Centre for Risk Studies

Workshop 9 April 2013

Cambridge Centre for Risk Studies Research Programme on Financial Catastrophe

Andrew Coburn

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Main Threads of the Cambridge FinCat Project 2013

State-of-the-Art Review

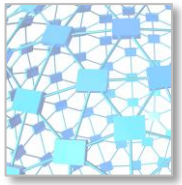
- Who is doing what; literature review; leading opinion survey; Workshop

Causes of Future Crises

- What might cause future FinCats? Defining a full taxonomy; Developing an authoritative historical catalogue; What will be different in the future?

Developing Hypothetical Scenarios

- What toolkit do we need to model the impacts of potential events? Can we ensure 'coherence' in their effects?



Understanding Extreme Financial System Behaviour

- Understanding financial network modelling, interconnectivity, network behaviour, critiquing common modelling approaches, social behaviour

Understanding Financial Catastrophes

Potential Causes of Future Crises

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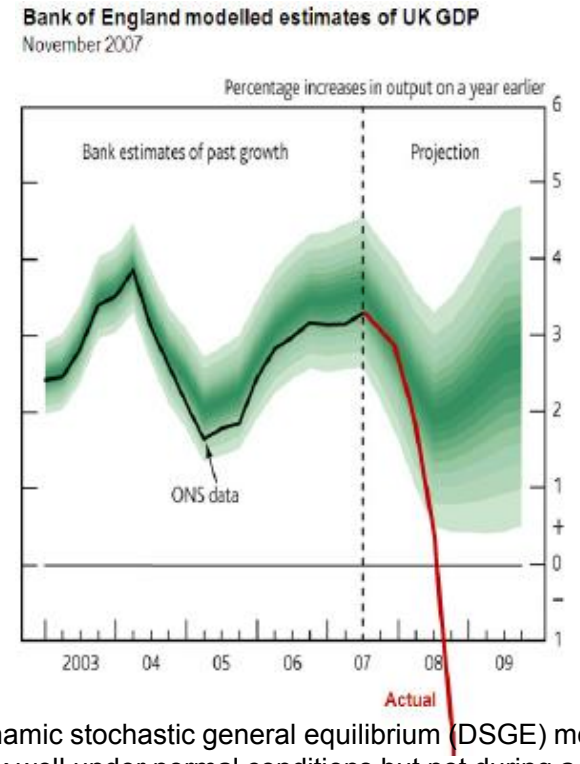
What Causes a Phase Change in Financial Regime?

- Models that perform well under normal conditions stop being useful when the regime switches to a new mode of operation under extreme conditions
- What are the potential causes of this 'Financial Catastrophe' regime switch?
- How often might it occur? And what is the frequency and severity distribution of these regimes?
- Are there models that do work to explain what happens in Financial Catastrophe

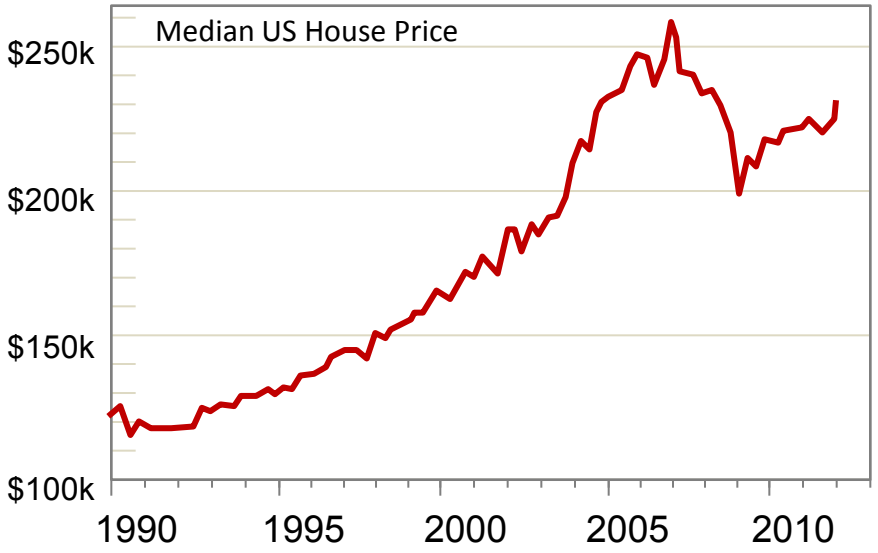


Dynamic stochastic general equilibrium (DSGE) models work well under normal conditions but not during a crisis

- "We suffered adverse 25-standard deviation events, several days in a row according to our models."
  - CFO of one of the world's largest hedge funds, after it had suffered huge losses in 2008
- "The 1987 'Black Monday' has a likelihood of 10^{-148} in traditional 'random walk' mathematics."
  - Economist Gene Stanley, Boston University
- "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

How Big a Shock Might Cause a Financial Regime Change?

- The emerging narrative for 2008 crisis has its roots in bursting of the US housing price bubble, after spectacular growth from 1990s
- The bubble fuelled financial creativity
  - Lending to sub-prime mortgage market
  - Creation of Mortgage-Backed Securities
  - Enabled institutions and investors around the world to invest in U.S. housing market
- In 2007, bubble burst and US house prices dropped 23% in 6 months
- Many financial institutions exposed
  - Losses triggered 'credit crunch' – a contagion spiral of lending withdrawal
  - Lehman Brothers losses of $5.6 bn from toxic mortgages triggered their 2008 bankruptcy
  - Major government bail-outs and capital injections to stem contagion
- Aggregate financial losses **$200 Bn of** subprime losses triggered **$2 trillion write down**
  - US rescue fund initially touted at $700 Billion



What Other Triggers Could Cause Similar Phase Changes?

- What **exogenous** shocks could cause a loss of several hundreds of billions of dollars to trigger a confidence failure?
  - Size threshold may rule out many potential causes of large losses (e.g. accidents, spills, natural catastrophe)
  - Remaining candidates are big geo-political events, pandemics, demographic/longevity risk, sudden climate change
- How do **endogenous** shocks occur within the system, and can these be categorized and understood?
  - Group-think, information asymmetry, asset bubbles, regulatory evasion

Long-Perspective Historical Catalog of Financial Crises

- Partnering with the Centre for Financial History (CFH) at Cambridge University http://www.centreforfinancialhistory.org/.
- CFH historians currently researching and documenting several hundreds of crises and providing detailed analysis for 40 selected events
- Covers 1500 to present
- Covers all geographical markets
- Will result in a 4-volume publication by Routledge in 2014

