BANK OF ENGLAND

Funding Liquidity Risk in a Quantitative Model of Systemic Stability

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12th Annual Conference of the Central Bank of Chile
7 November 2008

Motivation

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- Aim of RAMSI is to develop a unified quantitative framework to guide and sharpen risk assessment work.
  - A modular approach is used to integrate different sources of risk to the core UK banking system.
  - Key focus today on how we introduce funding liquidity risk.

- Closest model in this spirit is OeNB (2006) model of Austrian banking system.
  - But they do not model income or capture asset and liability feedbacks.
  - And their forecasting horizon is limited to one quarter.

RAMSI: Key Features

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- "Fundamental" (1st round) risk in RAMSI:
  - Credit risk
  - Income risk

- Funding Liquidity Risk
  - Increasing funding costs as bank fundamentals decline
  - Outright closure of funding markets to banks in stress

- "Contagion" (2nd round) risk in RAMSI:
  - Interbank network feedbacks
  - Asset and liability side feedbacks

Outline of the Talk

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- Model Overview
- Components of the Model
  - Particular focus on Funding Liquidity Risk
- Simulation Results

Model currently only at development stage

- Further validation and testing to be done
- Numerical results should not be construed to be an accurate measure of the systemic risk in the UK banking system.

Model Overview

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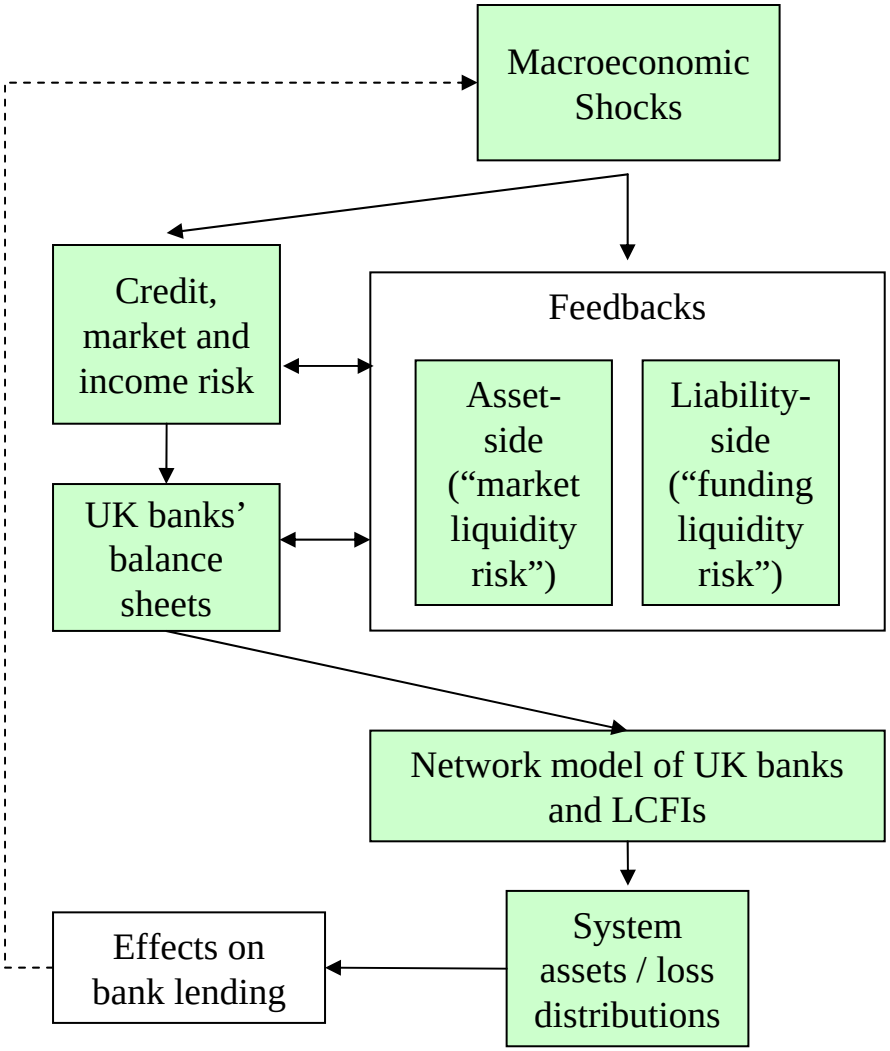
Model Architecture



Generic Bank

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- Net profits: $$NP_t = (CFA_t - CFL_t) - Credit\ loss_t + Trading\ Inc_t + Other\ Inc_t - Op\ Cost_t$$

- Balance sheet evolution: $$\Delta Shareholder\ Funds_{t+1} = Net\ Profit_t$$
$$\Delta Assets_{t+1} = f(Net\ Profit_t)$$
$$\Delta Liabilities_{t+1} = g(Net\ Profit_t)$$

- Failure generated by funding liquidity crises

- No financial stability policy intervention

Balance Sheets

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- Major component of RAMSI work.
- Balance sheets include:
  - Approx 400 asset and 250 liability classes
  - Maturity and repricing splits
  - Four-way geographical / currency splits
- Constructed from published accounts
  - Many rules of thumb and fixes applied.
- Cover the 10 major UK banks (as of end-2007!).

Components of the Model

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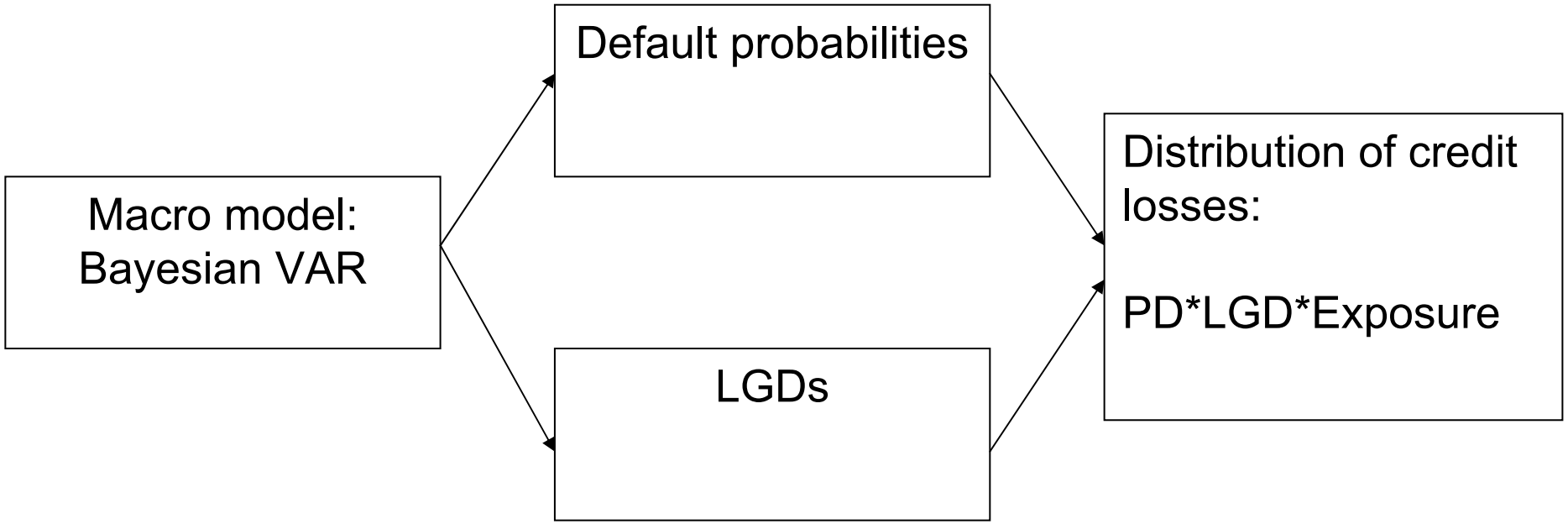
Macro-Credit Risk



Credit Risk

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- Exposures:
  - UK households (mortgages, credit card, other unsecured)
  - UK corporates
  - US, EA and RoW households (secured, unsecured)
  - US, EA and RoW corporates

- For asset class *i* (e.g. UK Mortgages), the loss is:

$$CreditLoss_t^i = PD_t^i * LGD_t^i * Asset_t^i$$

Net Interest Income

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- Risk-neutral pricing behaviour for most of the loan book: interest income expected to cover credit losses.

- Coupons are sticky: only a subset of the balance sheet can be repriced at any time.
  - Example: suppose mortgages are re-priced annually and there is an unexpected increase in mortgage PD.

    ➔ E(Income – Credit Loss) < 0 for four quarters

- Repricing maturity mismatch varies across banks.

- For other parts of the balance sheet, interest income and expense modelled as a spread relative to risk-free or LIBOR.

- On liabilities, funding costs vary dependent on implied rating of bank.

Net Profits, Taxes and Dividends

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- Net profits of a bank (before feedbacks):

$$NP_t = (CFA_t - CFL_t) - Credit\ loss_t$$
$$+ Trading\ Inc_t + Other\ Inc_t - Op\ Cost_t$$

- Tax rates and the ratio of dividends to profits are in line with recent history.
- Profits (or losses) are assumed to increase (or erode) Tier 1 capital directly.
- Tier 1 capital ratio computed using Basel II standardised risk weights to obtain RWA.

Reinvestment

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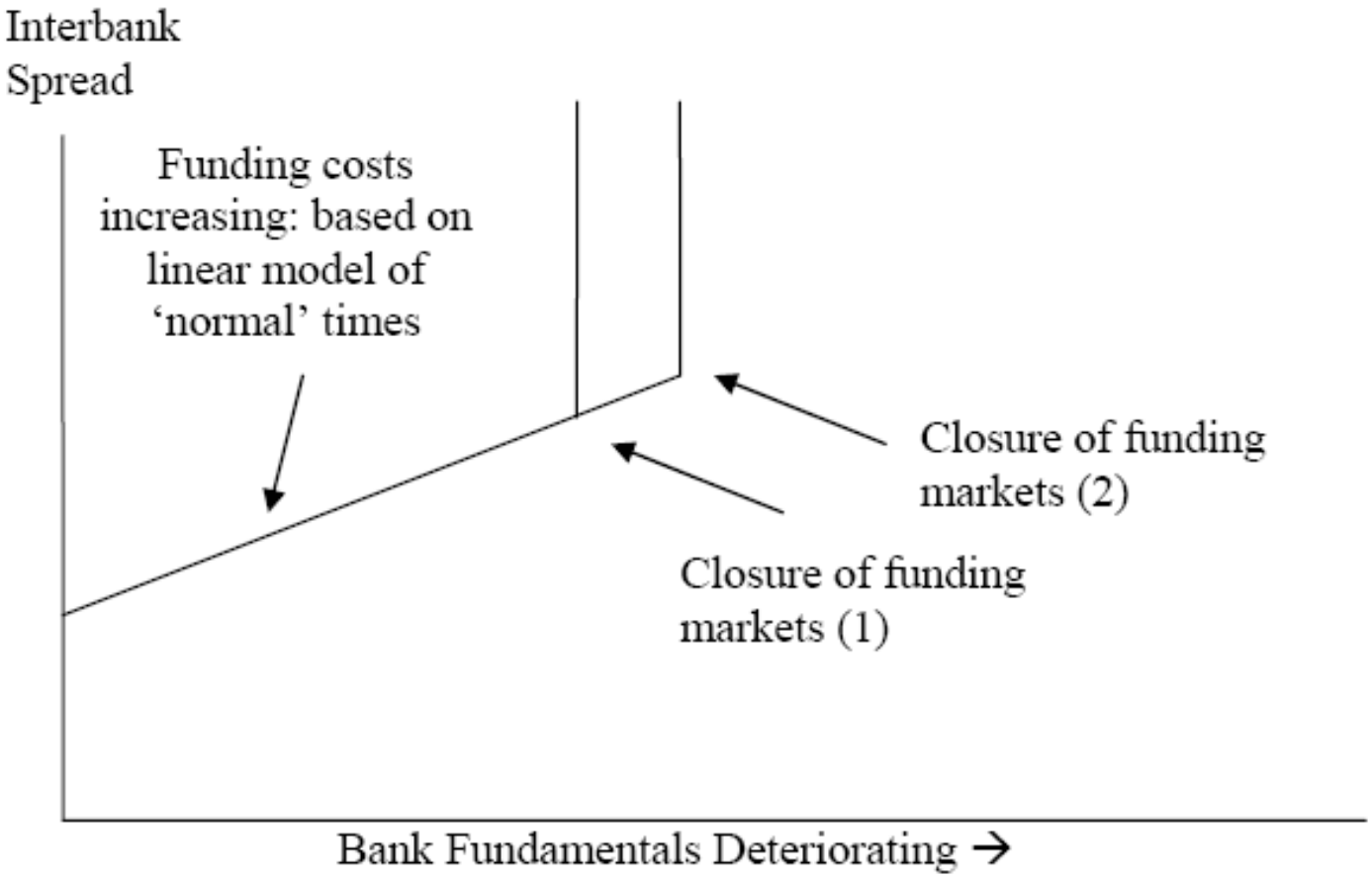
- Credit losses booked against the relevant exposure for the loss. To rebalance the balance sheet, we adopt a set of mechanical reinvestment rules:
  - Tier 1 ratio: *Banks have a bank-specific 'target' Tier 1 capital ratio which they aim to meet when investing their funds.*
  - Portfolio allocation: *Subject to the first rule, banks invest in assets in proportion to their shares on the bank's initial balance sheet*
  - Liability generation: *The first rule determines total assets after reinvestment and hence the amount of new liabilities which need to be raised. These net new liabilities are allocated in proportion to their shares on the bank's initial balance sheet.*

