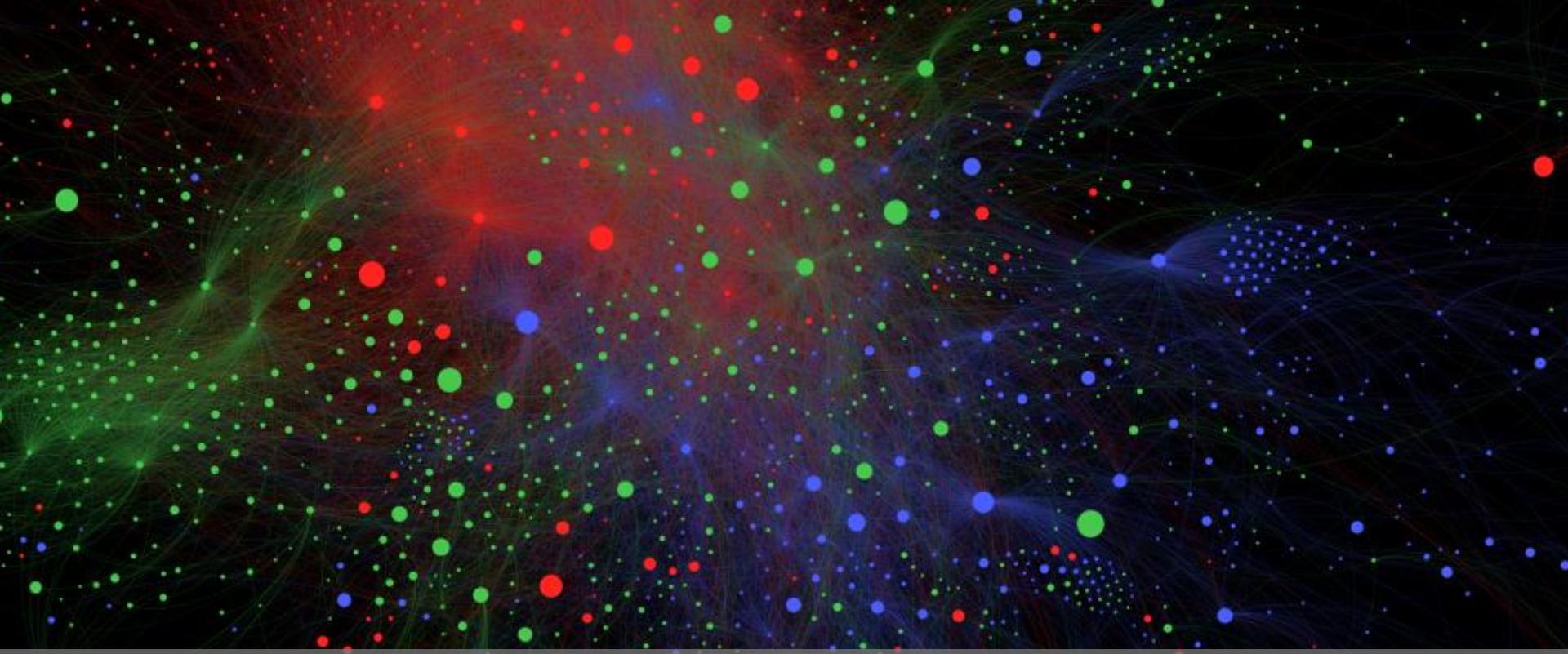


Financial Risk and Network Theory

Seminar 23 September 2014

Financial Catastrophe Risk Modelling

Centre for Risk Studies

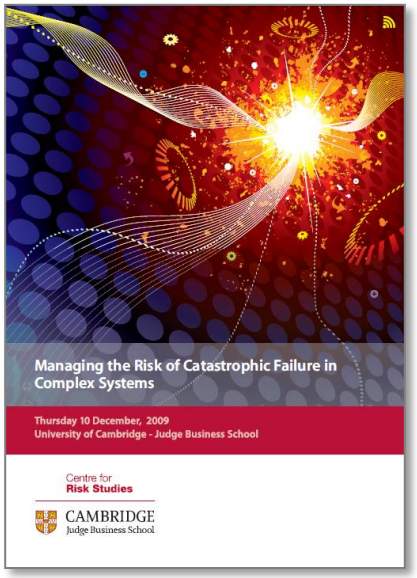
UNIVERSITY OF CAMBRIDGE Judge Business School

Dr Andrew Coburn
Dr Fabio Caccioli
Dr Andrew Skelton

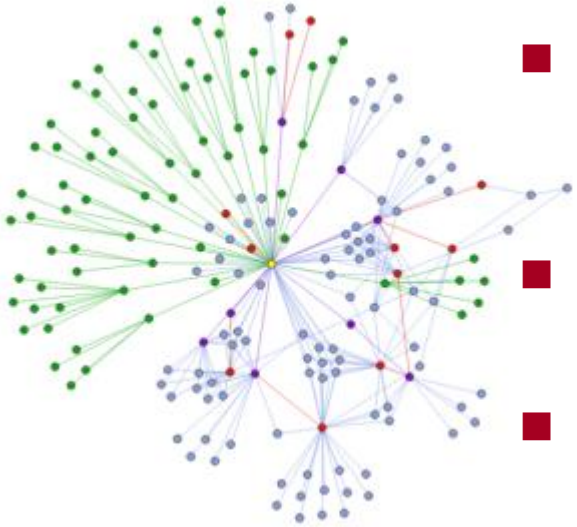
Cambridge Centre for Risk Studies

Risk journals

Understanding Catastrophic Failure in Complex Systems



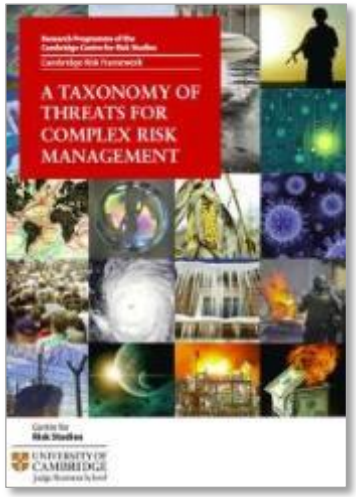
- Proceedings:
  - http://www.risk.jbs.cam.ac.uk/news/events/risksummits/risksummit2009.html
- Focus of the Centre for Risk Studies has been an enabler of projects and interchanges on complexity science and emergent behaviour
- Analysis of tightly-coupled systems, non-linear feedback loops, and failure analysis
- Risk Centre conference: **Managing the Risk of Catastrophic Failure in Complex Systems**
- Prompted a research programme into the effects of shocks on business networks: '**A Shock to the System**'
- Applying catastrophe risk modelling techniques to network analysis
- Has a focus on macroeconomics and financial impacts for practitioners



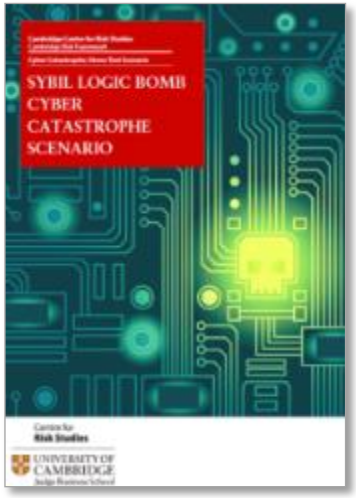
Sanjeev Goyal's Connections:
An Introduction to the Economics of Networks