Project lead
D'Maris Coffman
Director of
Centre for Financial History

Co-edited by
Larry Neal
Professor of Economics
University of Illinois

Centre for Financial History at Newnham College

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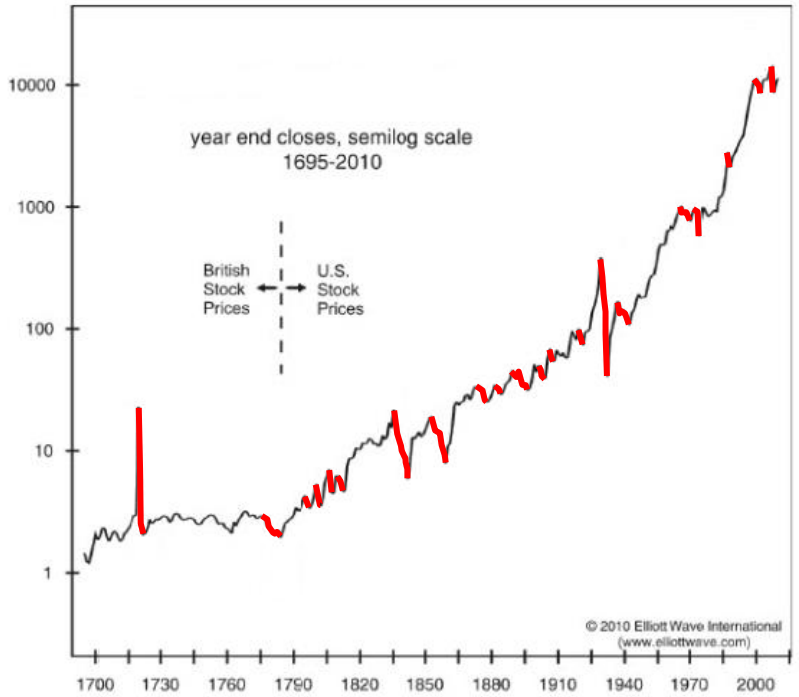
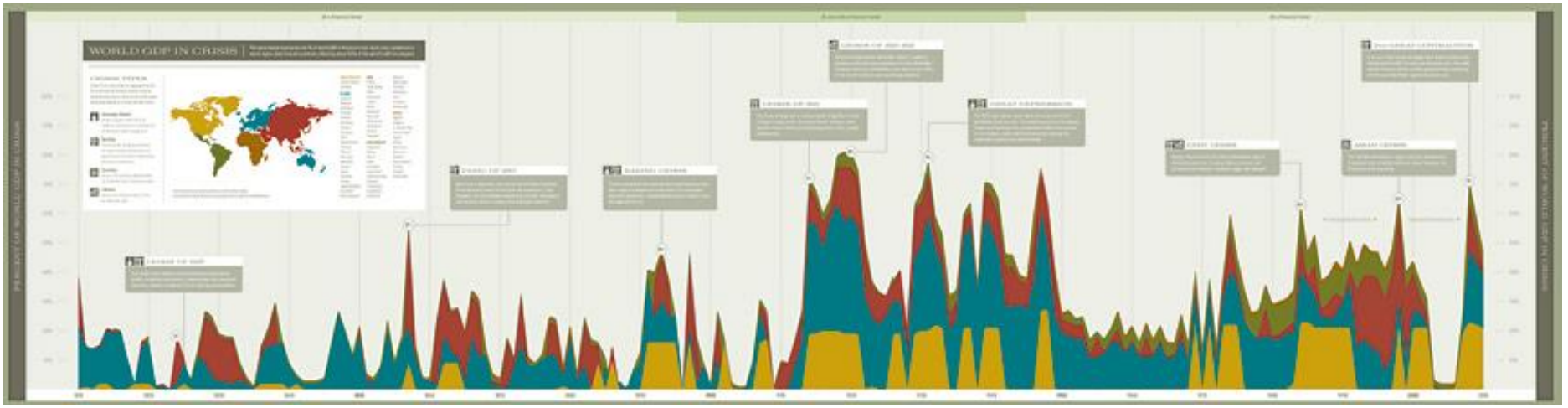
Long Term Historical Views of Financial Catastrophes



Source: Jay (2010)
http://fintrend.com/tag/bear-market/



Visual History of Financial Crises based on *This Time Is Different: Eight Centuries of Financial Folly* by Carmen M. Reinhart & Kenneth S. Rogoff. Depicts the cyclical history of financial crisis from 1810 to 2010 for sixty-six countries representing 90% of world GDP

Taxonomy of Financial Catastrophe

- Qualitatively different causes of **endogenous** financial shocks

Financial Shock

Asset Bubble

Financial Irregularity

Bank Run

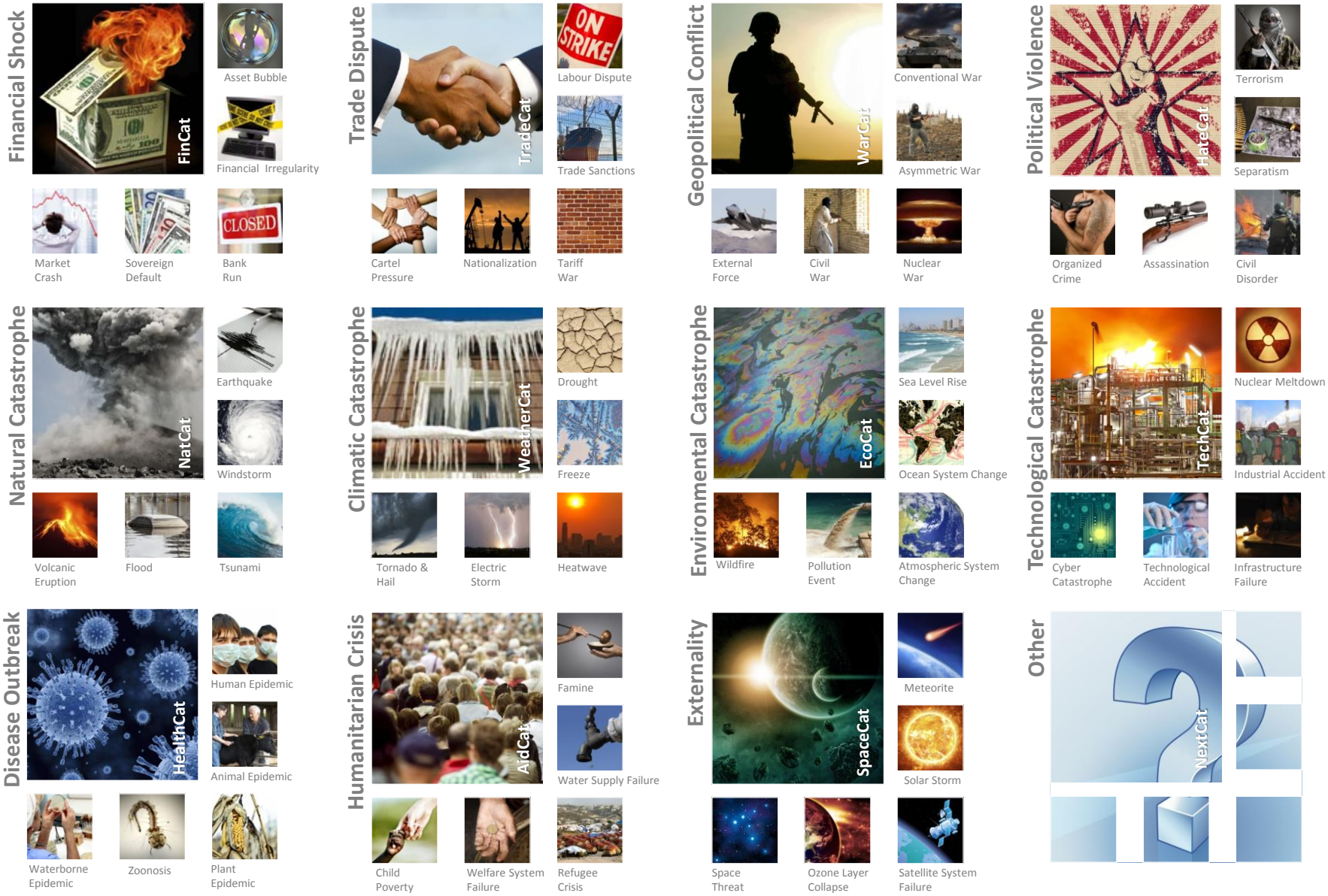
Sovereign Default

Market Crash

Based on Allen & Gale 2009,
Understanding Financial Crises

Potential Exogenous Shocks

Cambridge Risk Framework: Socio-Economic Macro-Threat Taxonomy



Scenarios of Exogenous Financial Shocks

Exploring the toolkit needed for coherence in understanding exogenous shocks

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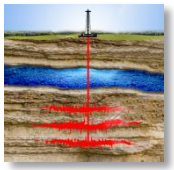
Hypothetical Scenarios of Exogenous Financial Shocks

Regime change in Middle East triggers extreme oil price escalation



Shale gas bonanza causes extreme oil price collapse

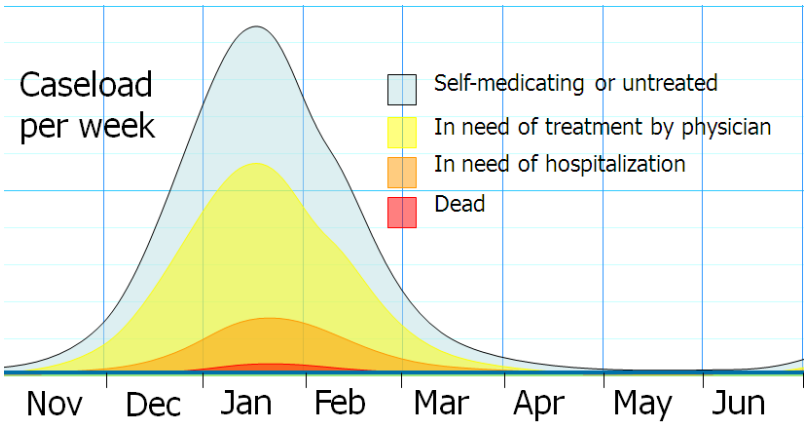
Global pandemic causes 6 month economic disruption

Extreme weather event causes 6 week disruption in Europe & United States

Choose your bubble… (China property?)