- No active disinvestment

Funding Costs and the Closure of Funding Markets



Bank Ratings and Funding Spreads

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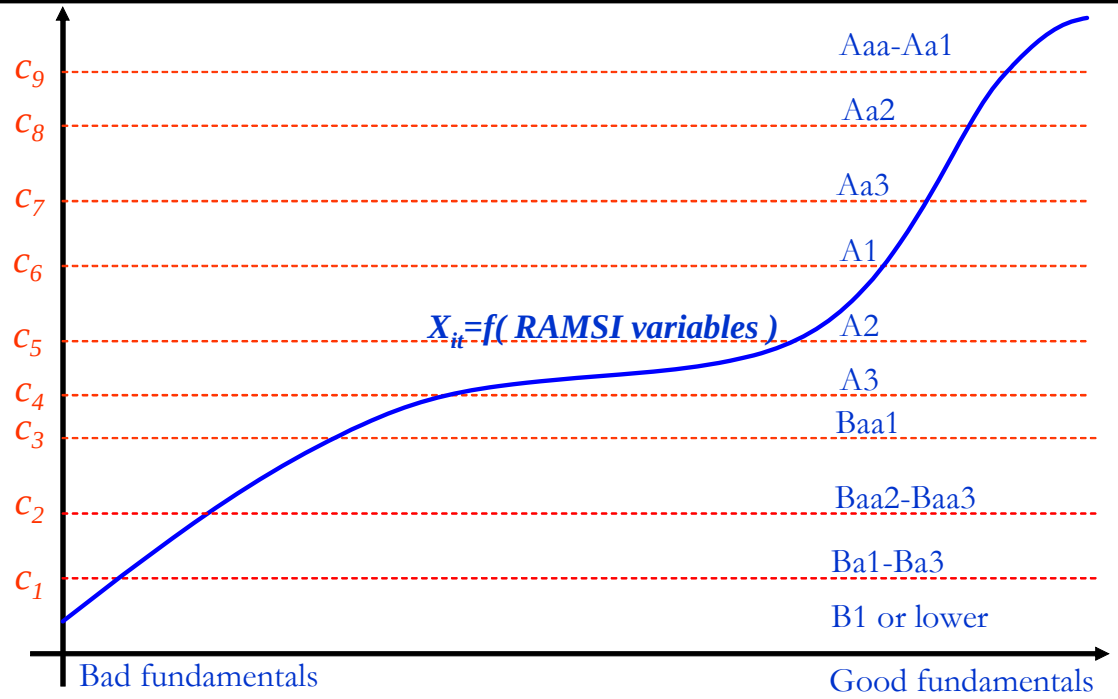
Modelled in two stages:

1. Rating index function produces ratings for each bank in each quarter.

2. Simple mapping from ratings to credit spreads.

Endogenous spreads apply to certain sources of wholesale funding.

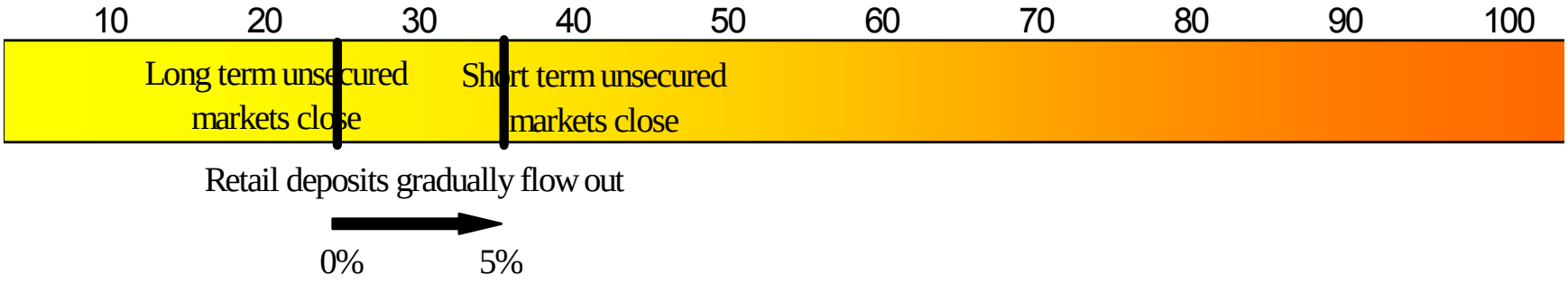
Rating Model



- Rating index function *f()* and cut-off points (c_j) estimated using a RAMSI-friendly version of Pagratis and Stringa (2008).
- In every simulation, realised values of RAMSI variables determine *f*. Rating assigned to banks depending on the max cut-off point c_j that is crossed by *f* (e.g. A1 if $c_6 < f(RAMSI_i) < c_7$).

Closure of Funding Markets: A 'Danger Zone' Approach

- Information on individual institutions – as the information on the bank deteriorates, danger zone points accumulate.
- As the score crosses set thresholds, funding markets close to that institution.



Why Danger Zones?

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- Liquidity risk is binary or at least non-linear.
- Confidence is key.
- Liquidity crises are rare events.
  - Data availability on those that have occurred is limited.
- Difficult to build statistical models to predict the onset of liquidity crises.

Key Triggers for Funding Crises

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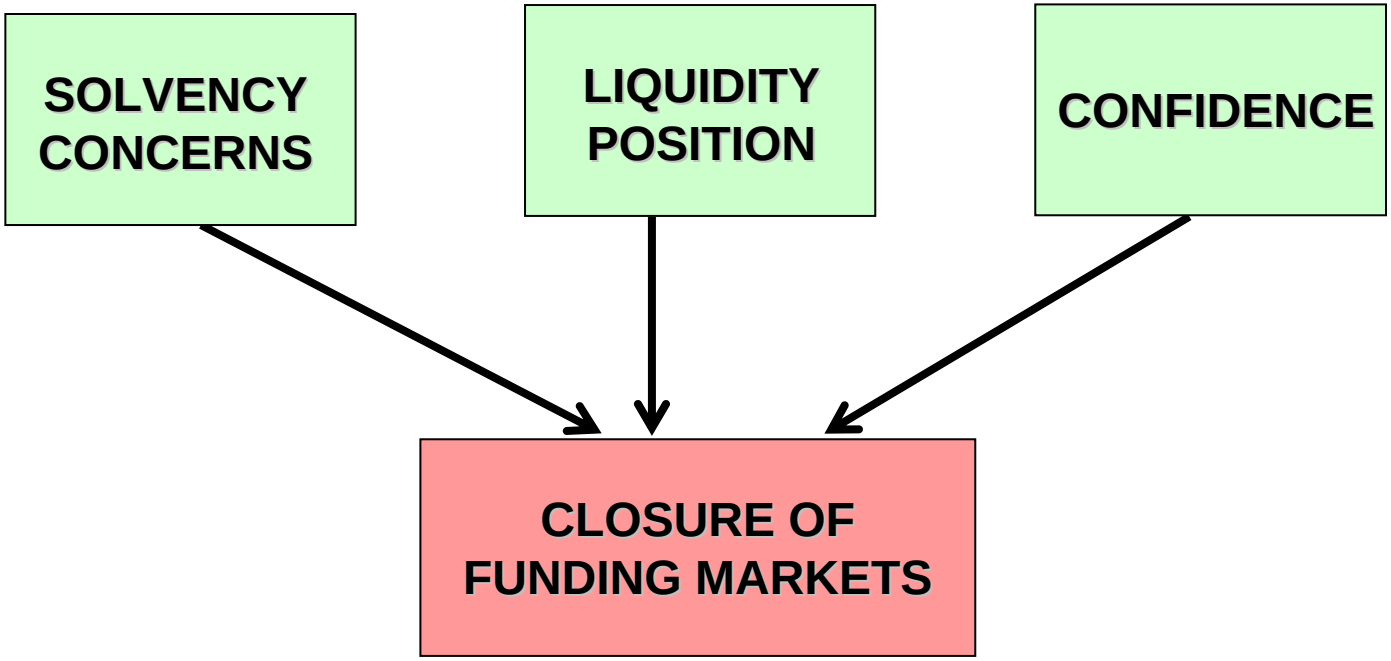
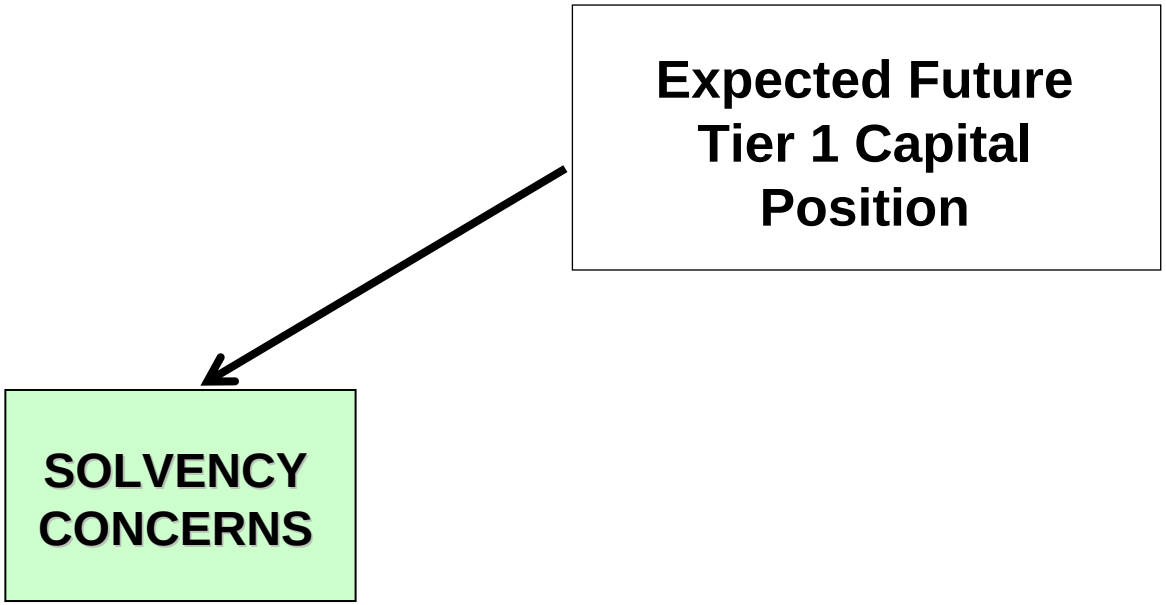
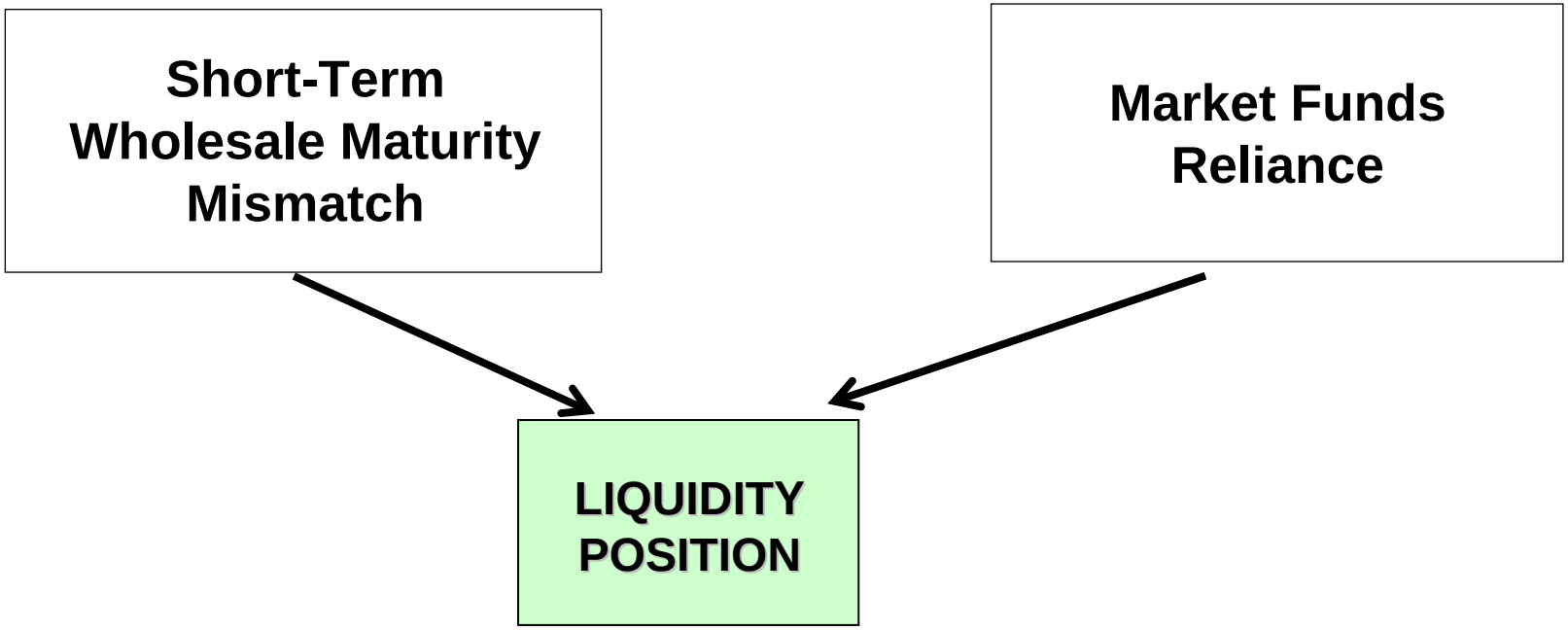