UNIVERSITY OF CAMBRIDGE Judge Business School | Centre for Risk Studies

Exogenous Shocks to the Economic & Financial System

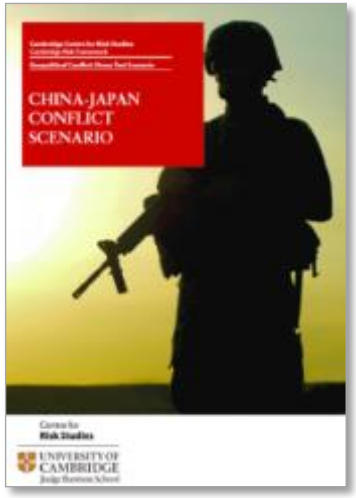


Taxonomy of Threats

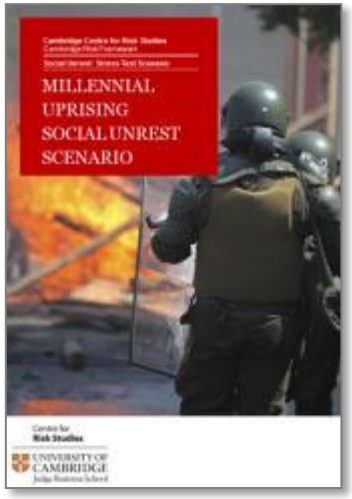


Cyber Catastrophe
Stress Test Scenario

Pandemic
Stress Test Scenario



Geopolitical Conflict
Stress Test Scenario

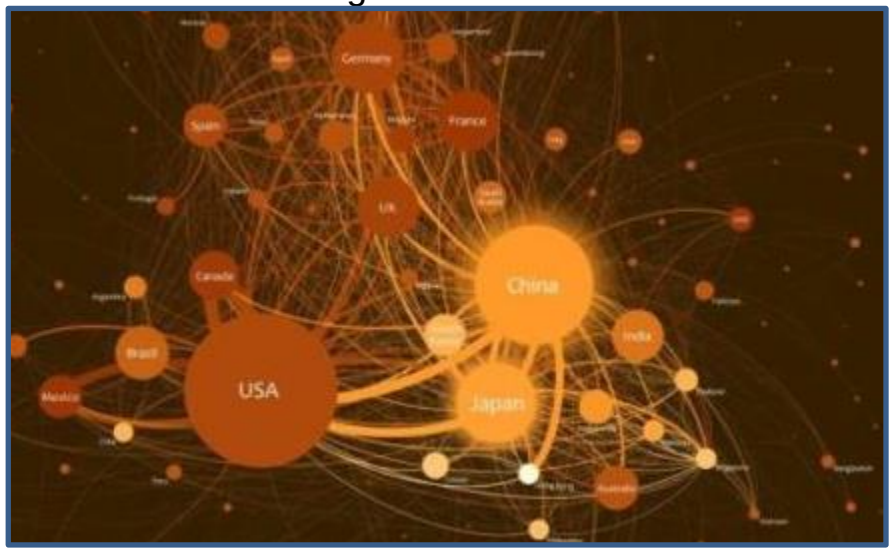


Social Unrest
Stress Test Scenario

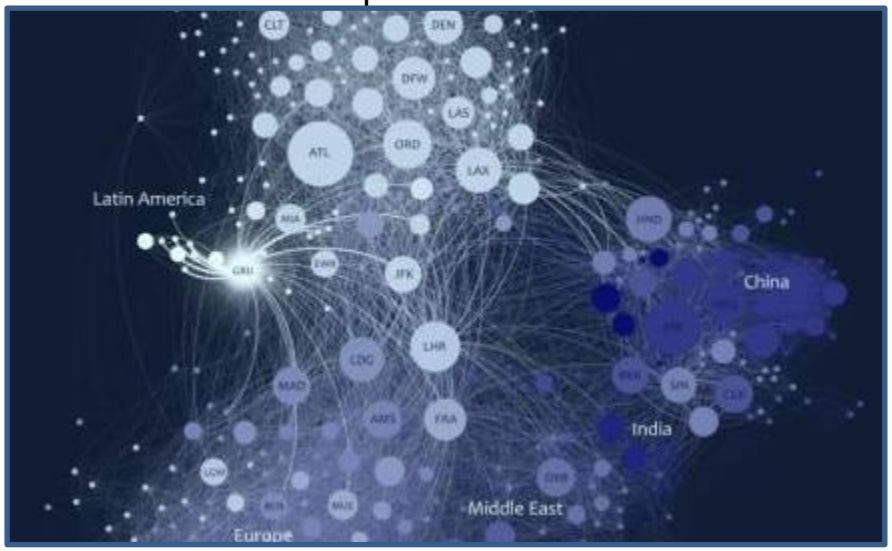
Reports available for download from:
CambridgeRiskFramework.com

Network Models and Connectivity

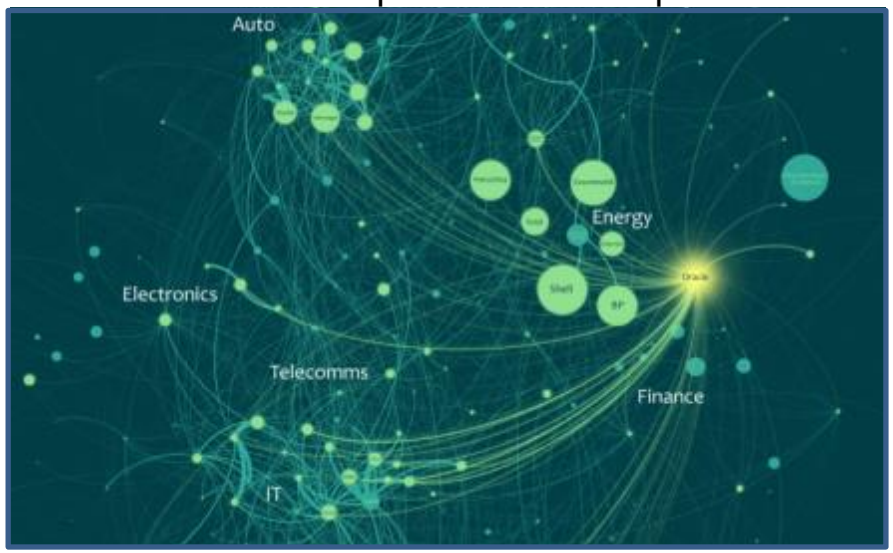
International Trading Networks



Travel Flows of People and Goods



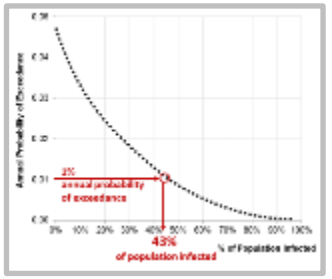
Business Relationships between Companies

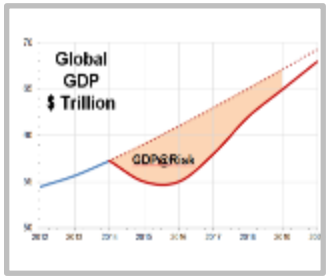


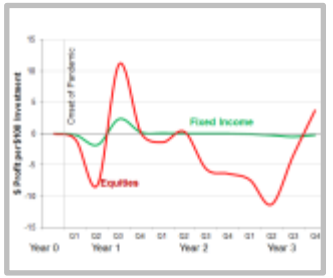
Communications and Social Media

Uses of Stress Test Scenarios by Practitioners

- Monthly reporting of potential losses against standard scenario
  - Monitoring progress of asset portfolio management towards resilience
- Risk capital allocation across different departments of operations
- Comparison of different drivers of vulnerability in portfolio or operations
- Counterparty risk and credit control management
- Business limit setting and allocation of underwriting loss potential
- **Stress tests**
  - **Need to be sufficiently severe to challenge managers assumptions of the status quo**
  - **Need to be plausible, coherent, and accessible**
  - **Have to reference the decisions made by managers**







Financial Stress Test Scenarios

Asset Bubble Shock

Global Property Bubble Collapse

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

Sovereign Default Shock

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 Trend

Food and Energy Price Spiral

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

De-Americanization of Financial System

Dollar Dethroned

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

Bubble Babble

theguardian

Bank of England governor warns of a bubble as UK house prices rise 10.5%

Mark Carney told MPs that high levels of mortgage debt can lead to overstretched owners cutting back on other purchases

Hilary Osborne and Angela Monaghan
The Guardian, Tuesday 15 July 2014 17.42 BST
Jump to comments (344)

CNBC

HOME U.S. ▾ NEWS MARKETS INVESTING TECH SMALL BIZ VIDEO SHOWS

Australia central bank warns about housing prices

CNBC.com staf
13 Hours Ago

FINANCIAL TIMES

ft.com > markets >

Property bubble is 'major risk to China'

By Jamil Anderlini in Beijing

FINANCIAL POST

TRENDING Apple | Tim Hortons | FP 500 | TFSAs | FATCA | Energy | BlackBerry | Housing

Canada in 'significant' housing bubble

JONATHAN RATNER | August 7, 2014 6:20 PM ET
More from Jonathan Ratner | @jonratner

GLOBAL INDONESIAN VOICES

Housing Bubble Forming in Indonesia, Here are the Signs

Posted On 02 Apr 2014 By : Global Indonesian Voic
housing bubble, property

, Nauriel Roubini, rightly speculated the housi
for 2008 recession. This time he is speculating
d other developing economies.