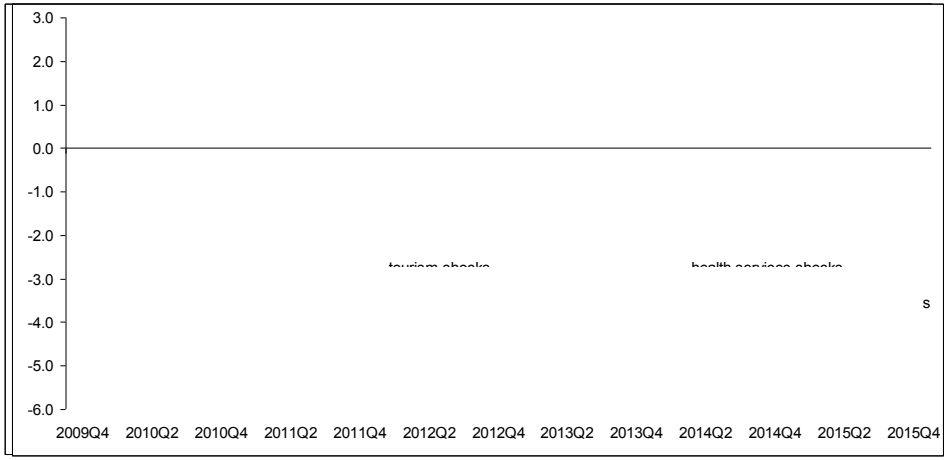
Pandemic Scenario

- Scenario of an Avian Influenza (H5N1) reassortment to create a virulent and highly infectious pandemic, originating in Vietnam, and spreading around the globe in weeks
- Uses epidemiological modeling to assess the wave of human illness and deaths
- 'Supply shock' disruption arises from absenteeism in the workforce
- A severe pandemic will freeze economic activity ('Demand shock') while the world's population hides from the disease
- It is possible for a severe pandemic to cause a loss of 10-20% of the world's annual GDP
- This shock would dwarf the housing bubble of 2007

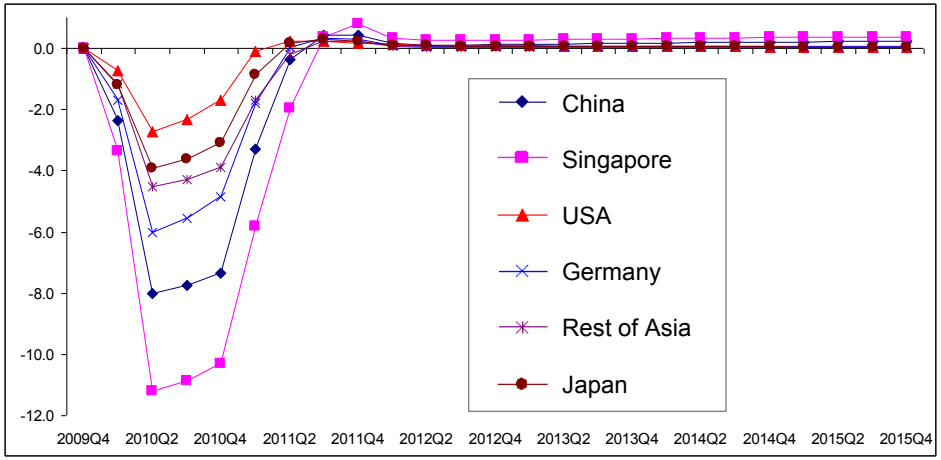


Pandemic Scenario Macro-Economic Impacts

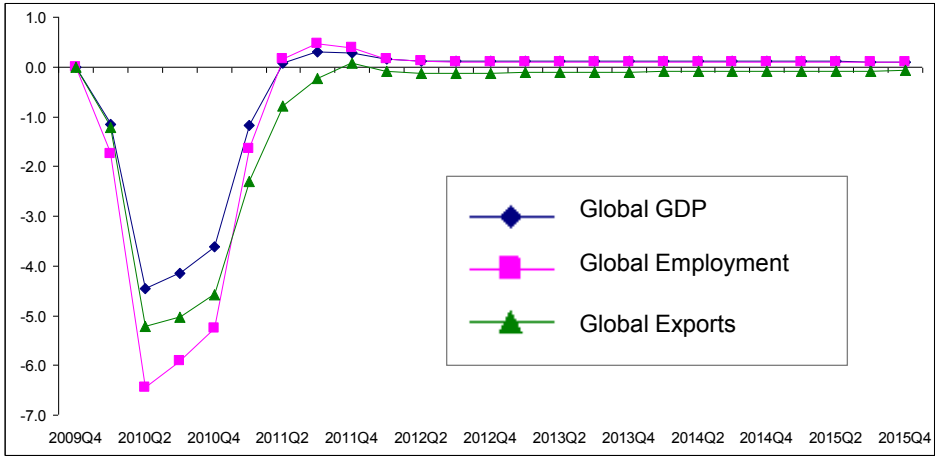
Effects of individual shocks of scenario on global employment (percentage deviations from baseline)



Effects of Scenario on GDP for selected regions assuming asymmetric real wage response (percentage deviation from baseline)



Effects of Scenario on global employment, GDP and exports assuming asymmetric real wage response (percentage deviation from baseline)



Modelled Market Impact

Equity Markets

YEAR							
EVENT 1	1	2	3	4	5	6	7
S&P500	-3.6%	2.8%	-0.2%	-0.3%	-0.3%	0.0%	0.0%
MSCI DM	-3.1%	3.0%	0.0%	-0.1%	-0.1%	0.0%	0.0%
MSCI EMA	-1.9%	3.1%	0.0%	0.2%	0.4%	0.0%	0.0%
MSCI EMNA	-3.3%	2.8%	0.2%	0.4%	0.5%	0.0%	0.0%

EVENT 2	1	2	3	4	5	6	7
S&P500	-10.8%	6.5%	3.7%	-0.6%	-0.5%	0.0%	0.0%
MSCI DM	-11.1%	7.6%	4.2%	-0.6%	-0.4%	0.0%	0.0%
MSCI EMA	-14.1%	13.3%	3.9%	-0.3%	0.1%	0.0%	0.0%
MSCI EMNA	-11.7%	8.2%	3.9%	0.1%	0.3%	0.0%	0.0%

S&P500 Index
Representative indices of the regional equity markets include:
MSCI Developed Markets (MSCI DM)
MSCI Emerging Market Asia (MSCI EMA)
MSCI Emerging Market Non-Asia (MSCI EMNA)

Fixed Income Markets

Bond Yield: Deviation from Baseline (in percentage points)

	Year						
EVENT 1	1	2	3	4	5	6	7
US 10 Year	-0.9	-0.3	-0.2	-0.3	-0.3	0.0	0.0
Euro 10 Year	-2.4	-0.2	-0.1	0.0	-0.1	0.0	0.0
UK 10 Year	-0.3	0.6	0.4	0.5	0.3	0.0	0.0
Japan 10 Year	-0.1	0.0	0.2	0.3	0.2	0.0	0.0