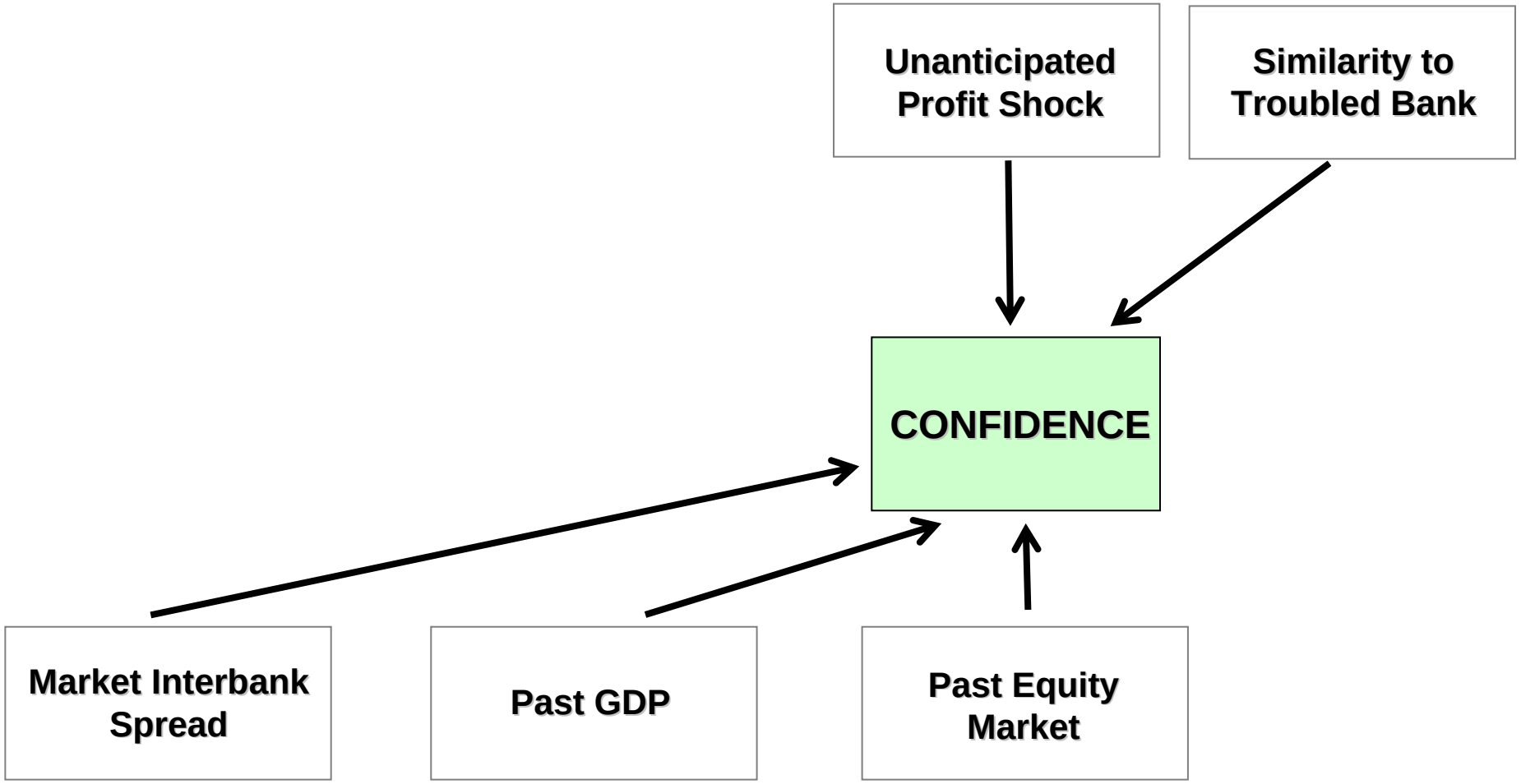
Danger Zones Structure: Solvency



Danger Zones Structure: Liquidity



Danger Zones Structure: Confidence



Integration into RAMSI

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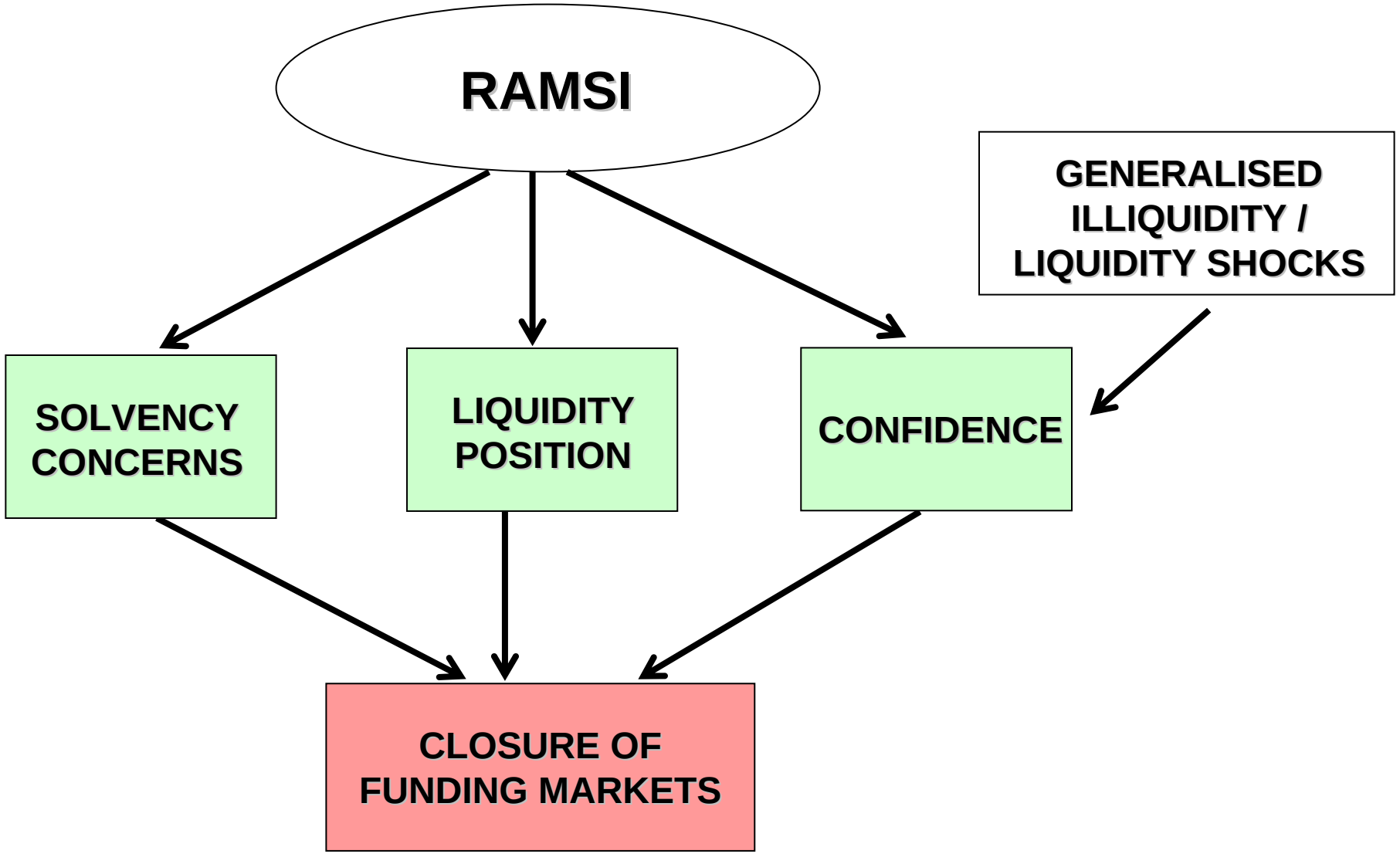
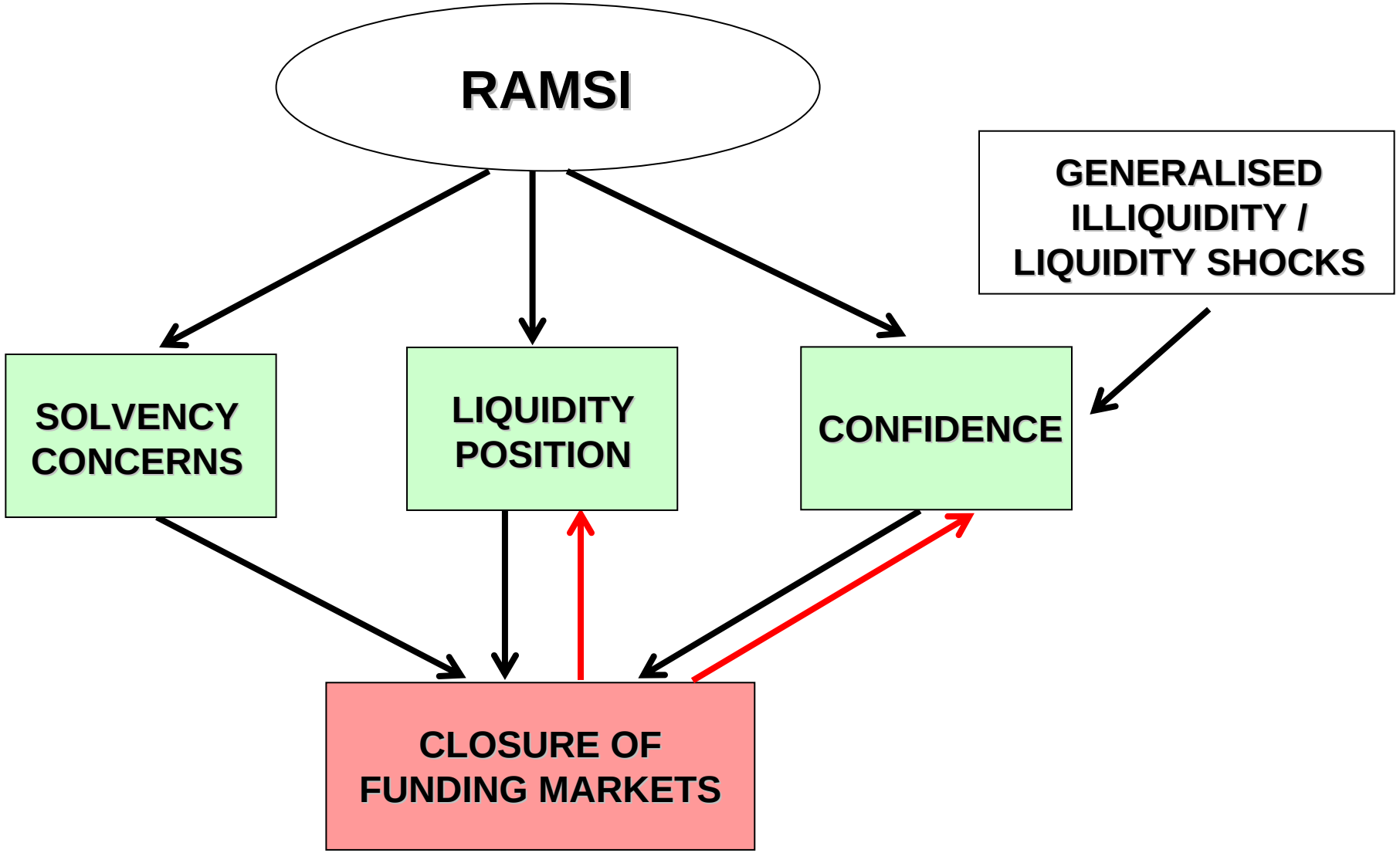
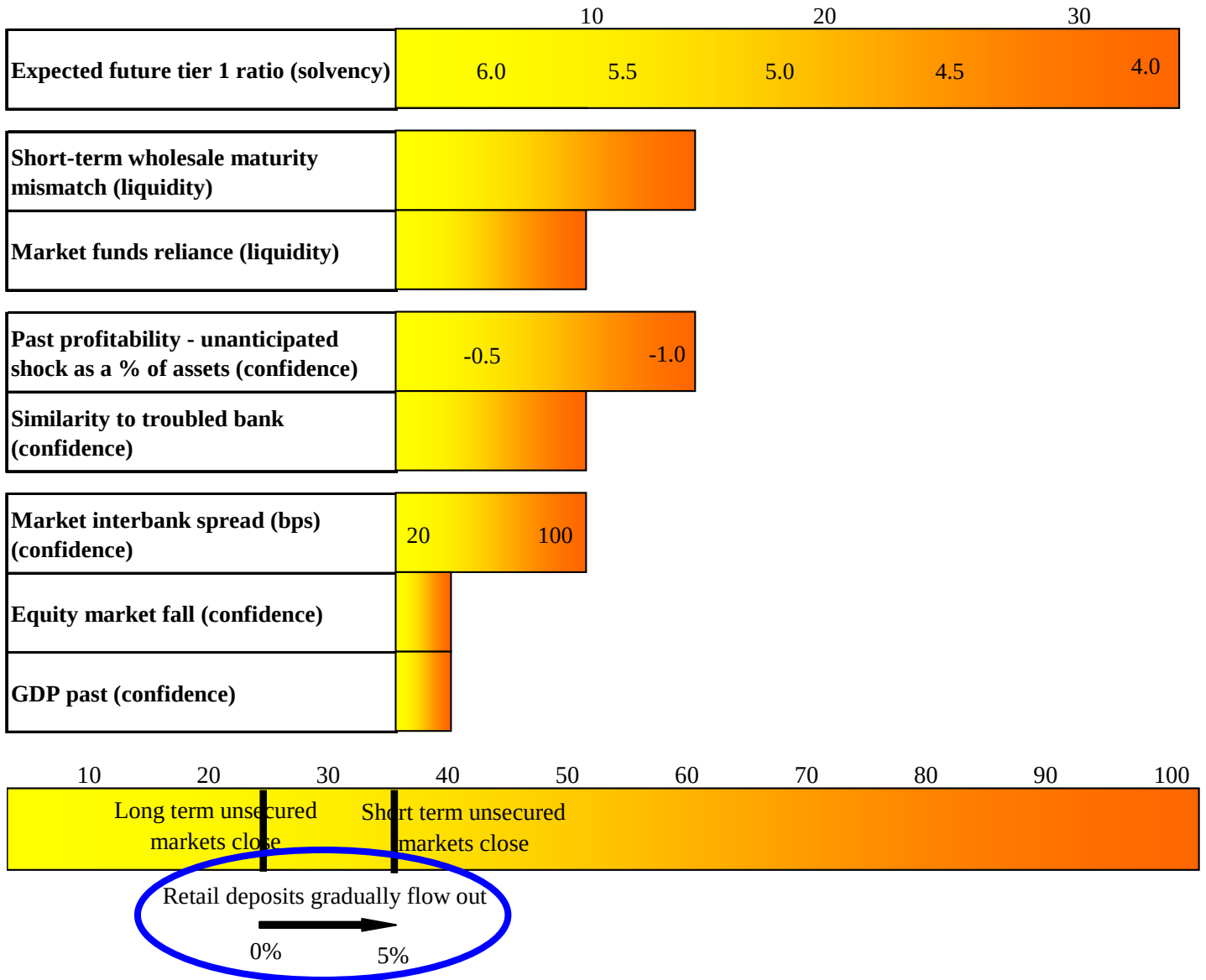


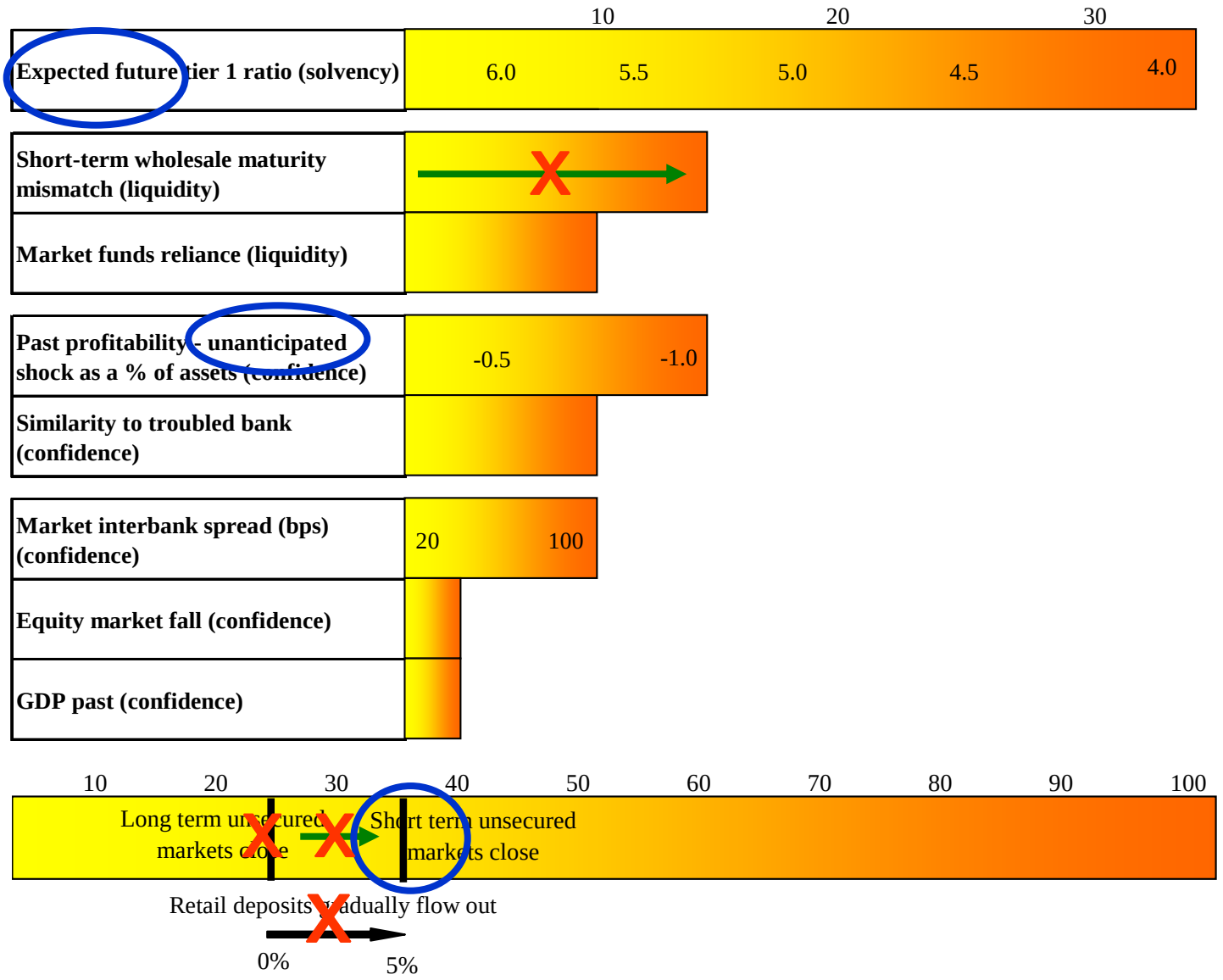
Integration into RAMSI



Overall Structure and Weighting



Danger Zones: Current Implementation



Secured Funding and ‘Safe’ Banks (Proposal)

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- Secured funding: if cannot repo assets, assume you can sell them at the prevailing market price (may be a fire-sale price).

- ‘Safe’ banks that receive inflows – those banks with less than 5 points when market-wide indicators are excluded.