The Nordic Housing Bubble

Like 56 Tweet 21 Pin it Share 14

By Jesse Colombo (This article is frequently

The Nordic Housing Bubble or Scandinavian Hou
during the past decade in Norway, Sweden, Finland,
Western European Housing Bubble, which is a part o

The Norwegian Housing Bubble

THE TIMES OF INDIA

Tue, Sep 16, 2014 | Updated 08:00PM IST

THE ECONOMIC TIMES

Increase in real estate prices giving rise to property bubble

Tags: stocks | secondary market | real estate | property | Noida | net wort
Inflation | Gold | economy | affordable housing

By: Santhosh Kumar, CEO - Operations, JLL India

Hyman Minsky, the noted American economist, linked an economy's life cycle with speculative investment bubbles which are endogenous to it. He stated that during prosperous times when the economy booms, corporate cash flows rise higher than corporate debts, and this leads to speculative euphoria.

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Shiller Warns of Housing Bubble After 225% Surge: Brazil Credit

By Blake Schmidt and Marisa Castellani Sep 5, 2013 7:41 PM GMT+0100 15 Comments Email Print

Robert Shiller, who predicted the collapse of the U.S. housing market, is warning that a bubble is emerging in Brazil at a time when a sluggish economy and persistent **inflation** are eroding investor confidence.

Since January 2008, **home prices** in **Sao Paulo** have soared 181 percent and jumped 225 percent in **Rio de Janeiro**, according to the FIPE Zap index. That's as much as twice the increase in rent prices, signaling that the housing market has become overheated, according to Shiller, a Yale University professor who helped create the **S&P/Case-Shiller Index (SPCS20)** of U.S. home prices, which has dropped 13.7 percent since 2007.

Photographer: Paulo Fridman/Bloomberg

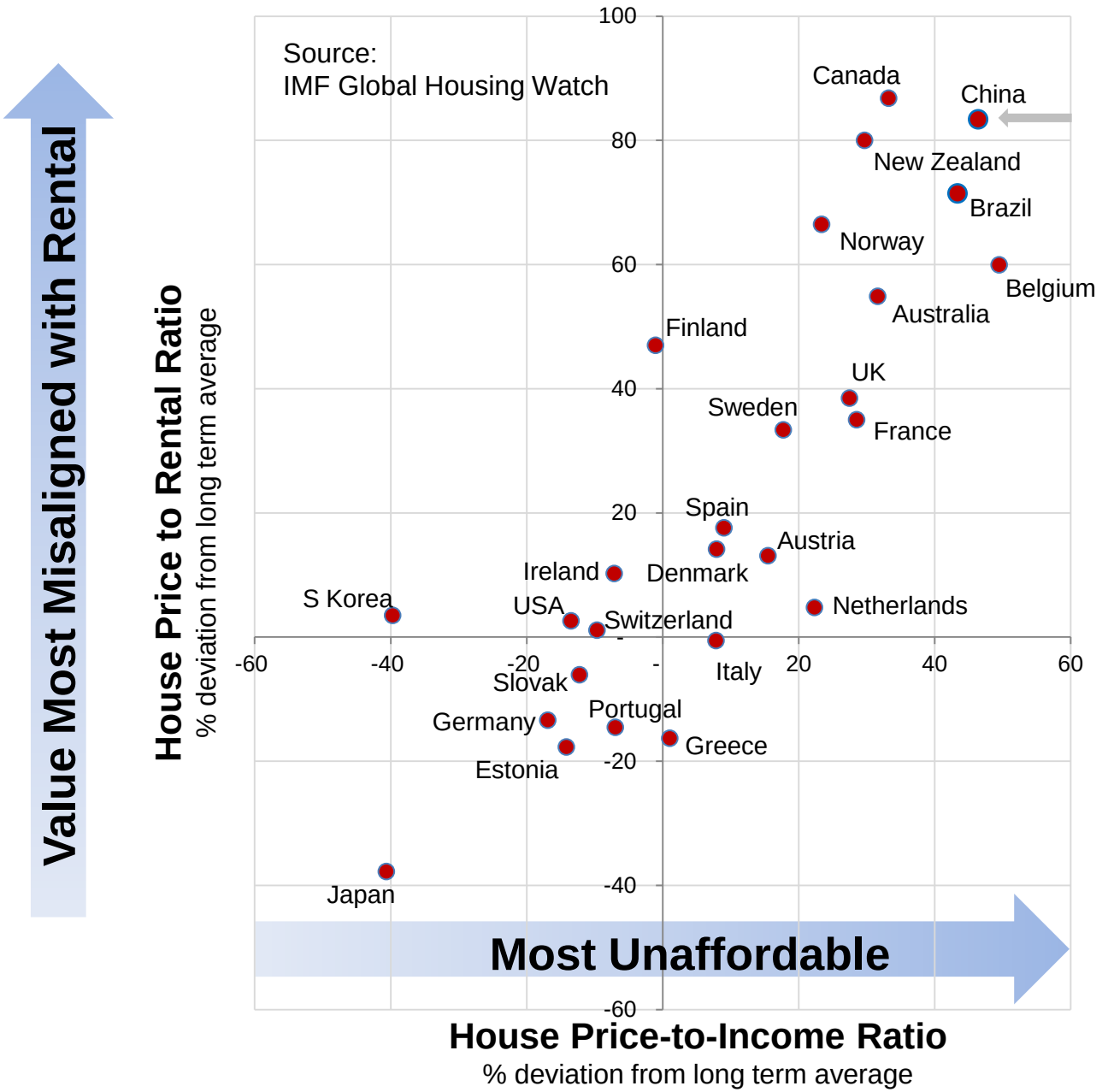
Since January 2008, home prices in Sao Paulo have soared 181 percent, according to the FIPE Zap index.

The warning comes as Brazil's economy heads for its weakest two-year expansion in more than a decade and the central bank raises **interest rates** by the most in the world to contain inflation. Mortgage lenders such as Caixa Economica Federal will have to pass on rising borrowing costs to consumers already struggling with

China Property Bubble

- China housing prices have sustained an **average annual growth rate of 17%** for past decade
  - Data based on 35 major Chinese cities, Aug 2014
- In same period, average growth of real GDP has been 10%
  - Impressive but far below housing price escalation
- Great housing boom has generated a large number of empty ('ghost') apartments across major cities in China
  - Large majority are sold but unoccupied properties held for appreciation rather than owner usage or rental income generation
  - Indicator of **strong speculative demand**, rather than excess supply
- In 2013 the national urban housing vacancy rate in China reached 22.4%
  - Far more than developed countries
  - Homeowner vacancy rate in U.S. was only about 3% during the peak of the U.S. housing bubble in 2006

Inflated Housing Markets



Property Market Bubble Risk

Tier 1: China & Emerging Markets
China, Hong Kong, India, Brazil, Philippines, Indonesia, Turkey

Tier 2: Commonwealth
Canada, Australia, New Zealand

Tier 3: Nordics
Norway, Finland, Sweden

Tier 4: UK
United Kingdom

Tier 5: Europeans
France, Belgium, Netherlands

Tier 6: Other Europe
Spain, Portugal, Italy, Greece, Ireland, Austria, Denmark

Tier 7: US
United States

Tier 8: Prudent Europe
Germany, Switzerland

Tier 9 Industrial Asia
Japan and South Korea

Tier 10 RoW
Other markets

Global Property Bubble Stress Test Scenario

- In this exercise we consider the geographical extent and the severity of the property price correction that would cause a significant contagion event through the financial system
- We use network analytics to define a plausible, severe hypothetical event for use as a stress test
- We are developing this as a stress test for use by practitioners managing investment portfolios
- This requires a model of the global financial system that can propagate property price corrections as a contagion process

