.0%	2.0%

US Distribution of Returns

Multiple Crisis Occur Simultaneously

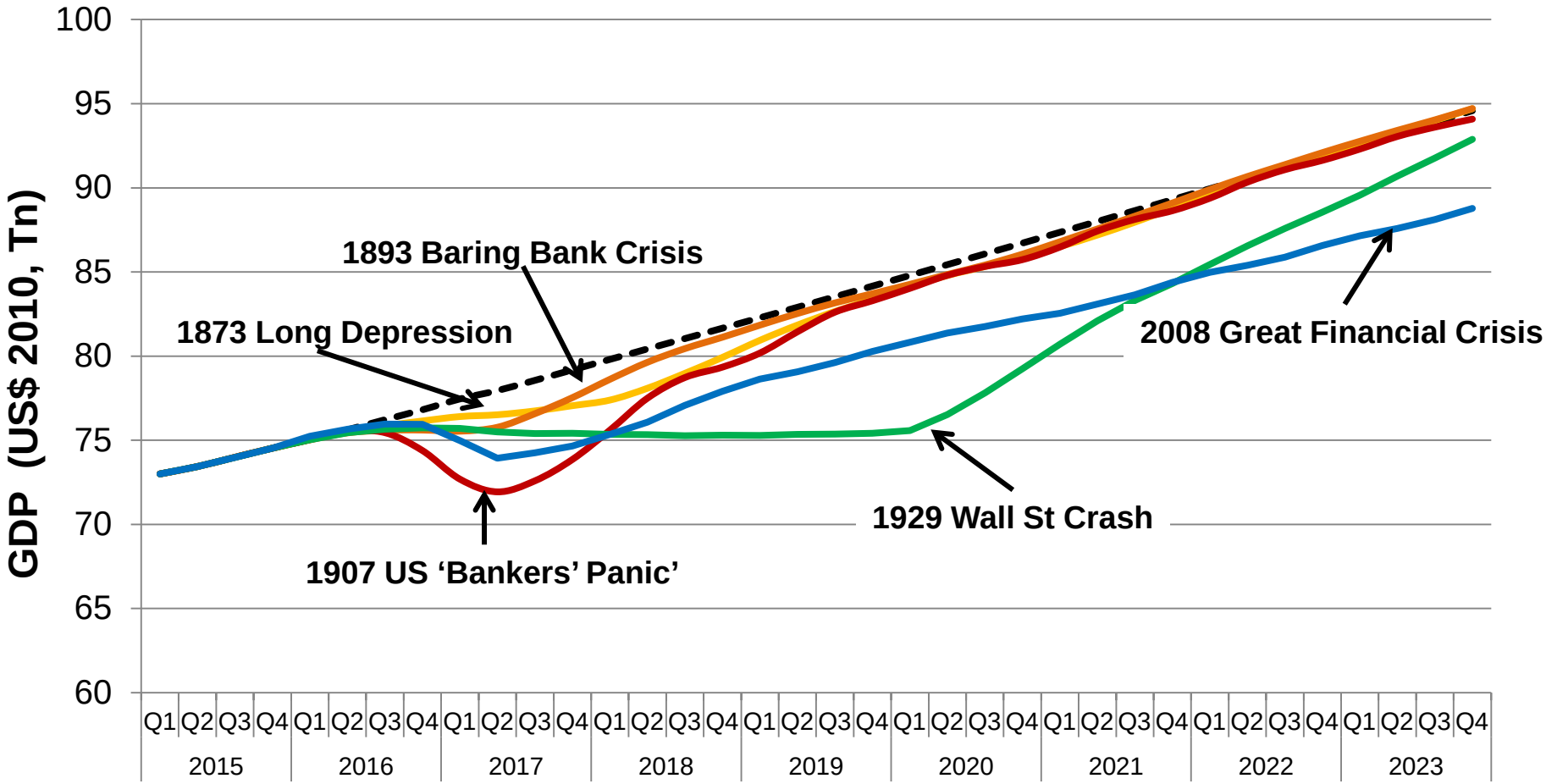
		Peak to Trough Loss		Crisis Type				
Year	Crisis	UK	US	Asset Bubble	Sovereign Crisis	Currency Crisis	Inflation Crisis	Banking Crisis
1720	South Sea Bubble	80%	-	x				x
1825	The Country Banking Crisis	43%	3%	x	x			x
1845	Railway Mania Bubble UK	9%	5%	x	x			
1857	Railroad Mania Bubble US	13%	23%	x				x
1866	Collapse of Overend and Gurney	7%	6%					x
1873	Long Depression	33%	47%		x			x
1890	Baring Bank Crisis	9%	42%	x		x		x
1907	US 'Bankers' Panic'	19%	26%	x				x
1929	Wall Street Crash	52%	85%	x		x		x
1983	Latin American Debt Crisis	5%	20%		x	x	x	x
1987	Black Monday	31%	30%					x
1997	Asian Crisis	12%	6%	x	x	x	x	x
2008	Great Financial Crisis	44%	48%	x	x			x