Northern Rock Case Study: Periods of Funding Stress

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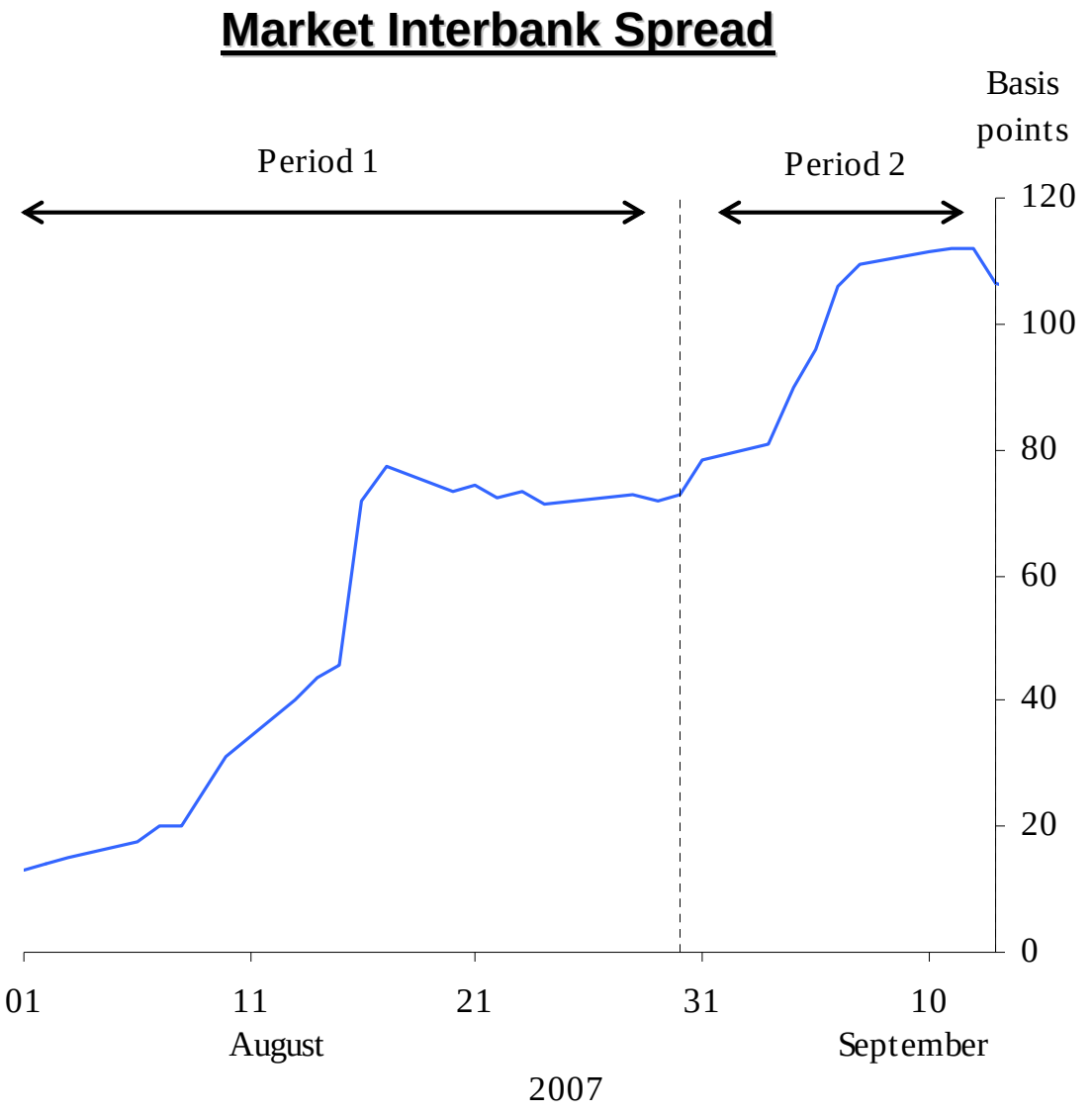
Period 1:

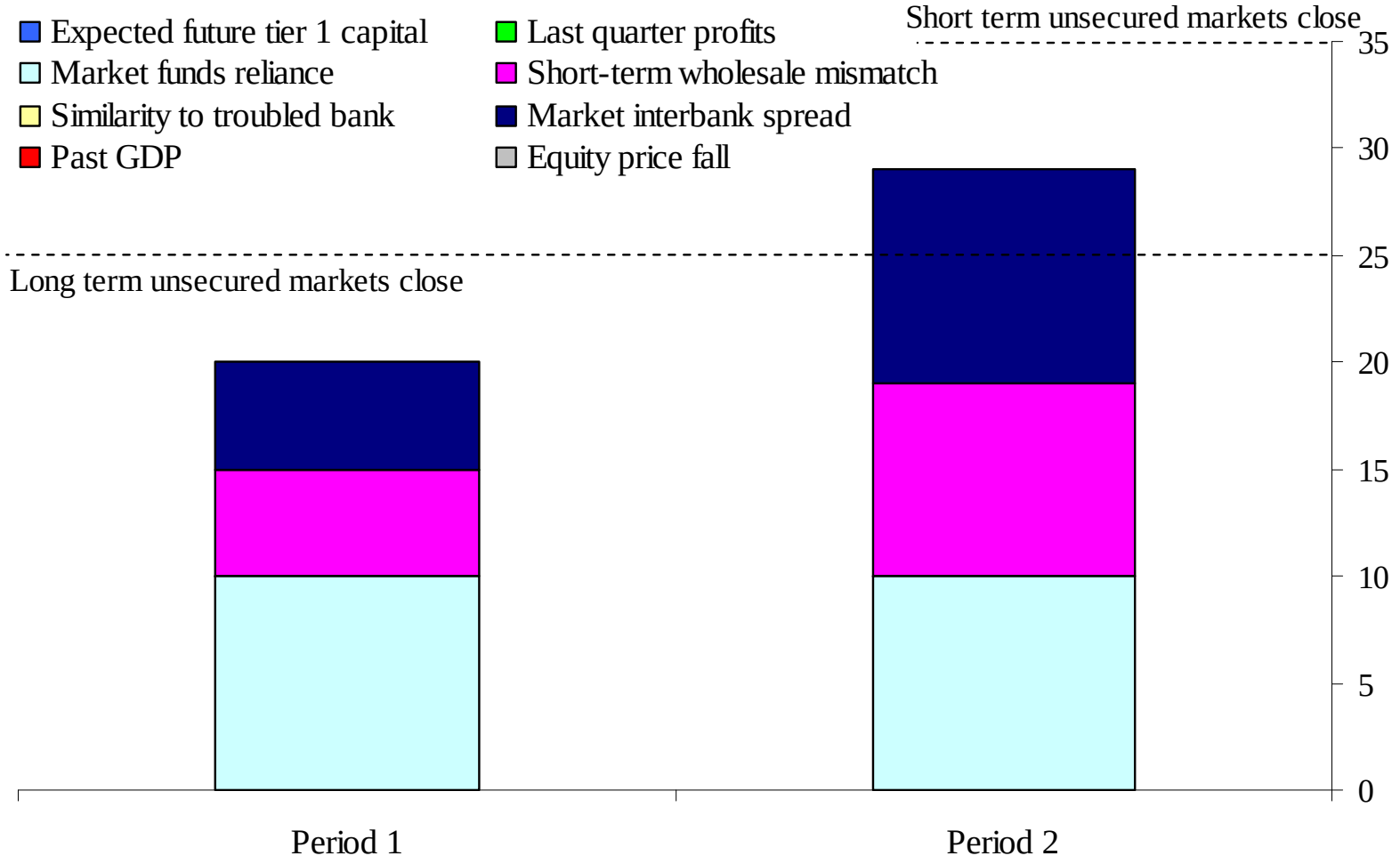
Beginning of the market turmoil

Period 2:

Period from end of August up to when Northern Rock receives BoE support



Northern Rock Case Study: Danger Zone Scores



Bankruptcy and the Network Model

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- When a bank is shut out of short-term unsecured funding markets, it is assumed to fail.

- Upon failure, the bank incurs a bankruptcy cost equivalent to 10% of its total non-interbank assets (James, 1991).

- Banks suffer interbank losses when counterparties fail and may themselves default as a result (network model). System cleared using Eisenberg and Noe (2001) algorithm.

Asset Fire Sales

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- Failure of a bank => its trading and available for sale (AFS) assets are sold => other banks incur mark-to-market losses on AFS assets => model checks whether further banks fail given these losses.

- Concave function: dependent on market depth, extent of fire sale; differs according to asset type: equities; corporate bonds; ABS.

- Asset prices recover assumed to recover fully at the end of each quarter.

Simulation Results

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Simulation Method

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- 3-year horizon with baseline 2007Q4
- 500 random draws for quarter 1; one draw for each subsequent quarter
- All draws from N(0, Σ), where Σ is the Bayesian VAR residual covariance matrix for 24 factors: UK, US, Europe, and Global