Developing a Model of Global Financial System

- Integrating multiple sources of data on banks, lending patterns, cross-holdings, and assets
- Currently includes 18,516 banks
  - Important to include all jurisdictions and markets as one global financial system
- This example focuses on cross-holdings and mortgage lending
- Future potential to link it to database of corporate enterprises

Data Sources include:

BUREAU VAN DIJK

bankscope

The Banker Database
A service from The Financial Times

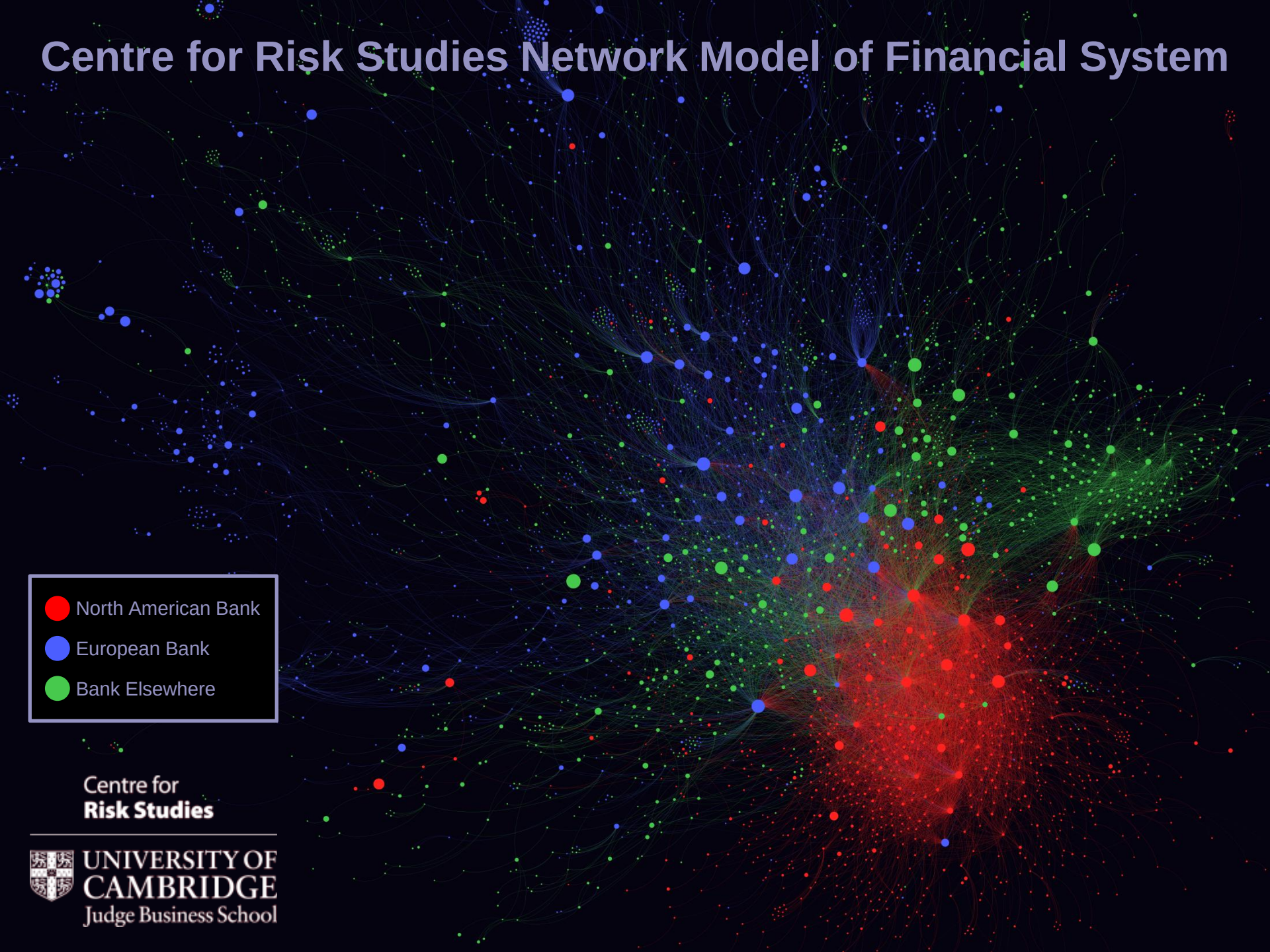
Bloomberg

EUROMONEY

Quandl

Google Finance

Centre for Risk Studies Network Model of Financial System



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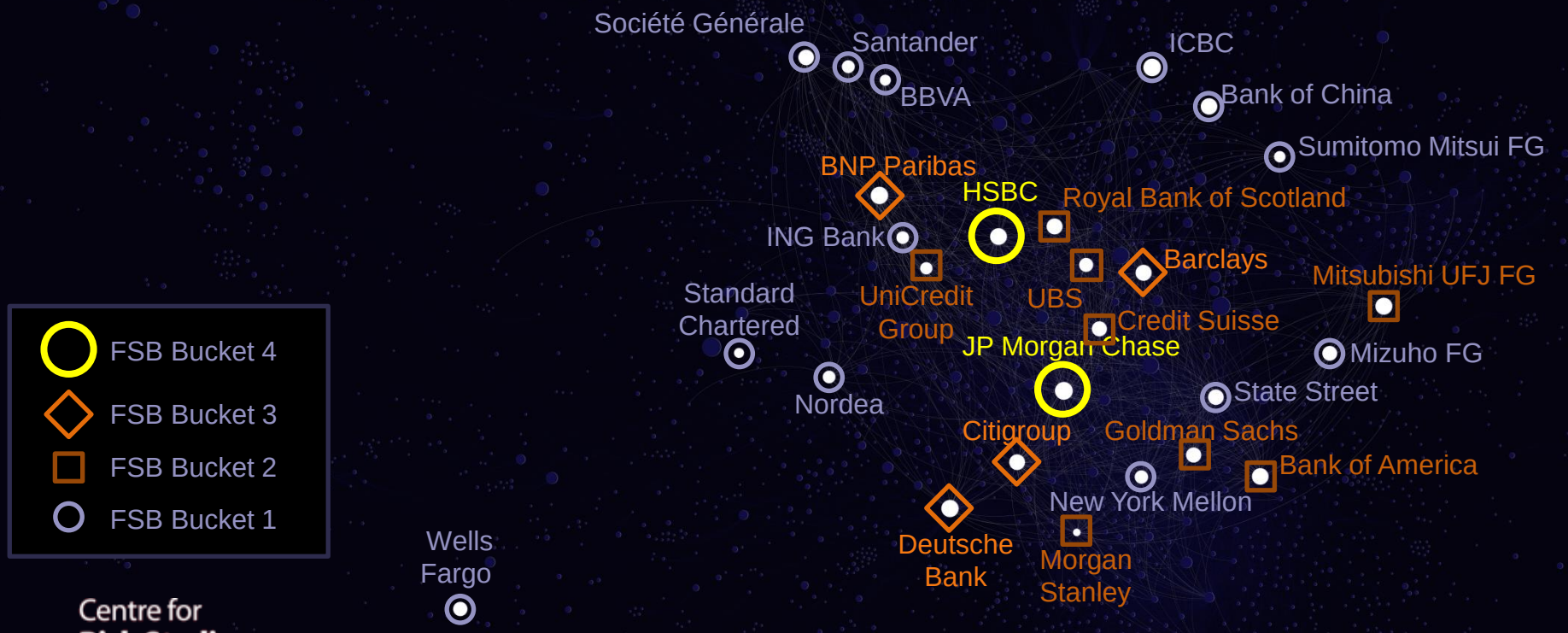
Summary of Financial System Statistics

- 18,516 banks
  - Total market value of **$214 Trillion**
  - Total equity value of **$17.4 Trillion**
- Mortgage assets total **$18.1 Trillion**
  - Mortgage lending exceeds the equity value of banks
- 3,520 banks have direct exposure to mortgage lending
- 3,628 banks have cross-holdings in banks with mortgage exposures
- All banks have exposure to assets that would devalue in the event of a property price correction