EVENT 2							
US 10 Year	-3.4	-2.5	-0.3	-0.6	-0.5	0.0	0.0
Euro 10 Year	-5.3	-2.6	0.7	-0.8	-0.4	0.0	0.0
UK 10 Year	-6.0	-2.4	1.3	-0.5	-0.1	0.0	0.0
Japan 10 Year	-3.5	-1.5	0.6	-0.2	0.0	0.0	0.0

Foreign Exchange Markets

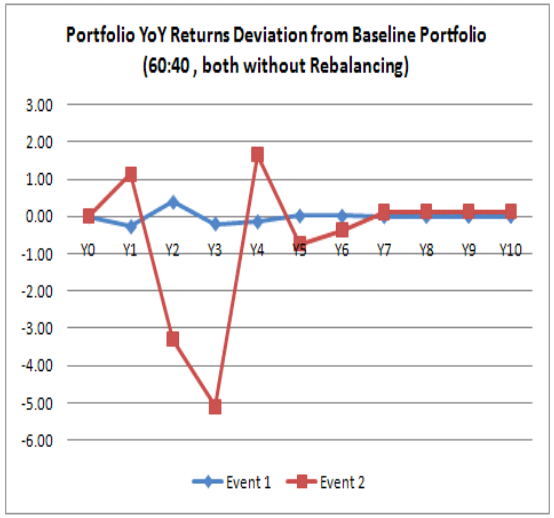
Event 1	Y0	Y1	Y2	Y3	Y4	Y5	Y6
United States	100	100.00	100.00	100.00	100.00	100.00	100.00
Euroarea	100	99.2	98.9	99.1	98.8	98.7	98.5
Japan	100	100.4	101.4	102.6	103.1	103.7	104.0
United Kingdom	100	98.7	98.6	99.0	99.1	99.2	99.2

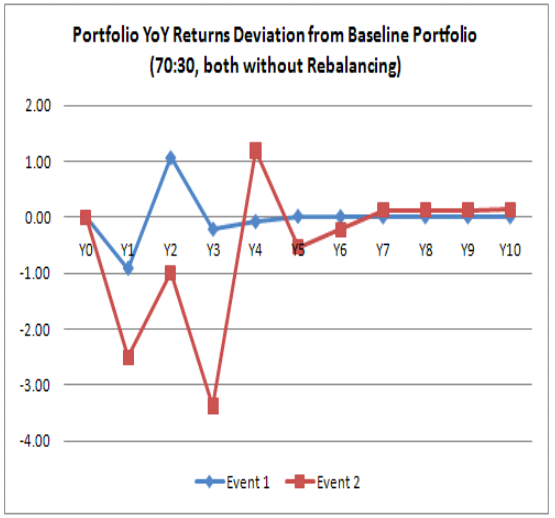
Event 2	Y0	Y1	Y2	Y3	Y4	Y5	Y6
United States	100	100	100	100	100	100	100
Euroarea	100	99.2	97.0	99.4	99.5	99.0	98.6
Japan	100	100.4	99.9	102.9	103.7	103.9	104.2
United Kingdom	100	98.7	96.3	99.4	99.9	99.5	99.3

60% equities; 40% bonds

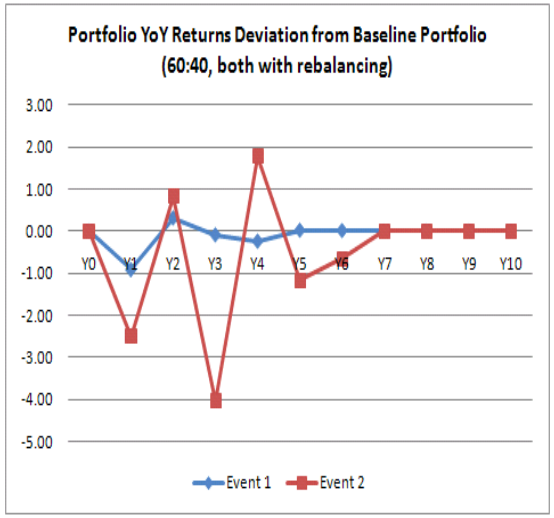
70% equities; 30% bonds

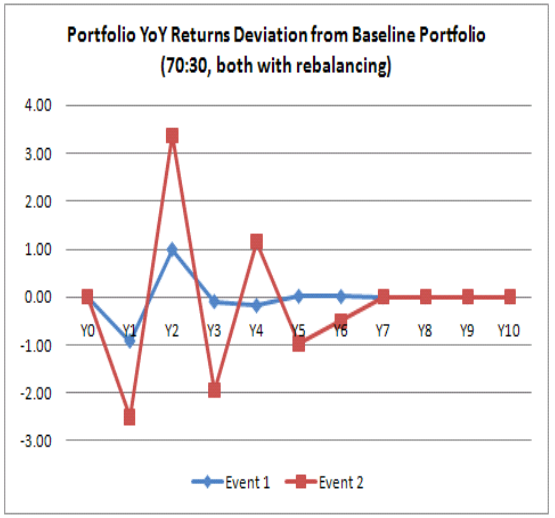
Without Rebalancing





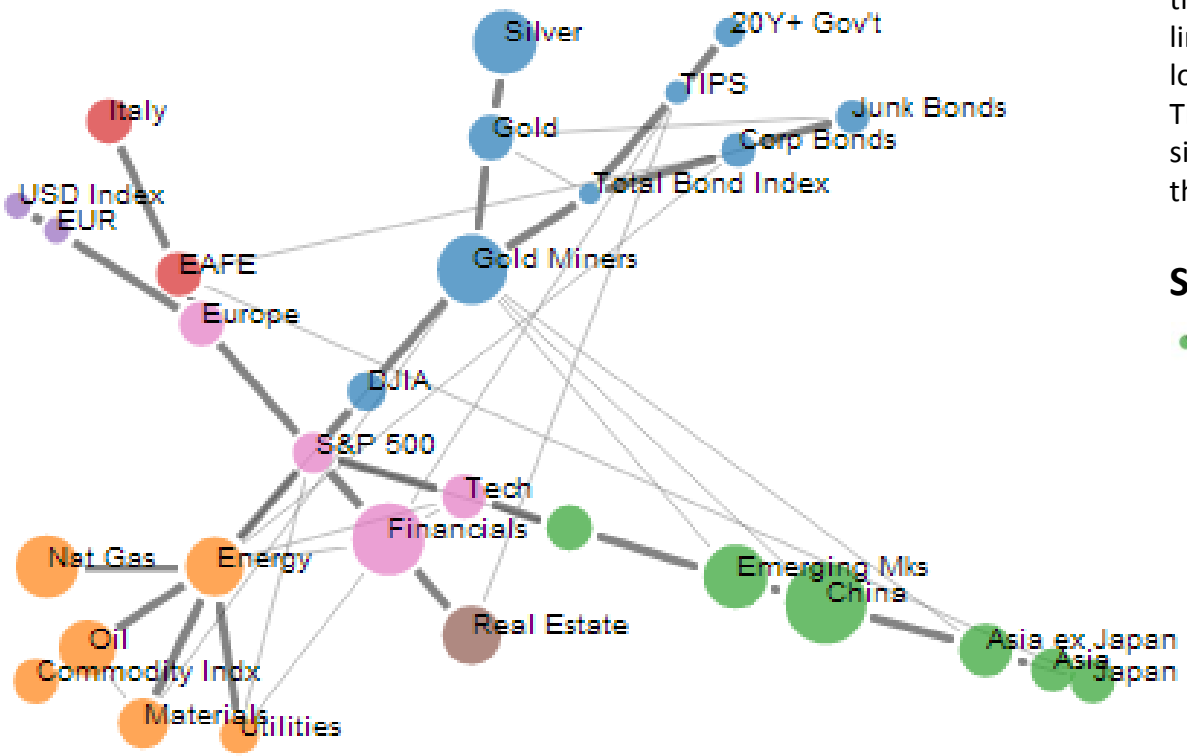
With Annual Rebalancing back to the intended weights