Estimating GDP@Risk



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

Modelling Historical Financial Crises

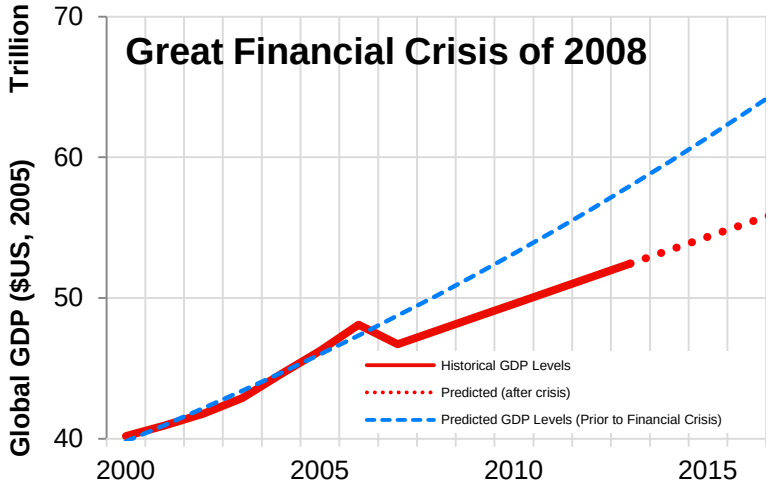


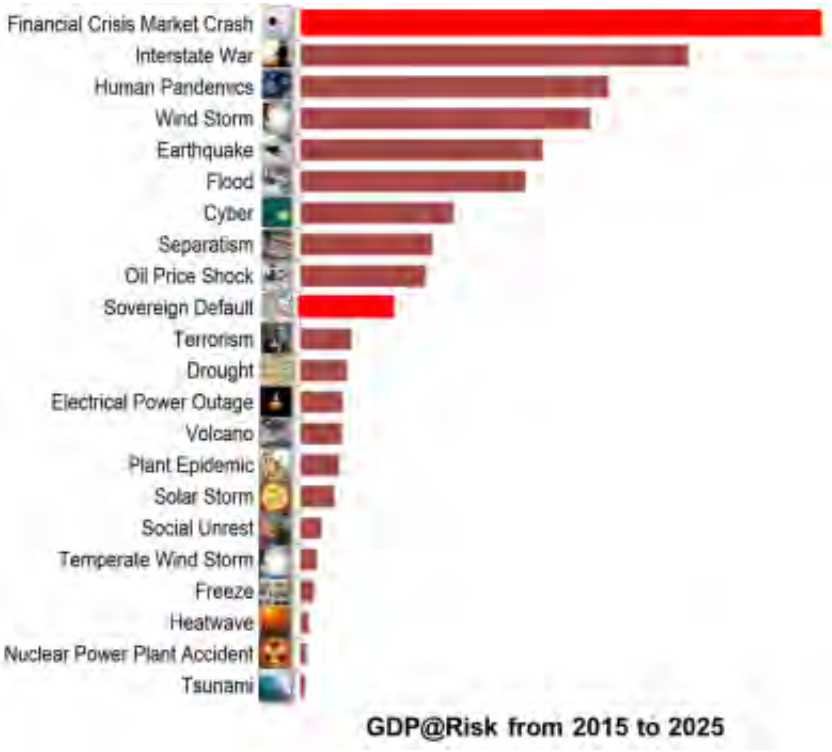
Historical & Scenarios: GDP@Risk

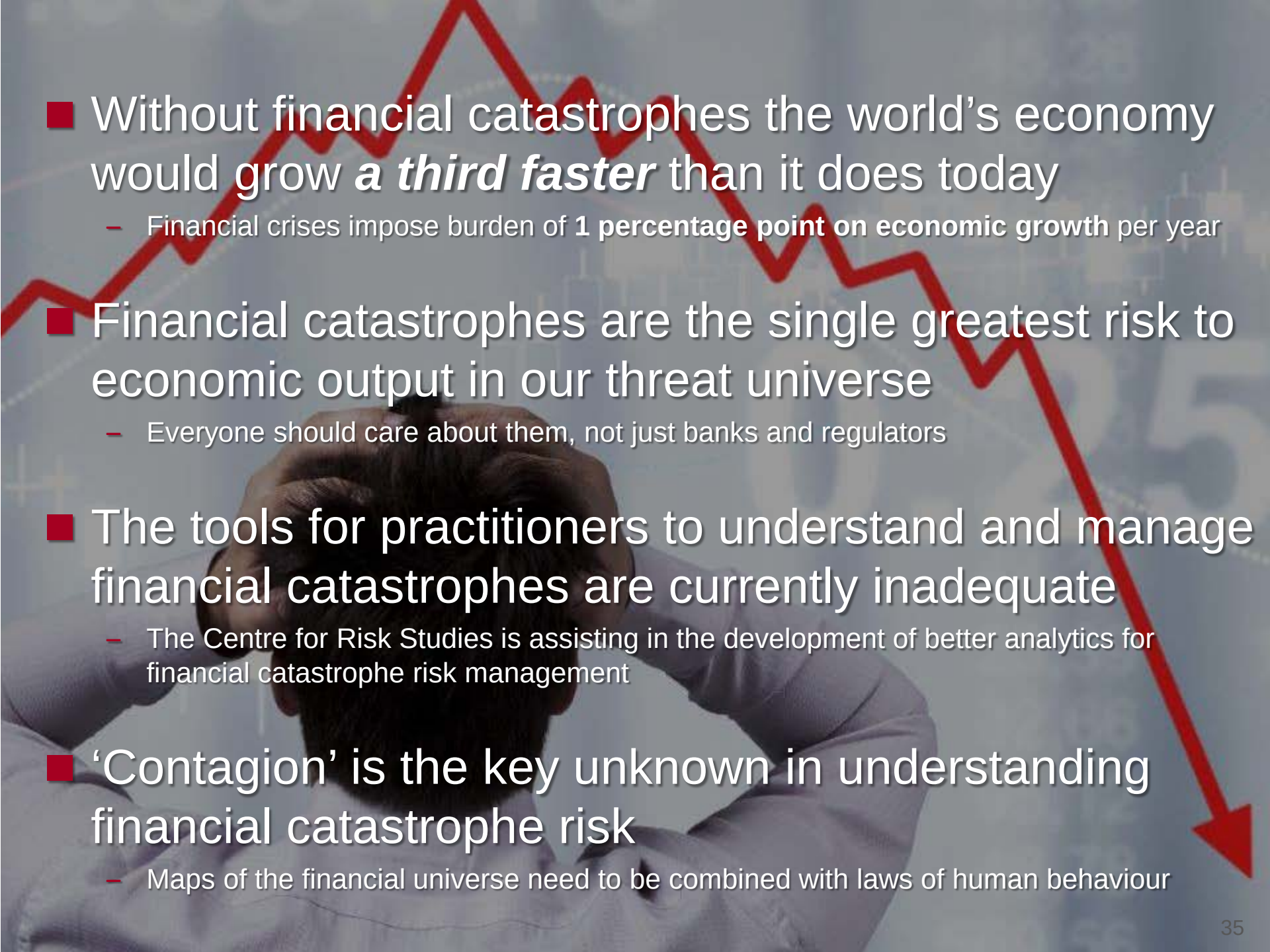
GDP@Risk US$ Trillion, 2010 prices	GDP@Risk
1893 Baring Bank Crisis	5
1873 Long Depression	7
1907 US 'Bankers' Panic'	14
2007 Great Financial Crisis	20
1929 Wall Street Crash	30
 CRS Dollar Deposed	2-3
 CRS High Inflation World	5-11
 CRS Eurozone Meltdown	6-20
 CRS Global Property Crash	11-23

The Economic Burden of Financial Catastrophes

- The Great Financial Crisis of 2008 destroyed an estimated **$18 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
  - Why don't we understand them better?







- Without financial catastrophes the world's economy would grow ***a third faster*** than it does today
  - Financial crises impose burden of **1 percentage point on economic growth** per year
- 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
- 'Contagion' is the key unknown in understanding financial catastrophe risk