Global Systemically Important Banks (GSIBS)



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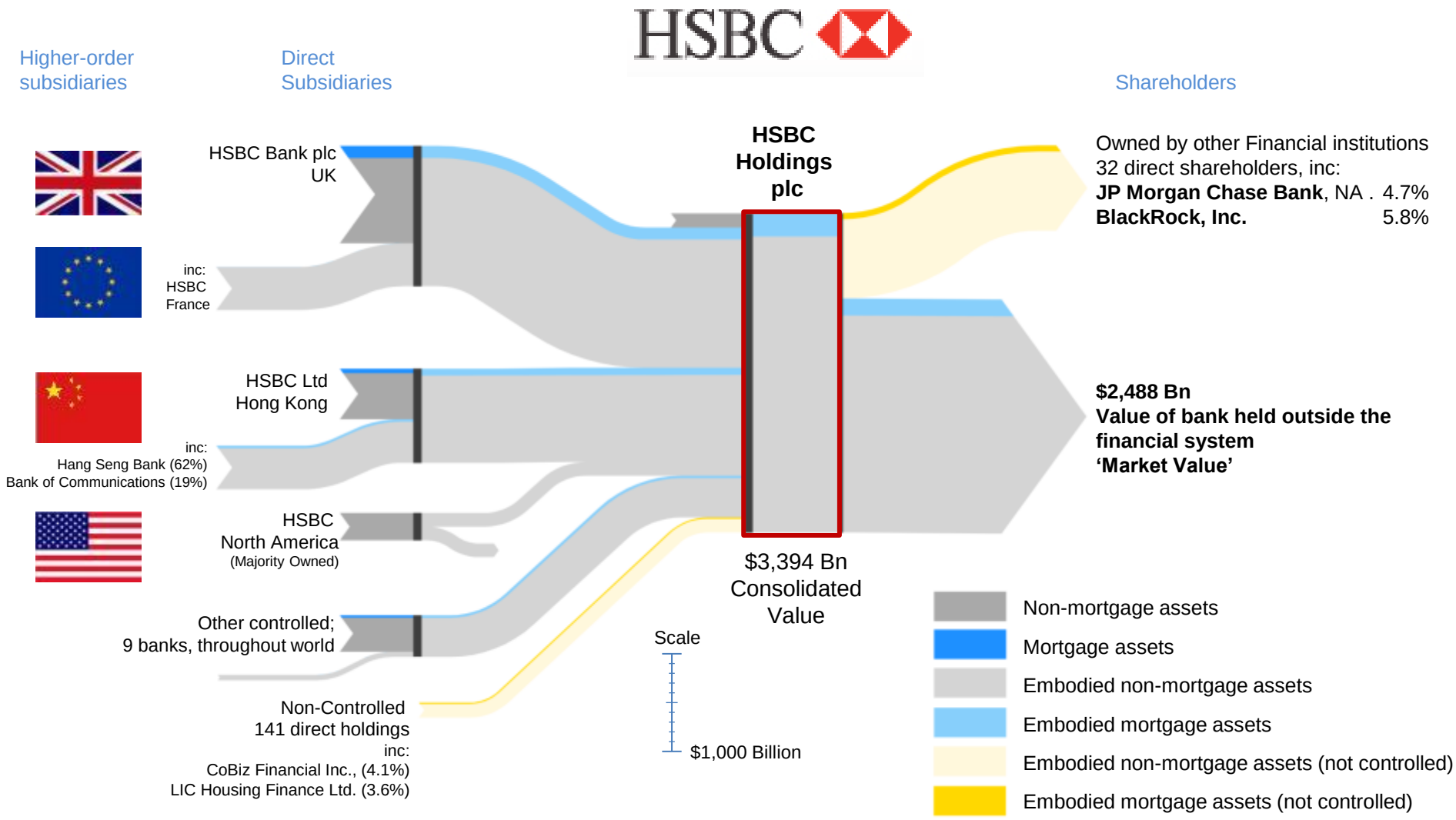
Mortgage Exposure of GSIBs

Financial Stability Board, November 2013

FSB Bucket	Financial Institution	Total Market Value (US$ Bn)	**Mortgage US$ Bn**	Mortgage Book as % of Total Value	Equity (US$ Bn)	**Mortgage/Equity**
4	**JP Morgan Chase**	3,280	**189**	6%	275	**69%**
4	**HSBC**	2,488	**181**	7%	220	**82%**
3	Barclays	2,095	**210**	10%	119	**176%**
3	Citigroup	1,949	**144**	7%	208	**69%**
3	Deutsche Bank	2,833	**128**	5%	128	**100%**
3	BNP Paribas	2,875	**106**	4%	167	**64%**
2	UBS	1,321	**180**	14%	83	**218%**
2	Mitsubishi UFJ FG	2,591	**168**	6%	253	**67%**
2	Credit Suisse	1,663	**134**	8%	134	**100%**
2	Bank of America	2,375	**19**	1%	381	**5%**
2	Goldman Sachs	1,700	**14**	1%	105	**14%**
2	Morgan Stanley	205	**5**	2%	24	**19%**
2	Royal Bank of Scotland	2,047	**0.4**	0%	233	**0%**
2	Group Crédit Agricole	2,353	**0**	0%	110	**0%**
1	Groupe BPCE	1,549	**376**	24%	75	**499%**
1	Bank of China	2,306	**230**	10%	167	**137%**
1	Santander	1,009	**121**	12%	80	**151%**
1	Société Générale	1,886	**105**	6%	82	**129%**
1	Nordea	956	**102**	11%	59	**174%**
1	State Street	1,861	**98**	5%	175	**56%**
1	ING Bank	947	**73**	8%	116	**63%**
1	Sumitomo Mitsui FG	698	**58**	8%	78	**74%**
1	Bank of New York Mellon	1,135	**50**	4%	104	**48%**
1	Unicredit Group	867	**50**	6%	86	**58%**
1	BBVA	631	**14**	2%	65	**22%**
1	Mizuho FG	1,583	**6**	0%	118	**5%**
1	ICBC	3,041	**5**	0%	210	**2%**
1	Standard Chartered	471	**3**	1%	37	**9%**
1	Wells Fargo	1,403	**2**	0%	139	**1%**
		50,119	**2,772**	6%		
	All Banks in Financial System:	219,000	**18,000**	8%		
	GSIBs as % of Total FS:	23%	**15%**			