Portfolio Correlation Visualization Demonstration

Routine Correlation



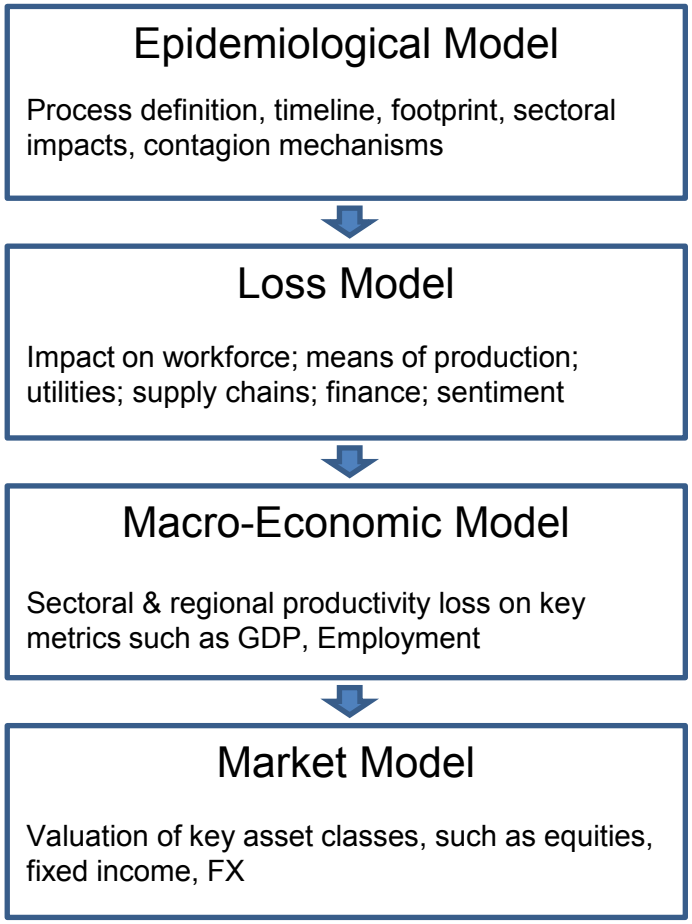
Asset Correlation Topologies

Nodes represent assets. Node size scales with variance of returns for the asset during the given period. Node color represents results of community detection.

Thick links form the minimum spanning tree of the correlation network. The length of thick links scale with correlation: long link means low correlation and short link high correlation. Thick links represent other statistically significant correlations. They do not scale with the correlation

Shock-induced Correlation

Investment Portfolio Shock Model Structure for Pandemic Event



Example Scenario (e.g. Global Pandemic)

Epidemiological model
of global disease spread

Productivity loss from workforce absenteeism
(Supply shock only)
Potential for simple demand shock analysis

Computable General Equilibrium Model [GTAP]
Alternatives include:
- Dynamic Simulation Generalized Linear models (DSGL)
- Markov Chain progression models

Equities	Simple Modified Dividend Discount Model (P/E ratios, margin growth & dividend yields)
Fixed Income	Interest rate yield projection model (bond term premium)
FX	Basic model of growth and inflation differentials of each country

Understanding Financial Network Behaviour

Simulating Cascading Failure

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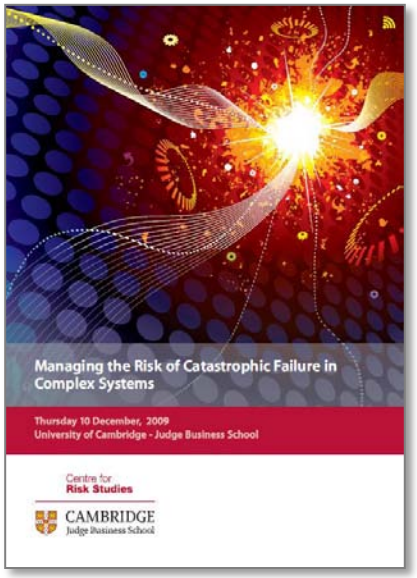
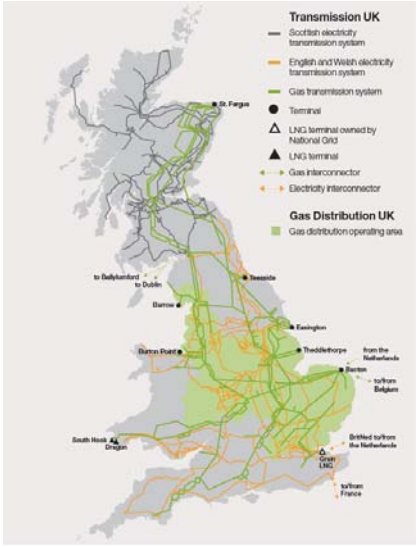
Understanding Financial Network Modelling

- Many researchers have embraced agent-based modelling (ABM) to explore how the financial system phase change occurs
  - Taking a 'Complex-Systems' approach to financial risk modelling
- Contagion is modelled using liquidity reduction and portfolio devaluation from one agent to another
- Exploring the connectivity of the financial system – what does the real world financial network look like?
  - Reveals that we don't know this very well: data on inter-connections is poor
- Models tend to be used to develop mechanistic scenarios or to explore idealized organizational structure for networks