Credit Losses and Net Interest Income in 2008, relative to 2007 Capital

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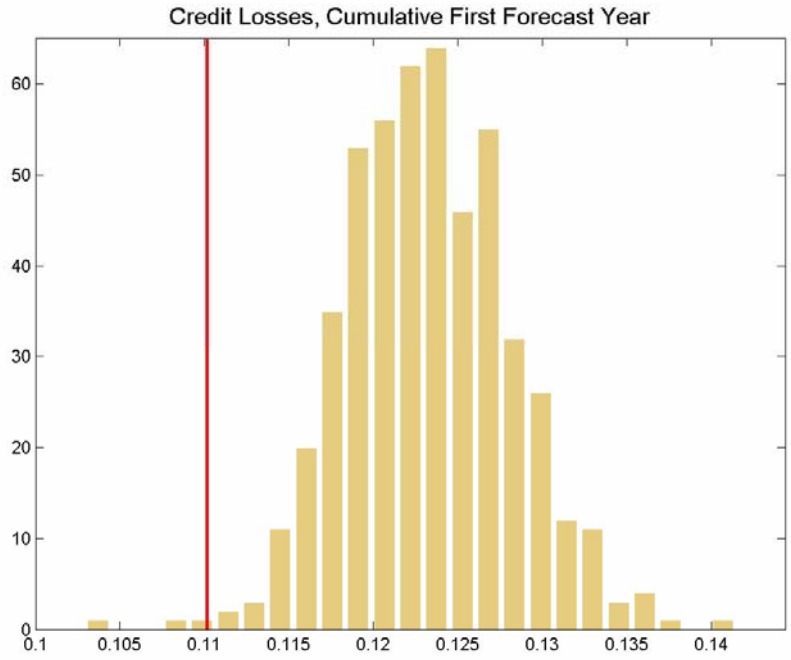
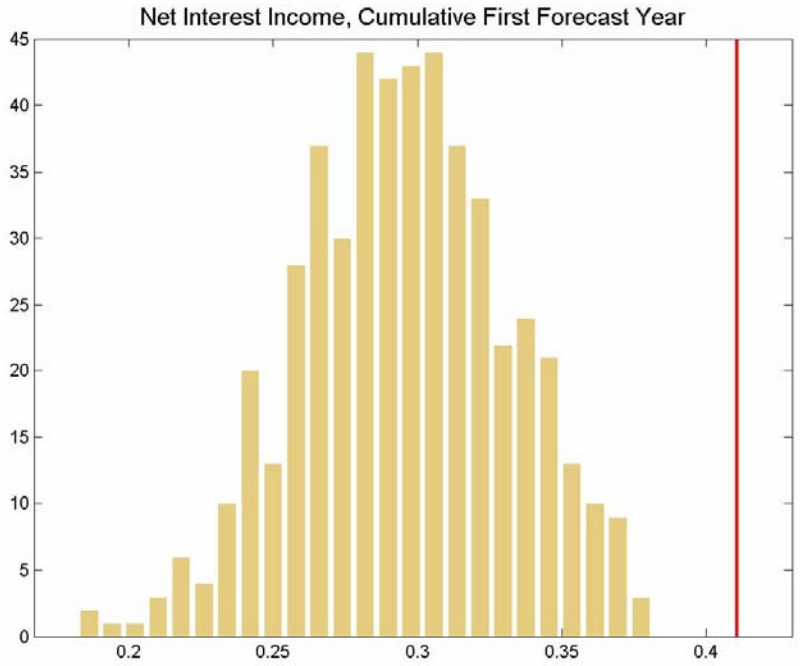
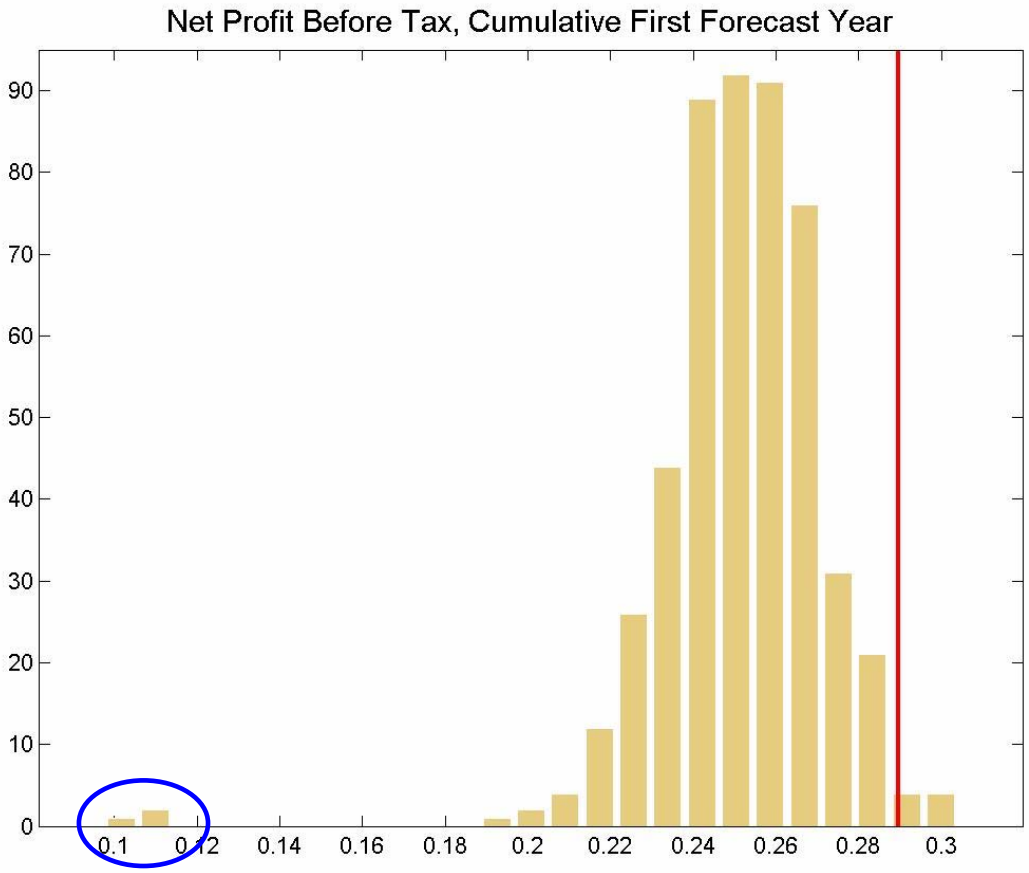
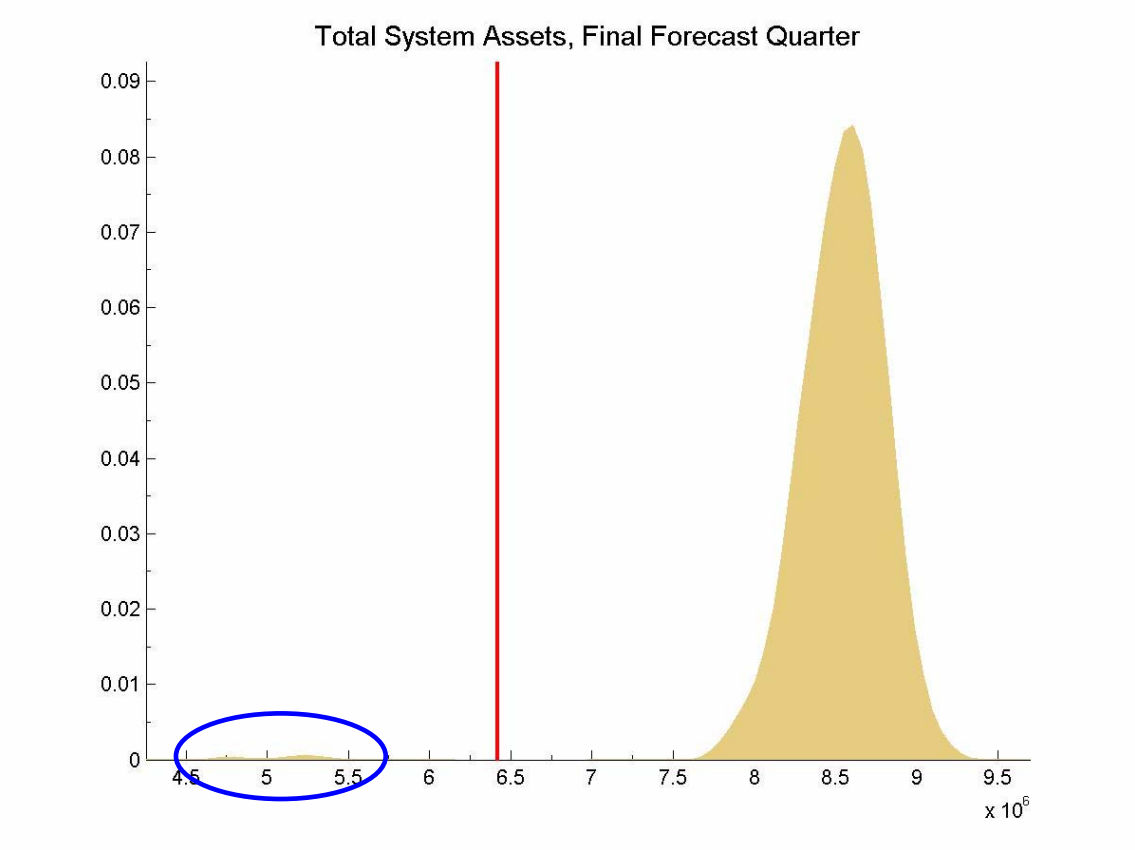




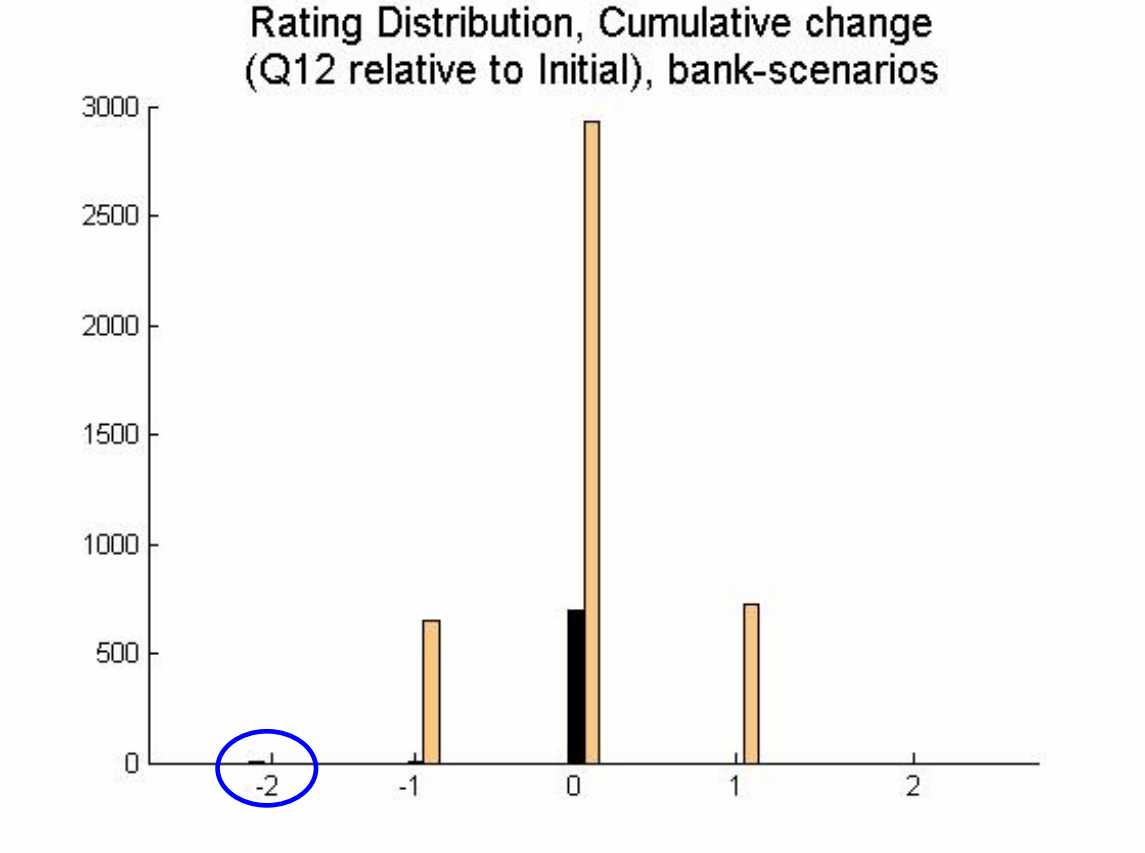
Net Profit Before Tax



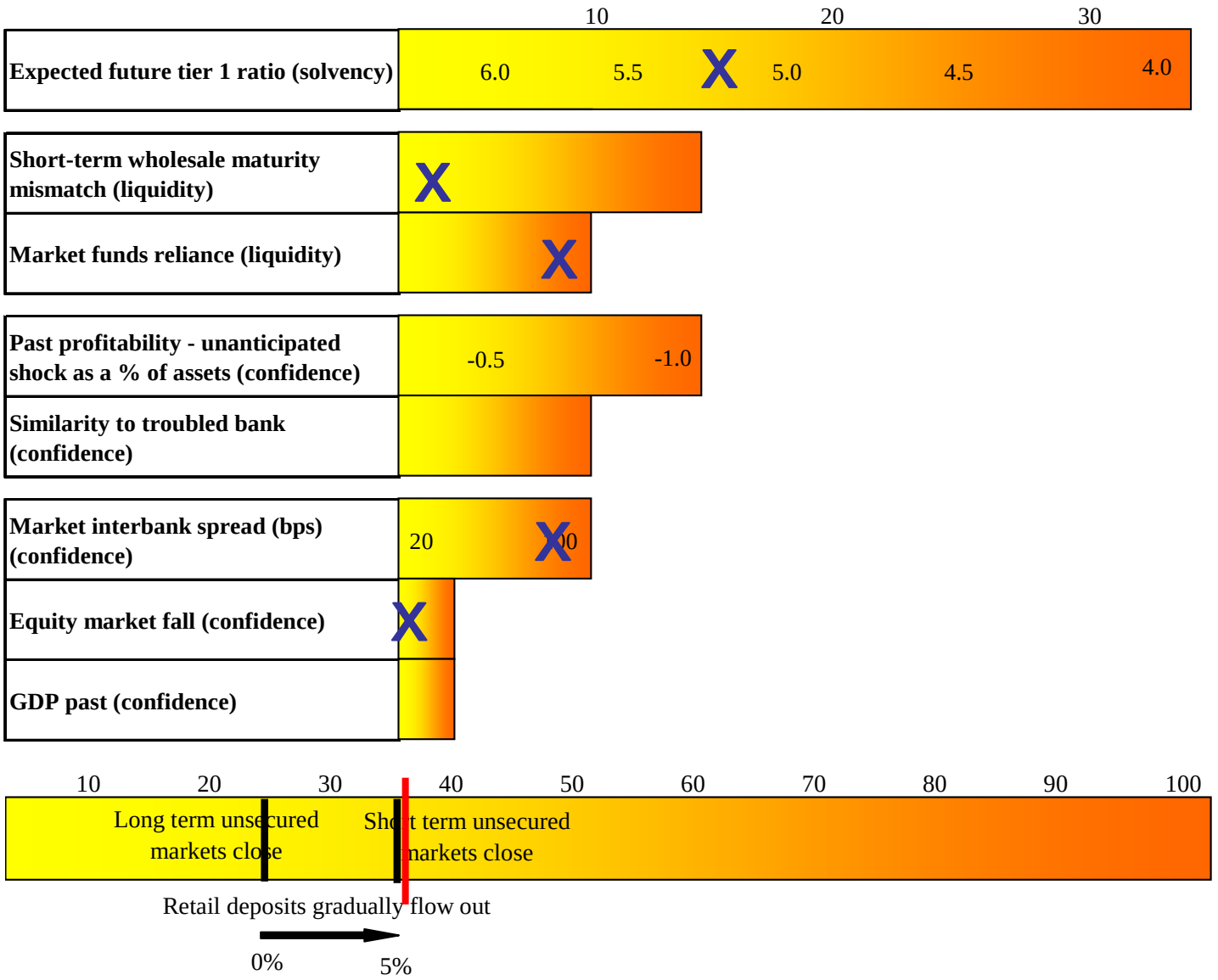
Total System Assets (Q12)