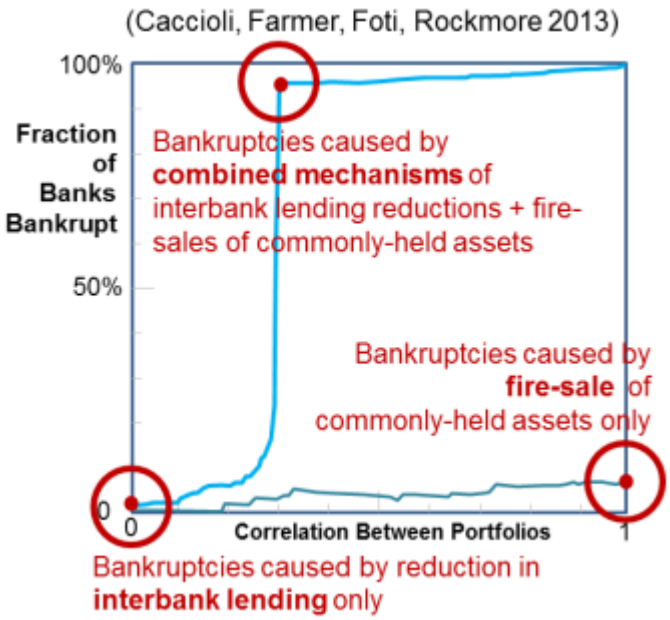
Consolidated mortgage

Analysis of Asset Structure of a GSIB



Contagion Mechanisms

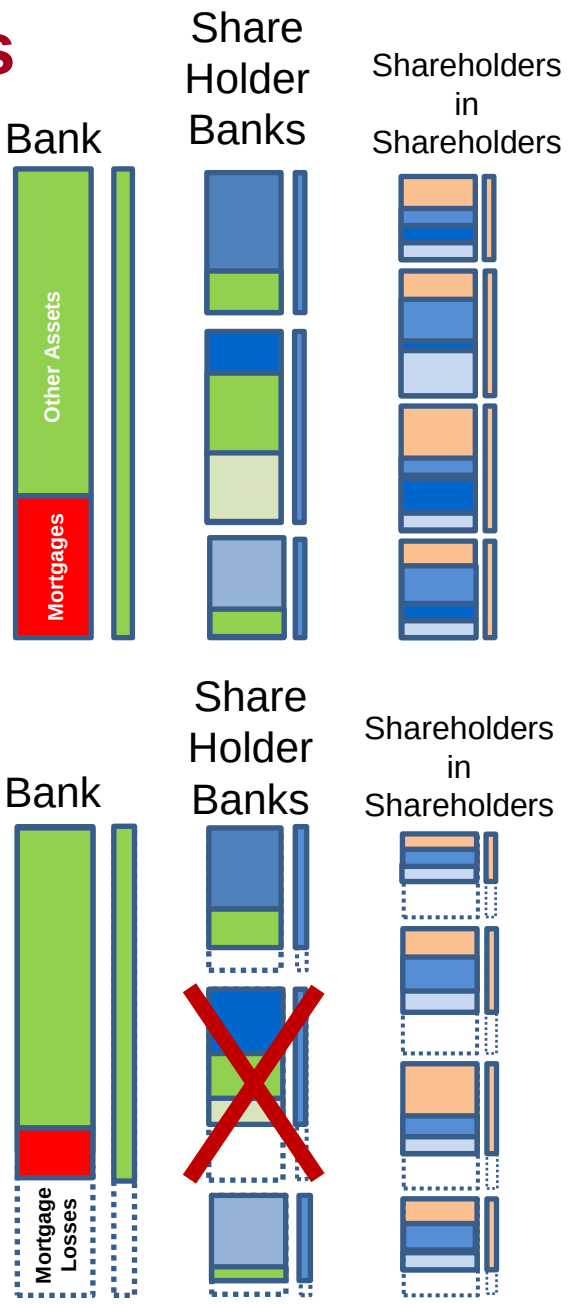
- What mechanisms cause financial contagion?
  - Interbank lending (**Counterparty Failure Risk**)
  - Commonly-held asset devaluation (**Fire-Sales**)
  - Ownership equity devaluation (**Cross-Holding**)
  - Repo borrowing calls (**Rollover Risk**)
- Interaction between these mechanisms is more important than a single mechanism on its own
- In this presentation we represent two:
  - Cross-Holding Loss (dynamically)
  - Commonly-Held Asset Fire-Sales (non-dynamically)



Interacting contagion mechanisms are more significant than individual mechanisms

Contagion Mechanics

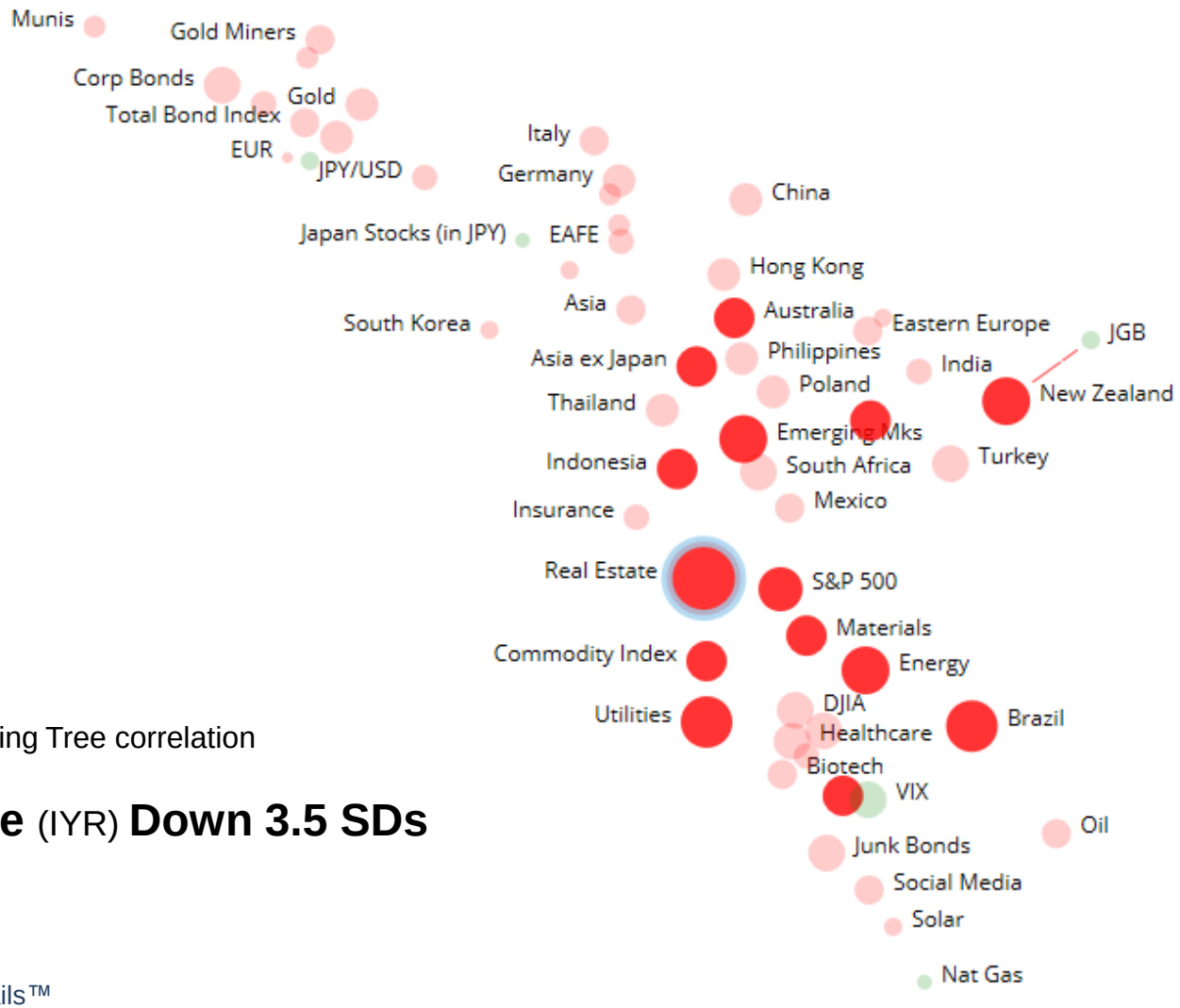
- Banks cross-share holdings are a significant contagion mechanism
  - We use the contagion model recently proposed by Elliott, Golub and Jackson (AER, forthcoming).
  - Bank cross-holdings can also be used as a proxy for interbank relationships (see Battiston et al. SR 2012)
- The “value” of a bank depends on the value of other banks it is connected to
- If a banks’ “value” falls below a given threshold the bank become distressed and discontinuously loses further value (as determined by a specified failure cost)
- A distressed bank causes direct losses to other banks it is connected to



How This Scenario Might Play Out

- Fed begins tapering as US economic growth accelerates and jobless rates drop below 6%
- Credit sensitive instruments sell off:
  - Corporate bonds, junk bonds, Munis, Real Estate, Utilities
- The most inflated property markets in emerging economies are hit first
  - China begins the property bubble deflation with a rapid pricing collapse
- Other inflated property markets follow suit, with different degrees of correction
  - Global housing bubble
- Contagion flows through the financial system
  - Significant loss of value to the entire system
- Lengthy recession ensues
  - Global economy returns to another cycle of negative growth

Correlation of Investment Assets with Real Estate



Minimum Spanning Tree correlation
Stress Test

Real Estate (IYR) **Down 3.5 SDs**

Source:

FNA HeavyTails™

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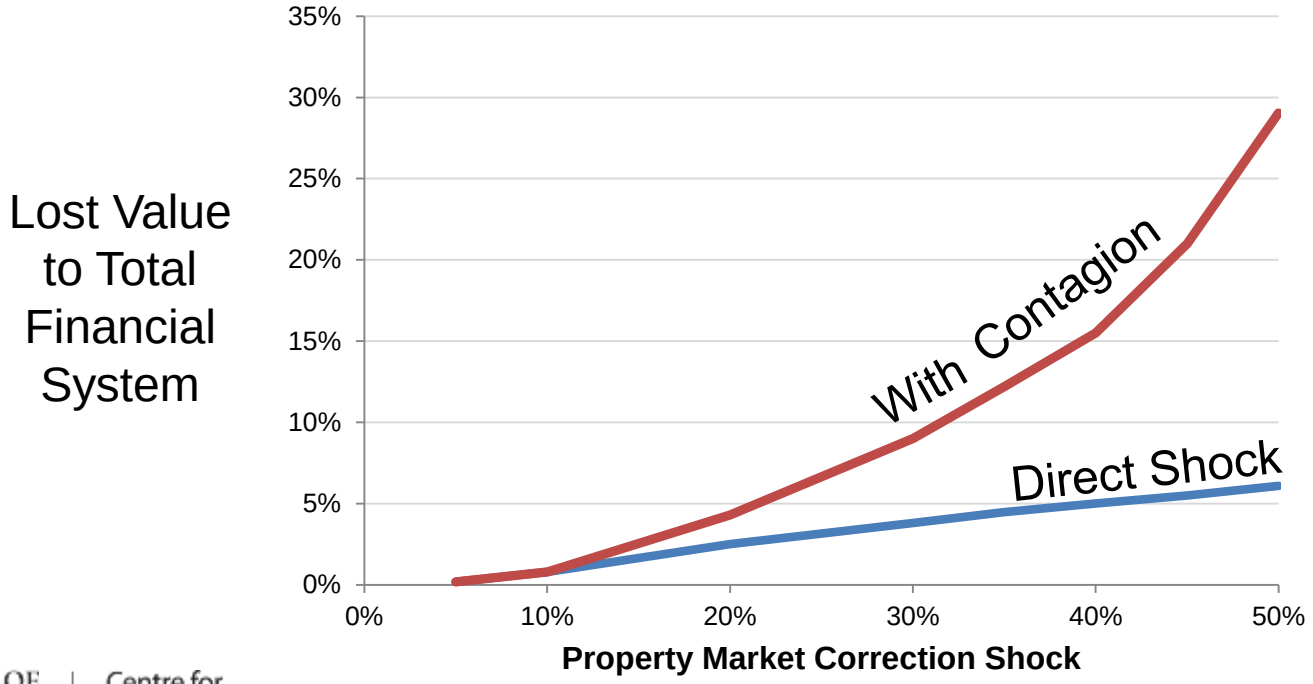
Finding the Contagion Point for Property Bubble

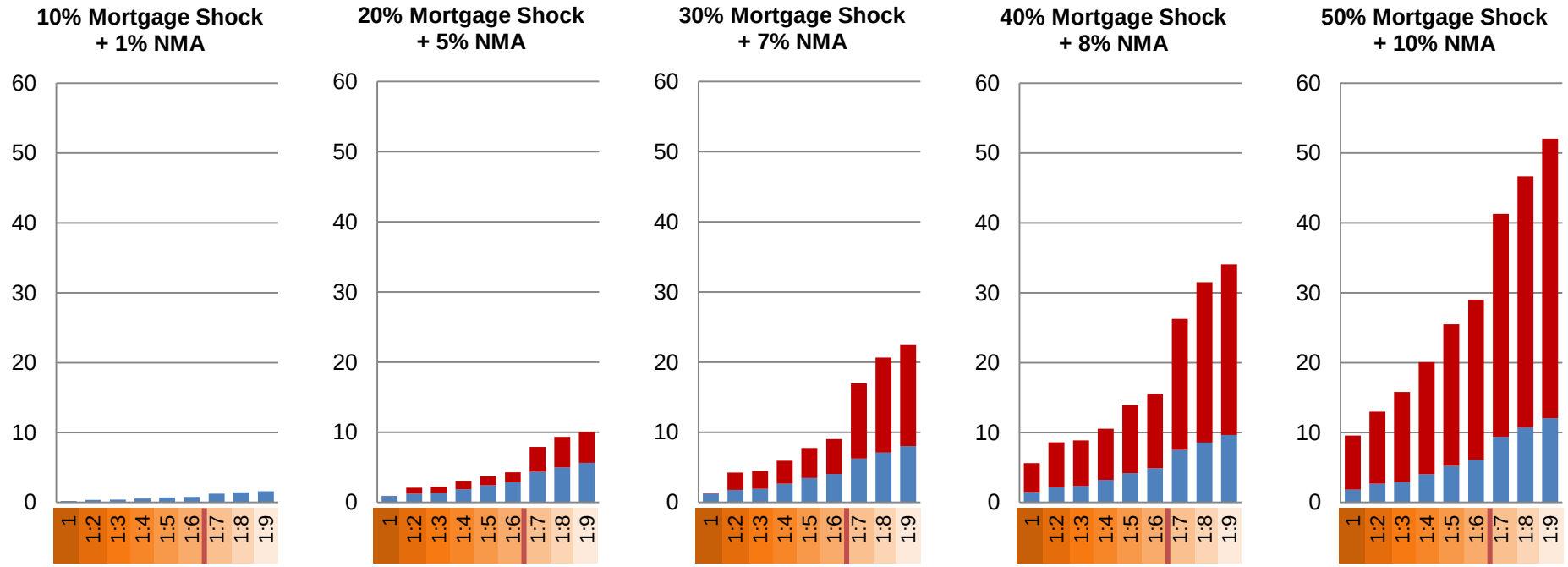
Top 6 Tiers of Property Markets

Property Value Reduction Shock:	**5%**	**10%**	**20%**	**30%**	**35%**	**40%**	**50%**
Asset Value Reduction:	0%	1%	5%	7%	7.5%	8%	10%
Lost Value to Total Financial System							
Direct Shock:	0.2%	0.8%	2.9%	4.1%	4.5%	4.9%	6.1%
Total Loss with Contagion (Same markets + International):	0.2%	0.8%	4.3%	9.0%	12.2%	15.5%	29.0%
Contagion amplifier:	0.0	0.0	0.5	1.2	1.7	2.2	3.8
Number of Failed Banks:	0	0	150	243	291	342	1,059
Banks that failed from Mortgage-shock:	0	0	159	239	284	324	1,027
Banks that failed through contagion:	0	0	0	6	7	18	32
Failed GSIBs:	0	0	0	2	4	6	14



Tier 1-6 Countries (Most exposed 24 markets)

Geographical Spread and Severity



Property Market Bubble Risk

Tier 1: China & Emerging Markets
China, Hong Kong, India, Brazil, Philippines, Indonesia, Turkey