Risk Centre Background:
Understanding Catastrophic Failure in Complex Systems

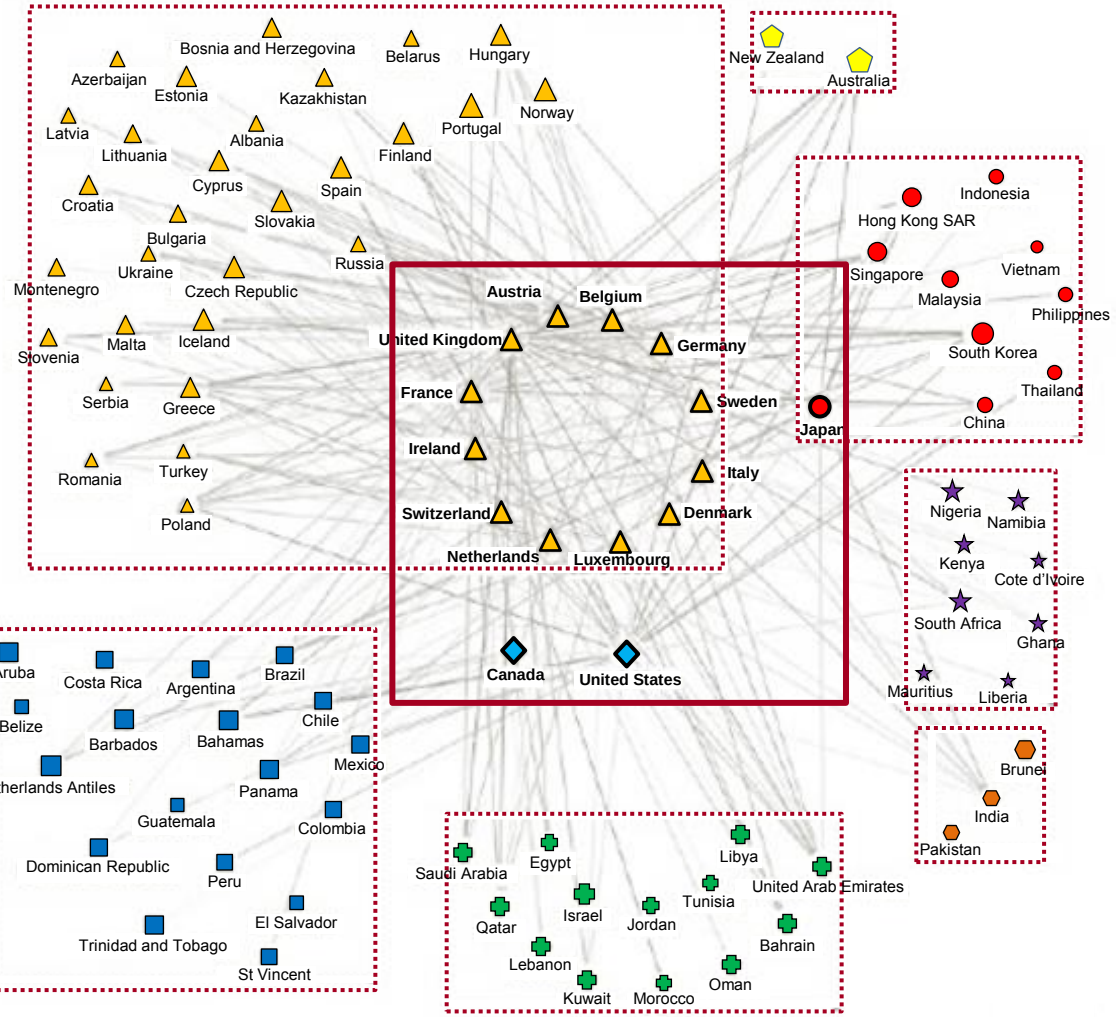




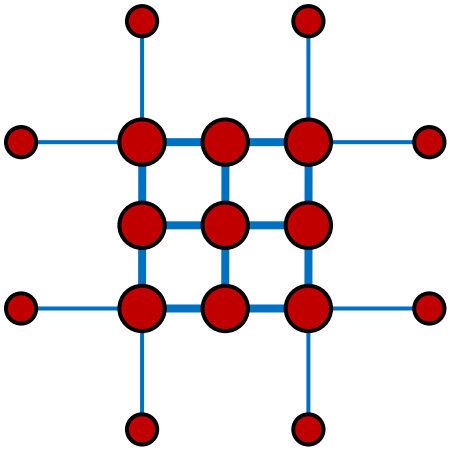
- Focus of the Centre for Risk Studies has been an enabler of projects and interchanges on complexity science and emergent behaviour
- Analysis of tightly-coupled systems, non-linear feedback loops, and failure analysis
- 2009 Annual meeting: **Managing the Risk of Catastrophic Failure in Complex Systems**
- Examples include
  - National grid engineering failures
  - Transportation systems
  - Economic systems and banking networks
  - Supply chains and business networks
  - Cyber attacks on national utility systems

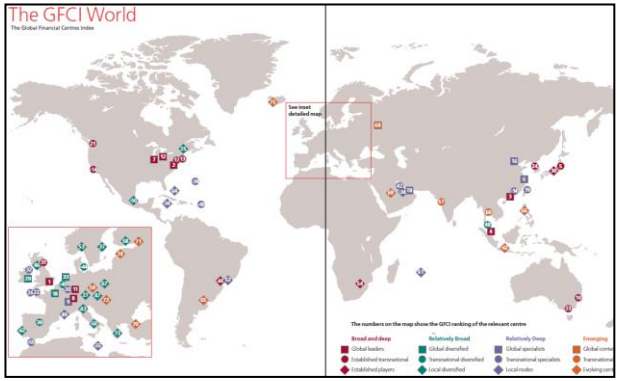
Sanjeev Goyal's Connections: An Introduction to the Economics of Networks

Network Structures of Banking Networks



Core Periphery Network





Source:
A network analysis of global banking: 1978-2009; Minoiu, Camelia ; Reyes, Javier A., IMF Working Paper
http://www.imf.org/external/pubs/ft/wp/2011/wp1174.pdf

A Banking Network Liquidity Contagion Model

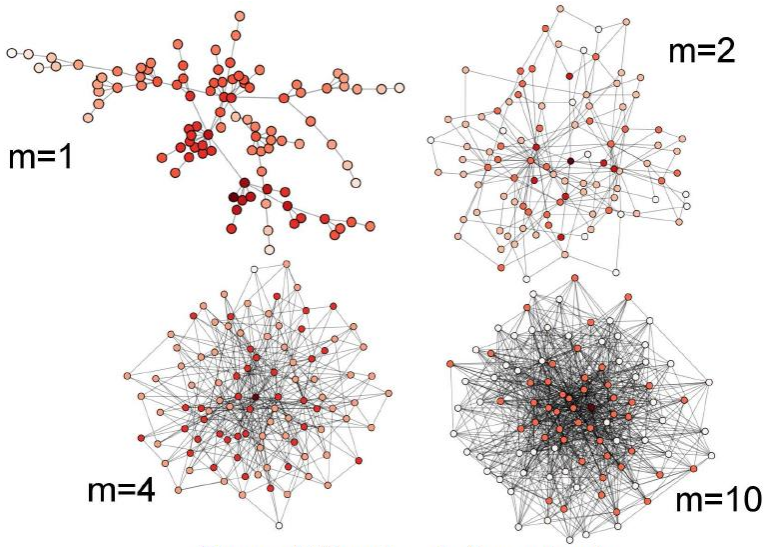
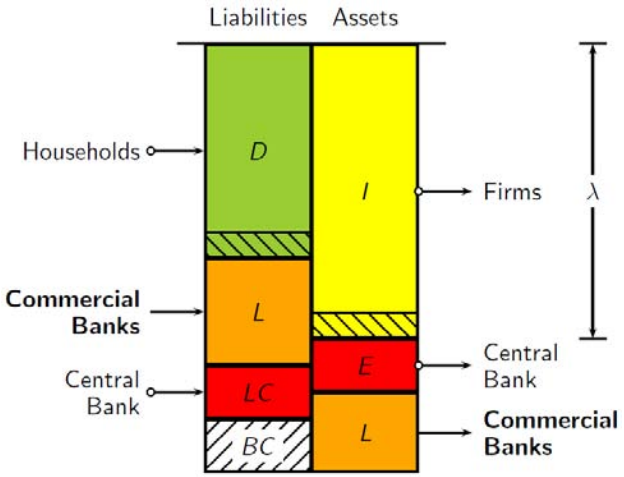


Figure: Different scale free networks



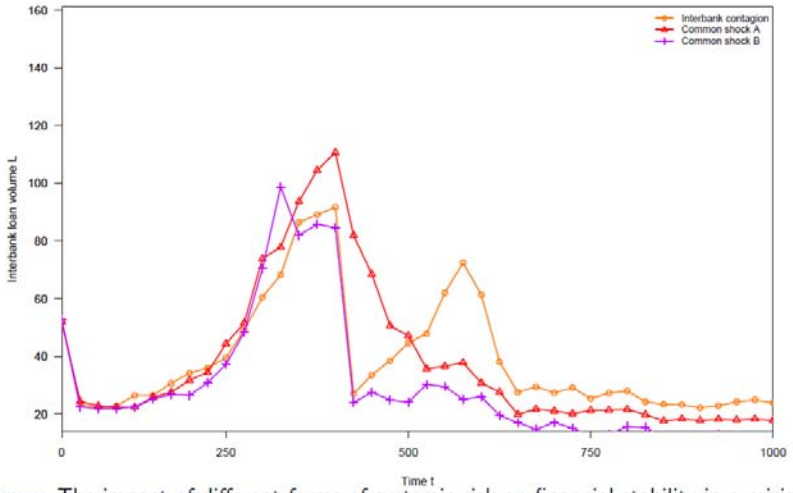


Figure: The impact of different forms of systemic risk on financial stability in a crisis scenario ($\rho_f^+ = 0.09, \rho_f^- = -0.08$) in a random network (connLevel=0.8)