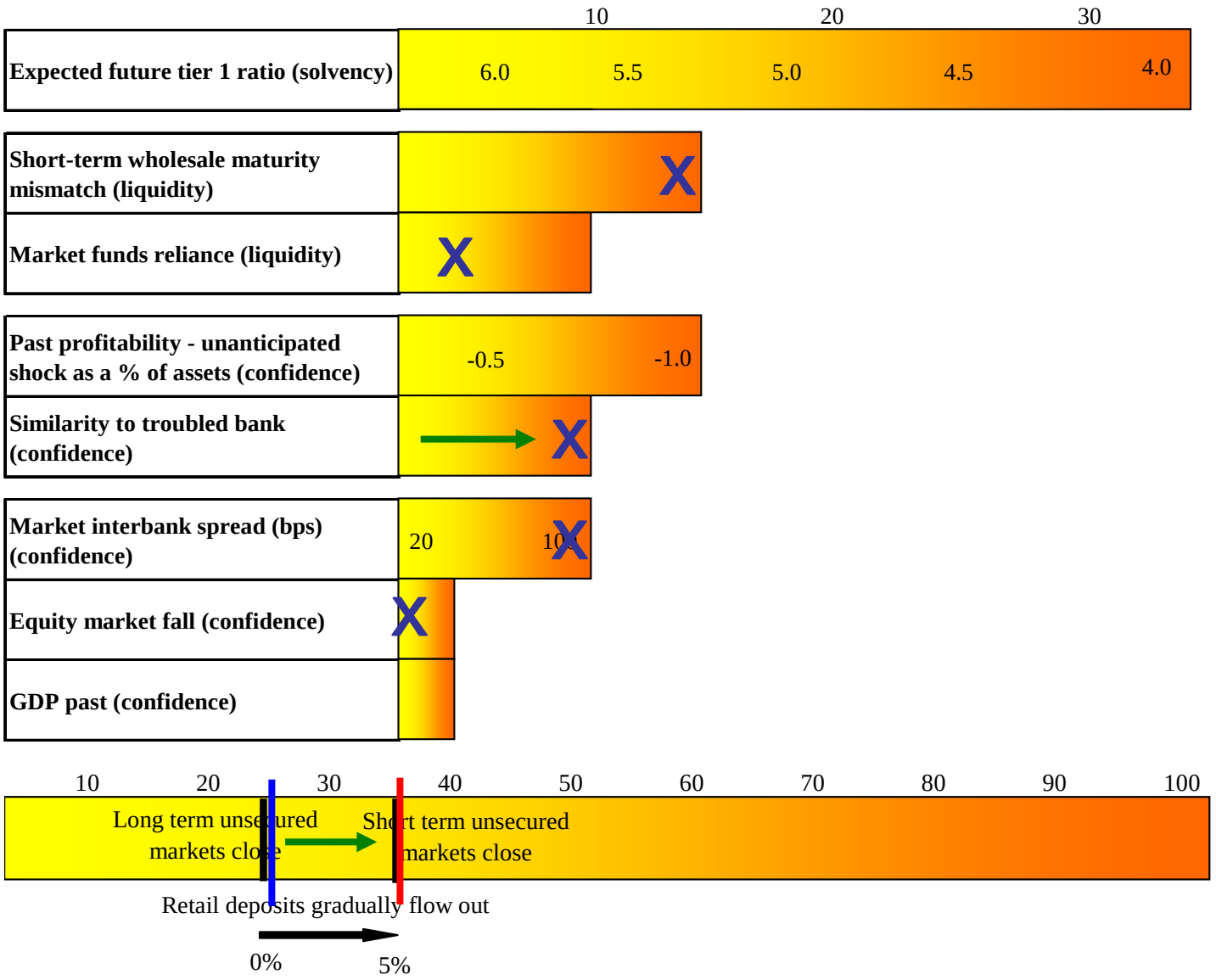
Changes in Ratings



DZ Scores (Tail Realisation): Defaulting Bank 1



DZ Scores (Tail Realisation): Defaulting Bank 2



Interbank Losses

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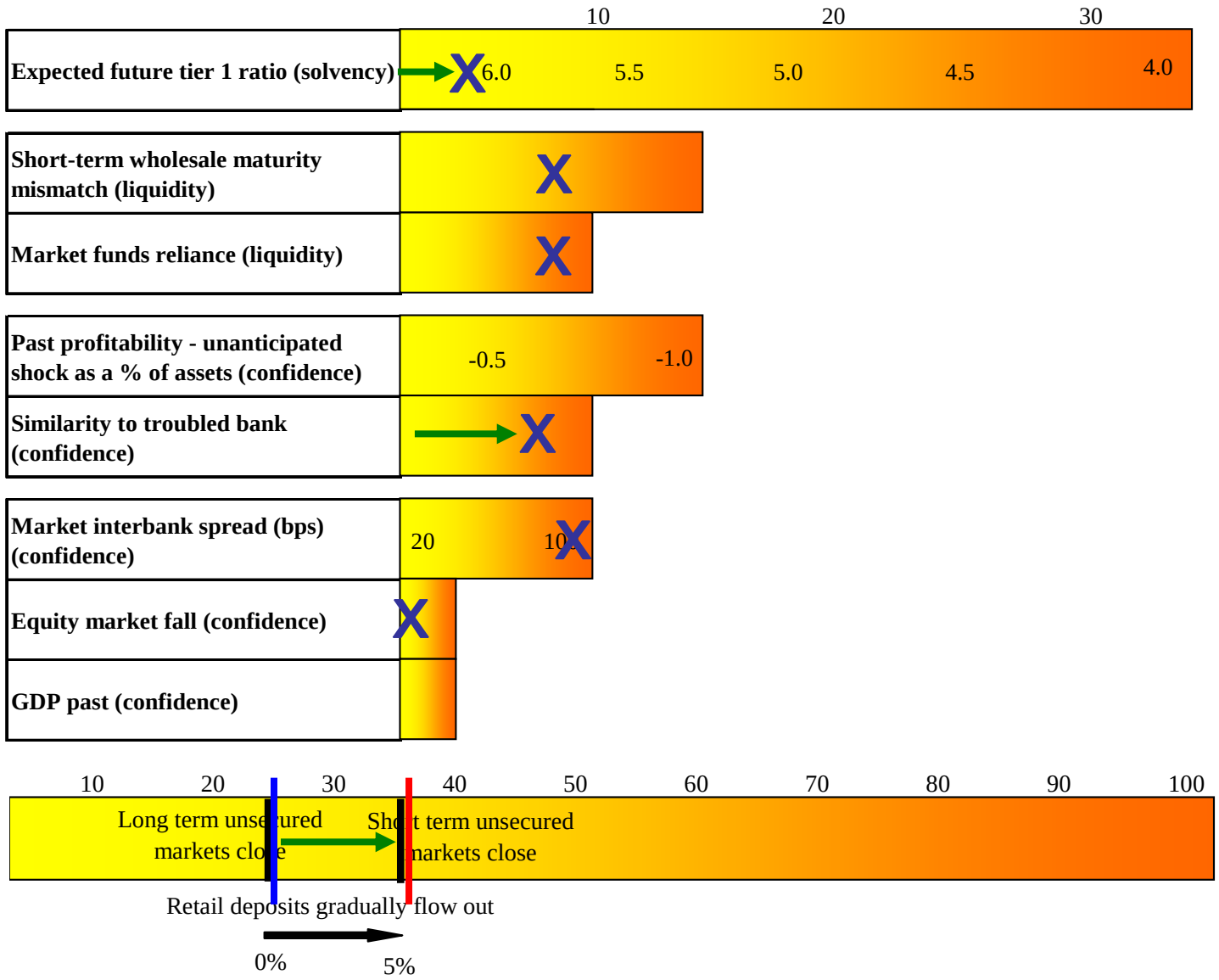
- The default of the first two banks causes interbank losses among the remaining banks:

Min	p25th	Median	p75th	Max
0.014	0.083	0.145	0.182	0.283

DZ Scores (Tail Realisation): Defaulting Bank 3



Model Outputs: What else can the model generate?

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- Stress tests
- Bank-by-bank results
- Contribution of various sources of risk
- “Intermediate” outputs
- Policy Experiments

Conclusion / Further Developments

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- Quantitative model for assessing systemic risk:
  - captures various sources of risk, and (some) key correlations amongst them.
  - integrates funding liquidity risk
  - includes a clear role for feedback effects.

- Further Developments:
  - Better modelling and calibration of some components.
  - Additional sources of randomness (e.g. liquidity shocks)
  - Considering banks' defensive actions
  - Introducing cash flow constraints and ex ante fire sales
  - Introduce feedbacks from the banking sector to the real economy (e.g. credit crunch).

Reserve Slides

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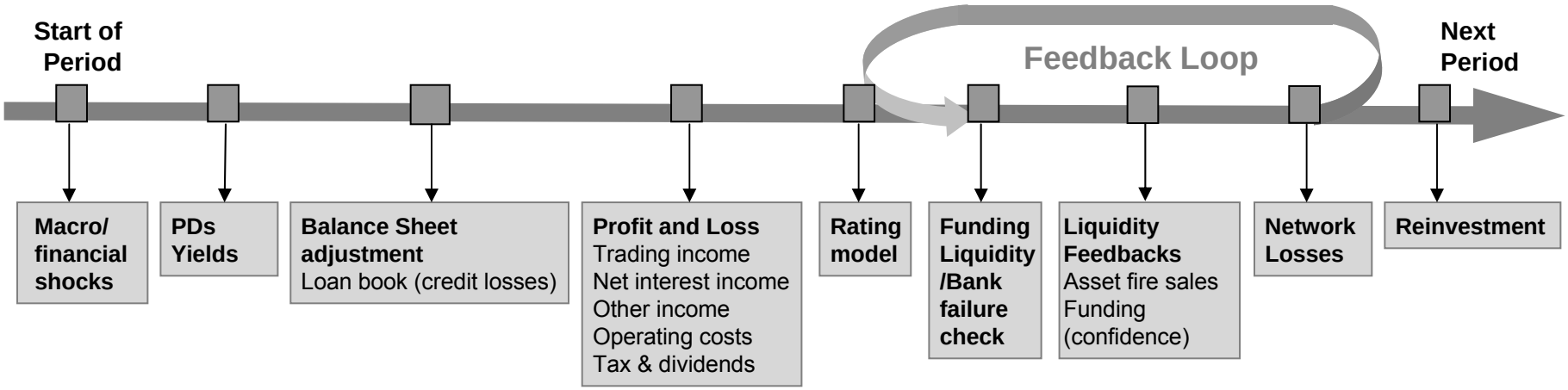
Model Dynamics



Stylised balance sheet and income statement

ASSETS	LIABILITIES
Loans to banks	Deposits from banks
Loans to customers	Customer accounts
Trading portfolio assets	Trading portfolio liabilities
AFS investments	Debt securities
Derivatives	Derivatives
Reverse repo	Repo
	Capital