  - Maps of the financial universe need to be combined with laws of human behaviour

Cambridge Centre for Risk Studies Published Reports

Taxonomy of Threats

Geopolitical Conflict
Emerging Risk Scenario

Pandemic
Emerging Risk Scenario

Cyber Catastrophe
Emerging Risk Scenario

Social Unrest
Emerging Risk Scenario

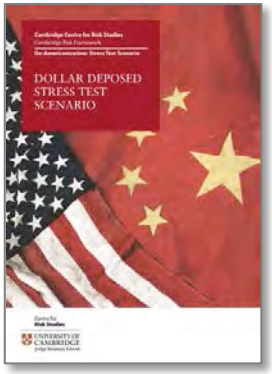
Ebola
Emerging Risk Scenario

Financial Catastrophes

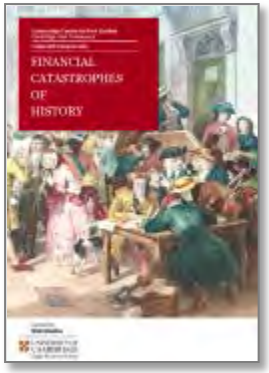
Global Property Crash
Financial Risk Scenario

Eurozone Meltdown
Financial Risk Scenario

High Inflation
Financial Risk Scenario



Dollar Dethroned
Financial Risk Scenario

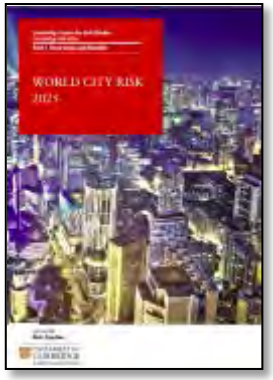


Historical Crises
Financial Risk

Available for Download from Website:
CambridgeRiskFramework.com

Lloyds Emerging Risk Report
Innovation Series
SOCIETY & SECURITY

Business Blackout
The insurance implications of a cyber attack on the US power grid



Forthcoming
Lloyds Co-Branded Report

World City Risk 2025

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