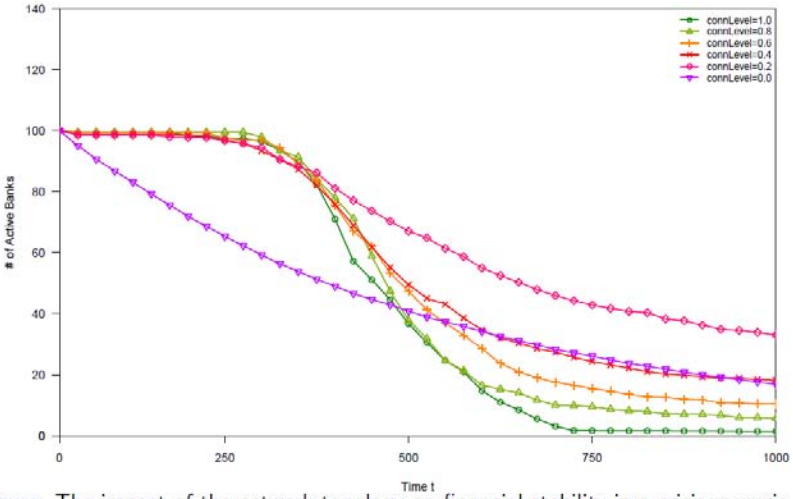
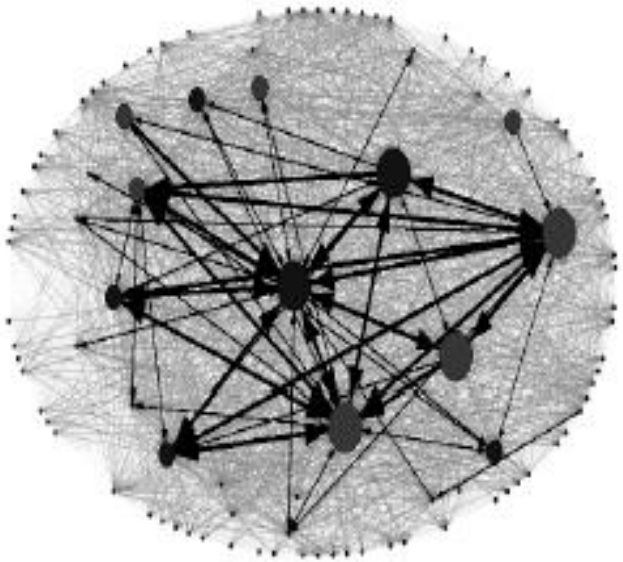


Figure: The impact of the network topology on financial stability in a crisis scenario ($\rho_f^+ = 0.09, \rho_f^- = -0.08$) in a random network

Co-Pierre Georg, 2012
'Black Rhino' model of shocks on a banking network

In Banking Networks a Core-Periphery Structure is Typical

		Netherlands	Germany[1]	Italy[2]	UK[3]
Description	Total number of banks	100	1800	±120	176
	Network density	8%	0.4%	±15%	3.2%
	Average number of core banks	± 15	± 45	± 30	16
	Average core size	± 15%	± 2.5%	± 25%	9.1%
Fit	Error frequency, as % of links	29%	12%	42%	47%
	Transition prob. core→core	83%	94%	83%	NA

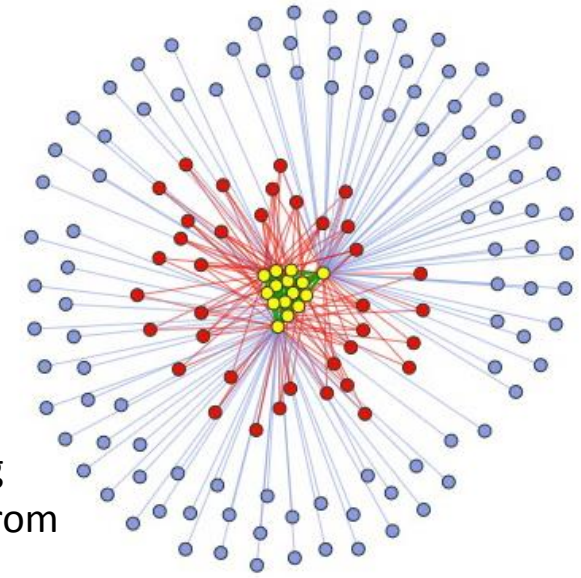


Source:
Finding the Core: Network structure in interbank markets
Daan in 't Veld and Iman van Lelyveld
Workshop on Supervising Financial Networks, Bundesbank, 13-14 February 2013

25% of financial institutions in Brazil are responsible for 90% of all the flows
Source:
Connectivity and Systemic Risk in Payment Systems – Miranda, Souzaand Tabak, Banco Central do Brasil

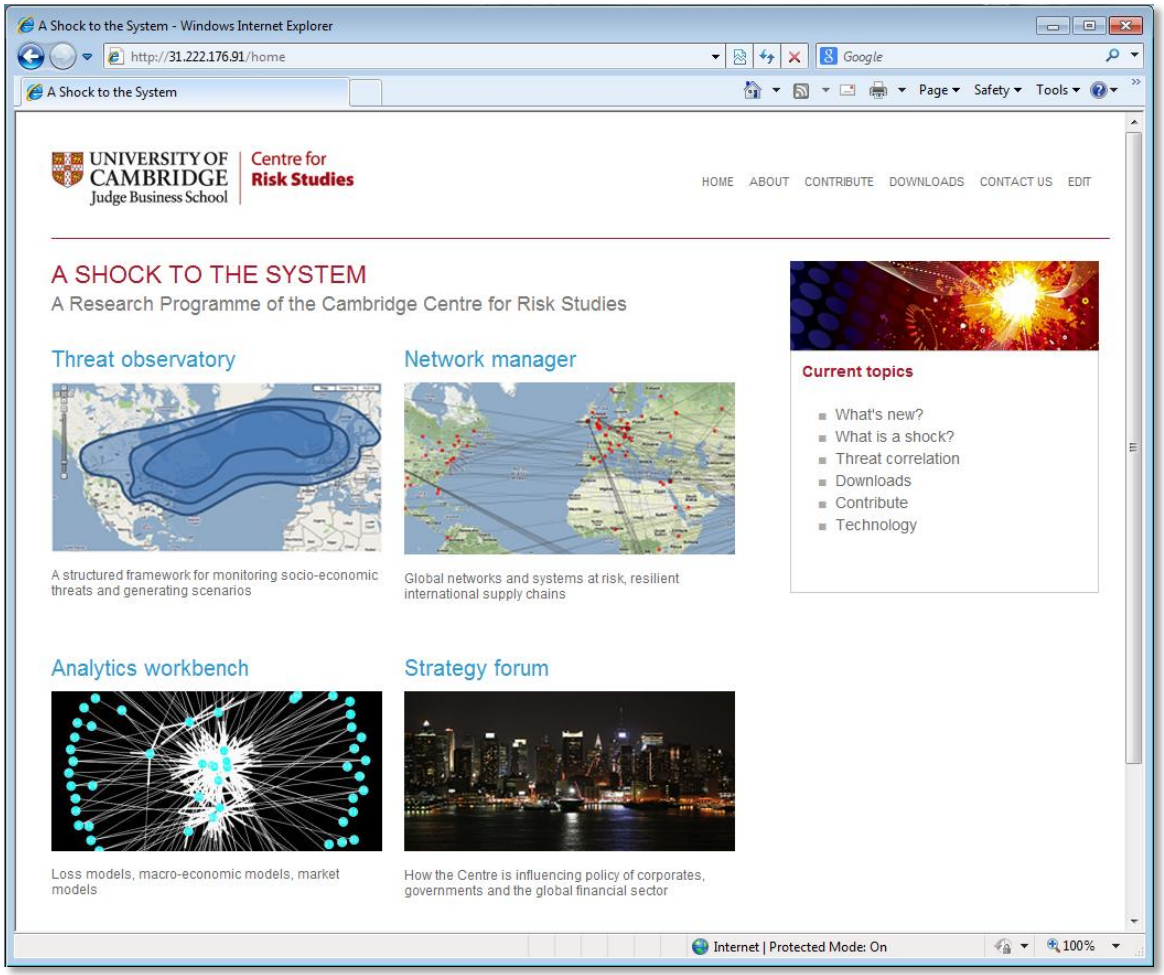
State of the Art of Banking Network Models

- Hasn't yet achieved realistic behaviour in network performance
  - Agent rules, confidence, and psychological behaviour is not well encoded
  - May not behave like a mechanistic system
- Not all the actors (central banks, companies, creditors) are well represented in these models
- Financial actors are a single agent
- Very simplified representation of real-world data



Topology of international banking network as a force-directed graph, from Cambridge FinCat Risk Model