Tier 2: Commonwealth
Canada, Australia, New Zealand

Tier 3: Nordics
Norway, Finland, Sweden

Tier 4: UK
United Kingdom

Tier 5: Europeans
France, Belgium, Netherlands

Tier 6: Other Europe
Spain, Portugal, Italy, Greece, Ireland, Austria, Denmark

Tier 7: US
United States

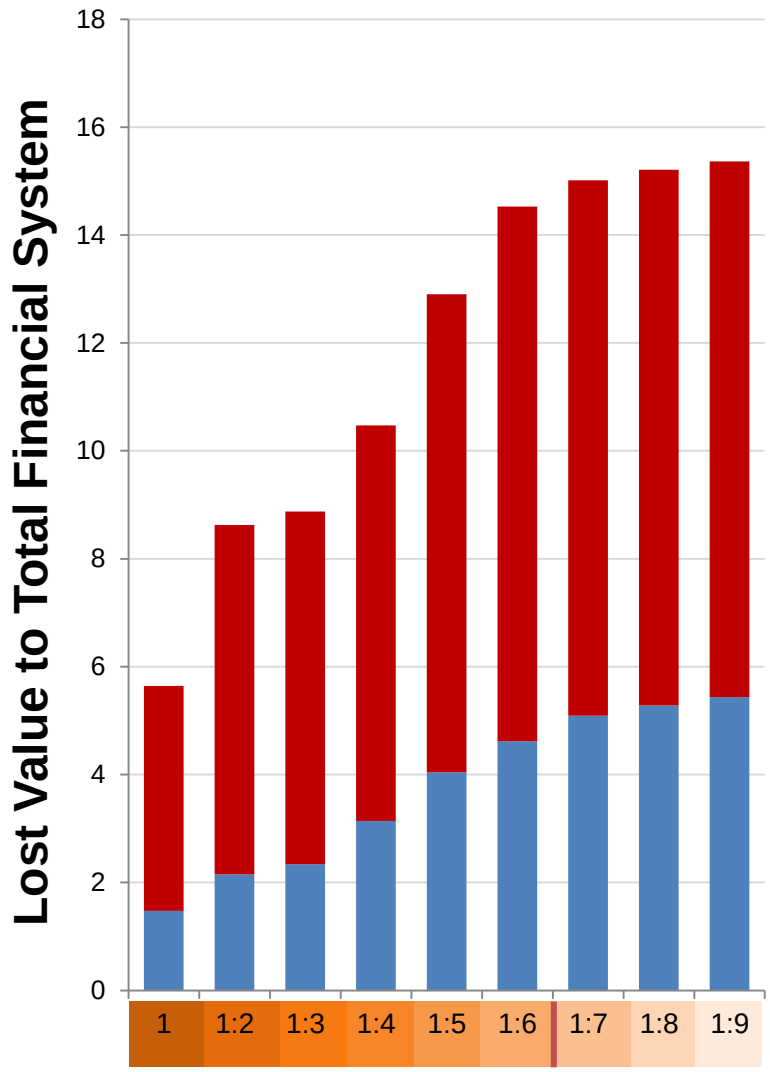
Tier 8: Prudent Europe
Germany, Switzerland

Tier 9 Industrial Asia
Japan and South Korea

Tier 10 RoW
Other markets

Global Property Bubble Stress Test Scenario (S1)

Property Market Bubble Risk	Property Correction Shock	Shock to Non-Mortgage Assets
Tier 1: China & Emerging Markets China, Hong Kong, India, Brazil, Philippines, Indonesia, Turkey	**40%**	8.0%
Tier 2: Commonwealth Canada, Australia, New Zealand	**40%**	8.0%
Tier 3: Nordics Norway, Finland, Sweden	**40%**	8.0%
Tier 4: UK United Kingdom	**35%**	7.5%
Tier 5: Europeans France, Belgium, Netherlands	**35%**	7.5%
Tier 6: Other Europe Spain, Portugal, Italy, Greece, Ireland, Austria, Denmark	**30%**	7.0%
Tier 7: US United States	**10%**	1.0%
Tier 8: Prudent Europe Germany, Switzerland	**10%**	1.0%
Tier 9 Industrial Asia Japan and South Korea	**10%**	1.0%
Tier 10 RoW Other markets	**0%**	0%



Global Property Bubble Stress Test Scenario

Global Property Bubble Stress Test Scenario

1 Tier 1 Markets – China and emerging markets – suffer property correction

Property Market Bubble Risk

Tier 1: China & Emerging Markets
China, Hong Kong, India, Brazil, Philippines, Indonesia, Turkey

Global Property Bubble Stress Test Scenario

2 Property correction wave spreads to Tier 2 markets: Commonwealth countries

Tier 1: China & Emerging Markets
China, Hong Kong, India, Brazil, Philippines, Indonesia, Turkey

Tier 2: Commonwealth
Canada, Australia, New Zealand

Global Property Bubble Stress Test Scenario

3 Tier 3 markets affected - Nordics

Property Market Bubble Risk

Tier 1: China & Emerging Markets
China, Hong Kong, India, Brazil, Philippines, Indonesia, Turkey

Tier 2: Commonwealth
Canada, Australia, New Zealand

Tier 3: Nordics
Norway, Finland, Sweden

Global Property Bubble Stress Test Scenario

4 Property price slump affects UK – Tier 4 market

Property Market Bubble Pop

Tier 1: China & Emerging Markets
China, Hong Kong, India, Brazil, Philippines, Indonesia, Turkey

Tier 2: Commonwealth
Canada, Australia, New Zealand

Tier 3: Nordics
Norway, Finland, Sweden

Tier 4: UK
United Kingdom

Global Property Bubble Stress Test Scenario

5 Property market corrections begin in Tier 5 – France, Belgium, Netherlands

Property Market Bubble Pop

Tier 1: China & Emerging Markets
China, Hong Kong, India, Brazil, Philippines, Indonesia, Turkey

Tier 2: Commonwealth
Canada, Australia, New Zealand

Tier 3: Nordics
Norway, Finland, Sweden

Tier 4: UK
United Kingdom

Tier 5: Europeans
France, Belgium, Netherlands

Global Property Bubble Stress Test Scenario

6 Property market collapse reaches other Europeans – Tier 6

Property Market Bubble Pop

Tier 1: China & Emerging Markets
China, Hong Kong, India, Brazil, Philippines, Indonesia, Turkey

Tier 2: Commonwealth
Canada, Australia, New Zealand

Tier 3: Nordics
Norway, Finland, Sweden

Tier 4: UK
United Kingdom

Tier 5: Europeans
France, Belgium, Netherlands

Tier 6: Other Europe
Spain, Portugal, Italy, Greece, Ireland, Austria, Denmark

Global Property Bubble Stress Test Scenario

7 Milder property pricing correction in US

Property Market Bubble Risk

Tier 1: China & Emerging Markets
China, Hong Kong, India, Brazil, Philippines, Indonesia, Turkey

Tier 2: Commonwealth
Canada, Australia, New Zealand

Tier 3: Nordics
Norway, Finland, Sweden

Tier 4: UK
United Kingdom

Tier 5: Europeans
France, Belgium, Netherlands

Tier 6: Other Europe
Spain, Portugal, Italy, Greece, Ireland, Austria, Denmark

Tier 7: US
United States

Global Property Bubble Stress Test Scenario

8 Tier 8 countries affected

Property Market Bubble Risk

Tier 1: China & Emerging Markets
China, Hong Kong, India, Brazil, Philippines, Indonesia, Turkey

Tier 2: Commonwealth
Canada, Australia, New Zealand

Tier 3: Nordics
Norway, Finland, Sweden

Tier 4: UK
United Kingdom

Tier 5: Europeans
France, Belgium, Netherlands

Tier 6: Other Europe
Spain, Portugal, Italy, Greece, Ireland, Austria, Denmark

Tier 7: US
United States

Tier 8: Prudent Europe
Germany, Switzerland

Global Property Bubble Stress Test Scenario

9 Finally reaches least exposed markets – Tier 9

Global Property Bubble Stress Test Scenario

10 Global wave of property market collapse is complete

Key Metrics of Consequences of Scenario

- Our fictional 'Global Property Crash of 2015' wipes out 5-15% of the value of the financial system
  - It is highly systemic, and has strong contagion characteristics
- Four GSIBs fail
- It is geographically diverse and has implications for all major markets
- This **$10-32 Trillion value loss** could potentially be significantly larger than the value loss to the system suffered in the 2008-9 Great Financial Crisis
  - We estimate the lost Global GDP 2007-12 at $18 Trillion **($20 Trillion** at today's values)
  - The GFC caused a lengthy period of reduced economic activity
- Performance of individual financial institutions is highly heterogeneous
  - Internal risk management processes can dramatically change the outcome for specific financial entities

Conclusions: A Research Agenda

- Practitioners are learning from the pioneers of network theory in finance
- Looking for practical applications and real-world calibrations to guide ‘what-if’ estimates
- Less interested in prediction or best estimate forecasts…
- …more interested in uncertainty characterization and considering worst cases and extreme limits
- The Centre for Risk Studies is looking to play a role in developing network theory for application in business decision support
- **Empowering practitioners to manage their own risk will reduce systemic risk better than regulation**

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