Components of Cambridge Risk Framework

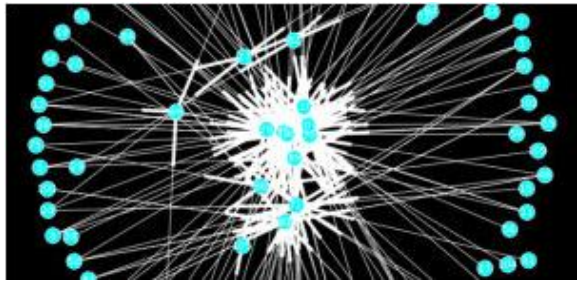


http://www.CambridgeRiskFramework.com

Threat Observatory

Network Manager

Analytics Workbench



Strategy Forum

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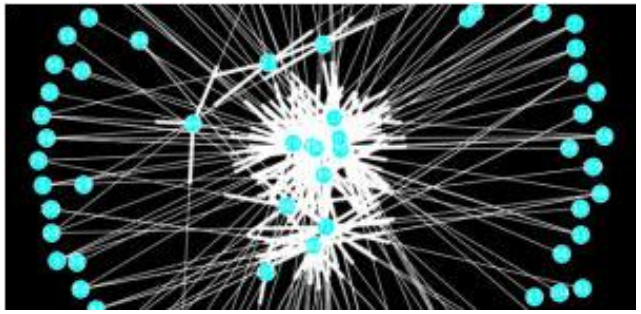


The Analytics Workbench

- System shock provides an open source, cloud-based modeling platform
- Provides a toolkit and interface data standards for impact assessment and network analysis
- Highlights various models
  - Soon functional from the website itself
- Enables users to ‘plug-in’ third-party models from outside and ‘plug-out’ models, data, and interfaces to other modeling platforms
- Open invitation to other modeling teams to interface with Risk Centre Framework

Models currently on the platform

Black Rhino
Modelling Contagion in Financial Networks
Co-Pierre Georg
Interdisciplinary Group of Complex Systems, Universidad Carlos III de Madrid

GTAP
Global Trade Analysis Project Model
Purdue University, West Lafayette, IN 47907, USA

Cambridge FinCat
Country contagion model
Louise Pryor
Cambridge Centre for Risk Studies

RISC
Resilient International Supply Chain model
Cambridge Centre for Risk Studies

Collaboration with other models

fna financial network analytics

Oil Price FLARE Model
Simulation of crude oil pricing
BP Treasury Department

Model the Future Not the Past

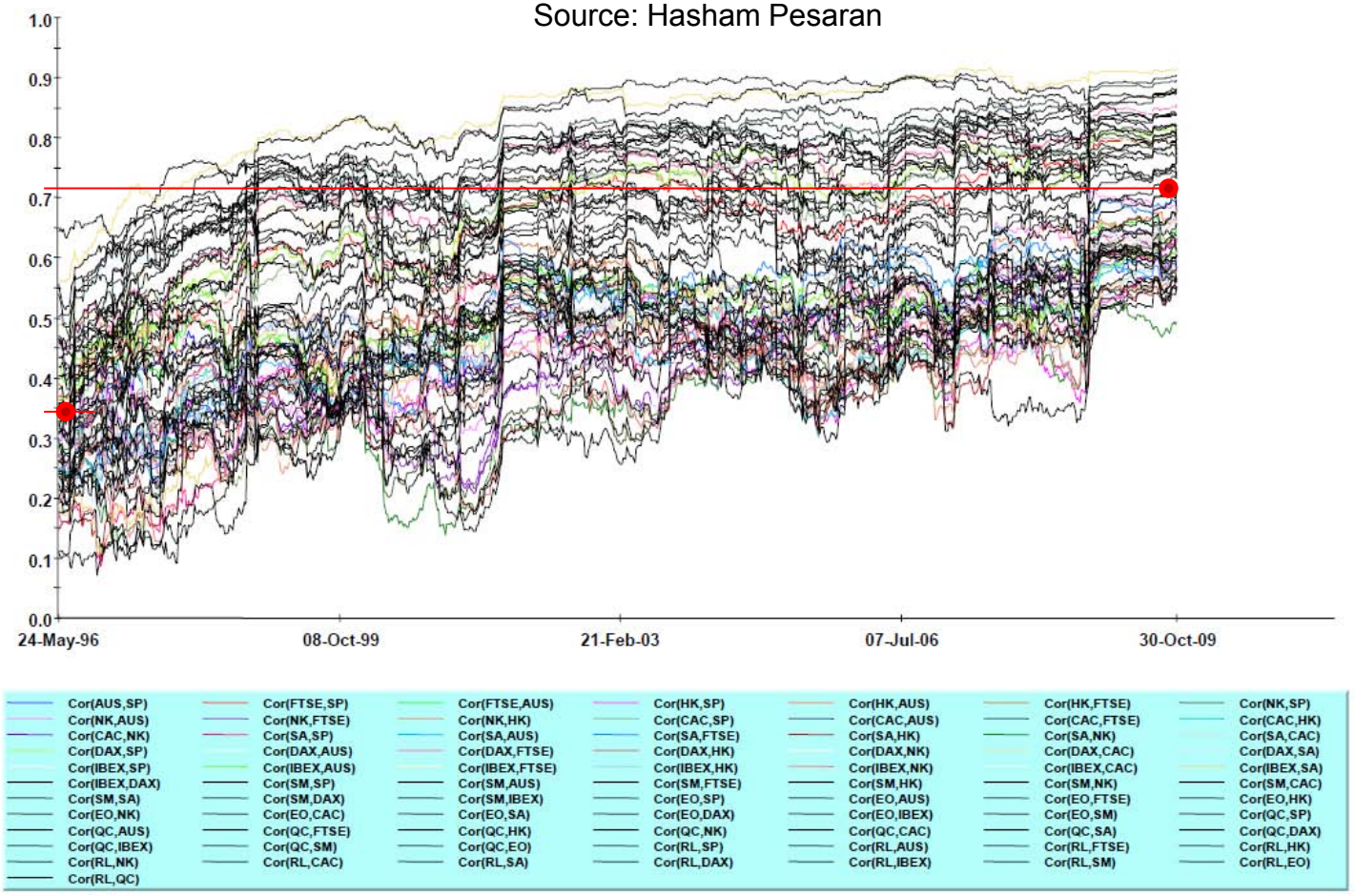
Next time ***will*** be different, because:

- New regulatory regimes for our banking systems are aimed at making financial crises less likely
  - We need to account for increased capital requirements etc in analysis of future risk
  - Different regulatory markets are imposing different rules
- Connectivity is increasing rapidly – the structure of the financial networks is changing
- Modelling and understanding of financial catastrophe is itself changing
  - How might this impact the chances of future catastrophes?

A Globalizing Economy Means Increasing Correlation

SP New York S&P
FTSE London
NK Japan
DAX Germany
CAC Canada
AUS Australia
RL
SP Singapore
HK Hong Kong
IBEX Spain
SA South Africa
SM Shanghai
EO
QC

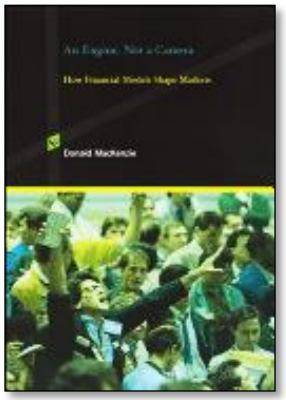
Conditional Correlations of Equity Futures (weekly returns)
Source: Hasham Pesaran



- Equity markets in different countries are twice as correlated as they were 15 years ago
  - i.e. the measured correlation index between price movement in pairwise equity markets in many different countries have doubled in the past 15 years

An Engine, Not A Camera

- Modellers are used to building representations of things they observe
- Financial Catastrophe represents a new challenge: the conceptual models themselves influence the process they are modelling
  - What would be the impact of an early warning?
- This is a key case of the observer effect: measurements of certain systems cannot be made without affecting the systems
- How might users of a new generation of financial catastrophe models affect the chances of a future catastrophe?



An Engine, Not a Camera
How Financial Models Shape Markets
Donald MacKenzie
Professor of Sociology,
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