INCOME STATEMENT

Net interest income

Fees and commissions

Trading income

Other income

Total operating income

Operating expenses

Impairments

- On loan book
- On AFS book

Profit before tax

Tax

Profit after tax

Dividends

Retained earnings

List of BVAR Variables

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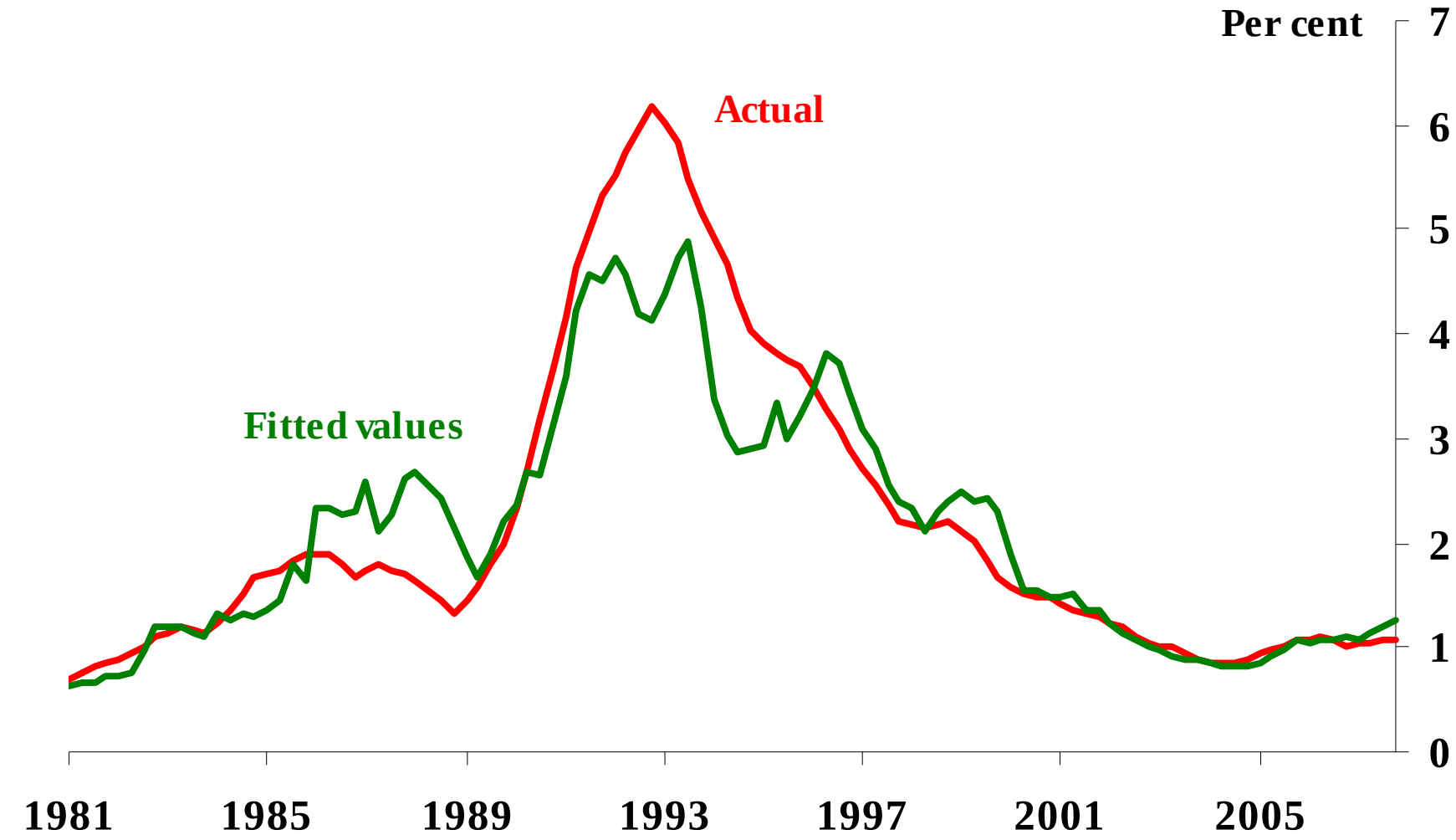
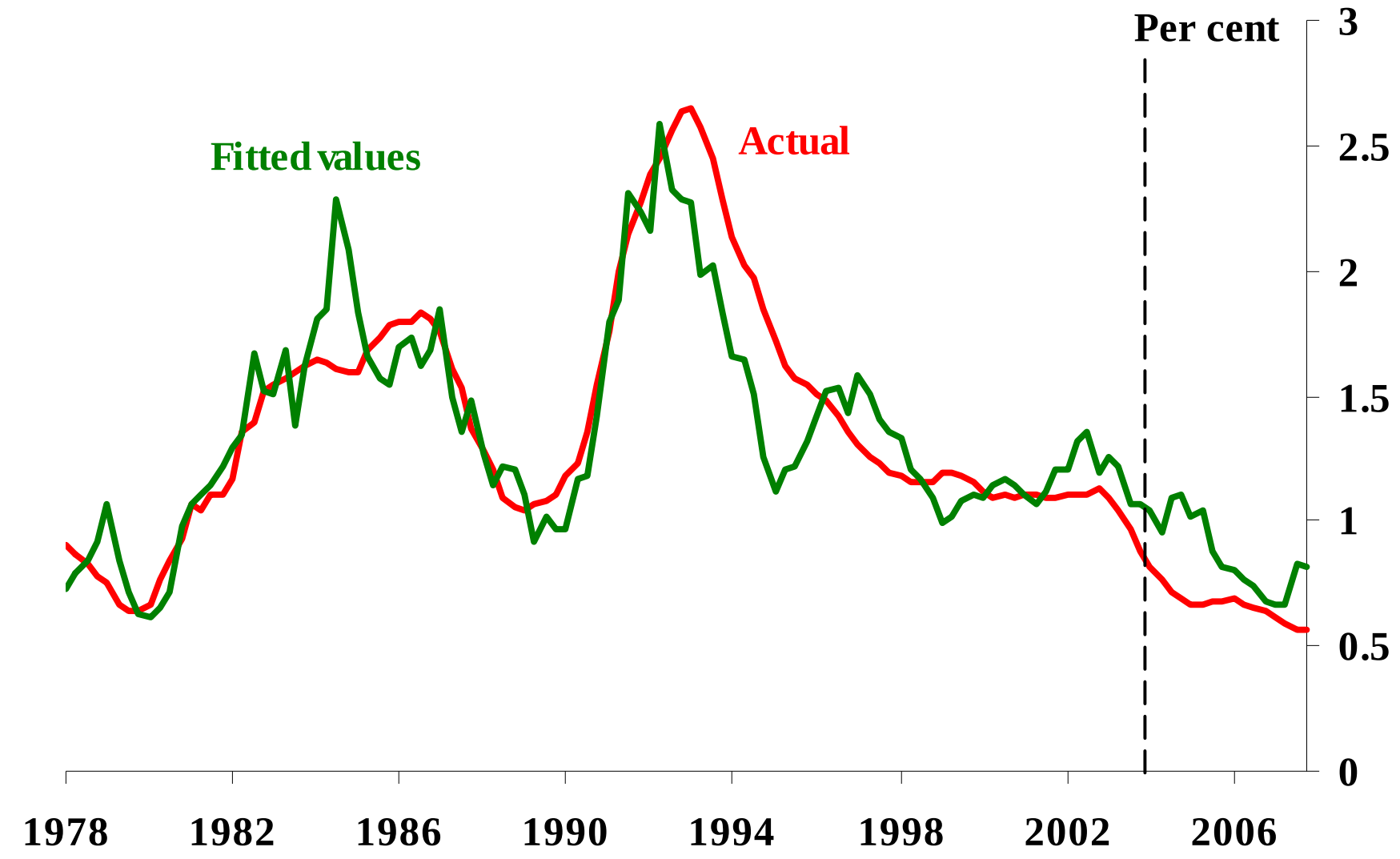
UK	US	EA	World
Real GDP	Real GDP	Real GDP	Real oil prices
CPI inflation	CPI	CPI	Real world equity price index
£ERI	3-m T-Bill rate*	3-m T-Bill rate*	
Real FTSE All Share	10-yr govt bond rate*	10-yr govt bond rate*	
3-m T-Bill rate*			
3-yr govt bond rate*			
10-yr govt bond rate*			
Unemployment*			
Real house prices			
Real comm. prop. prices			
Income gearing*			
Corporate lending*			
3-month LIBOR spread*			
10-yr corporate spread*			

Mortgage arrears: In sample fit



Corporate liquidations: In sample fit



Loss Given Default

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• Stochastic LGD, driven by residential and commercial property price inflation:

$$LGD_t^{secured} = LGD_{t-1}^{secured} - \frac{1}{3}\left(\Delta\left(houseprice_t\right)\right)$$

$$LGD_t^{corp} = LGD_{t-1}^{corp} - \Delta\left(commprice_t\right)$$

• e.g. a 30% fall in house prices raises the secured LGD from 20% to 30%

Other Income and Costs

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- Simple estimated equations

- Non-interest income excluding trading income:
  - Pro-cyclicality: Based on empirical evidence from US data, fees and commissions are found to be strongly pro-cyclical.
  - Bank-specific determinant: 2007 levels of non-interest income used as a base for forecasts.

- Operating expenses:
  - Banks target cost / income ratios.
  - But banks are unable to immediately adjust expenses given a significant drop in operating income (i.e. there is some stickiness to operating expenses).

Continental Illinois

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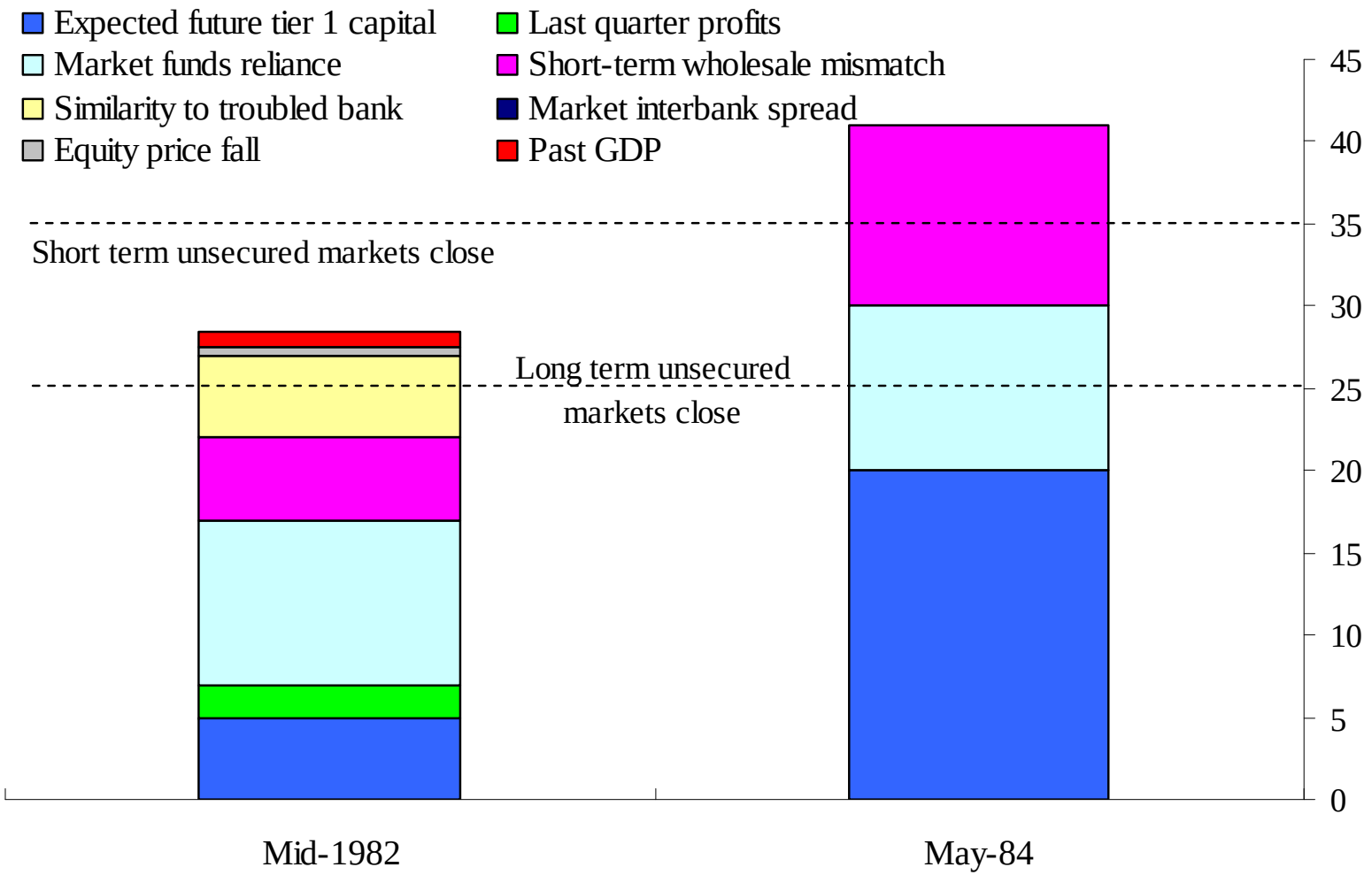
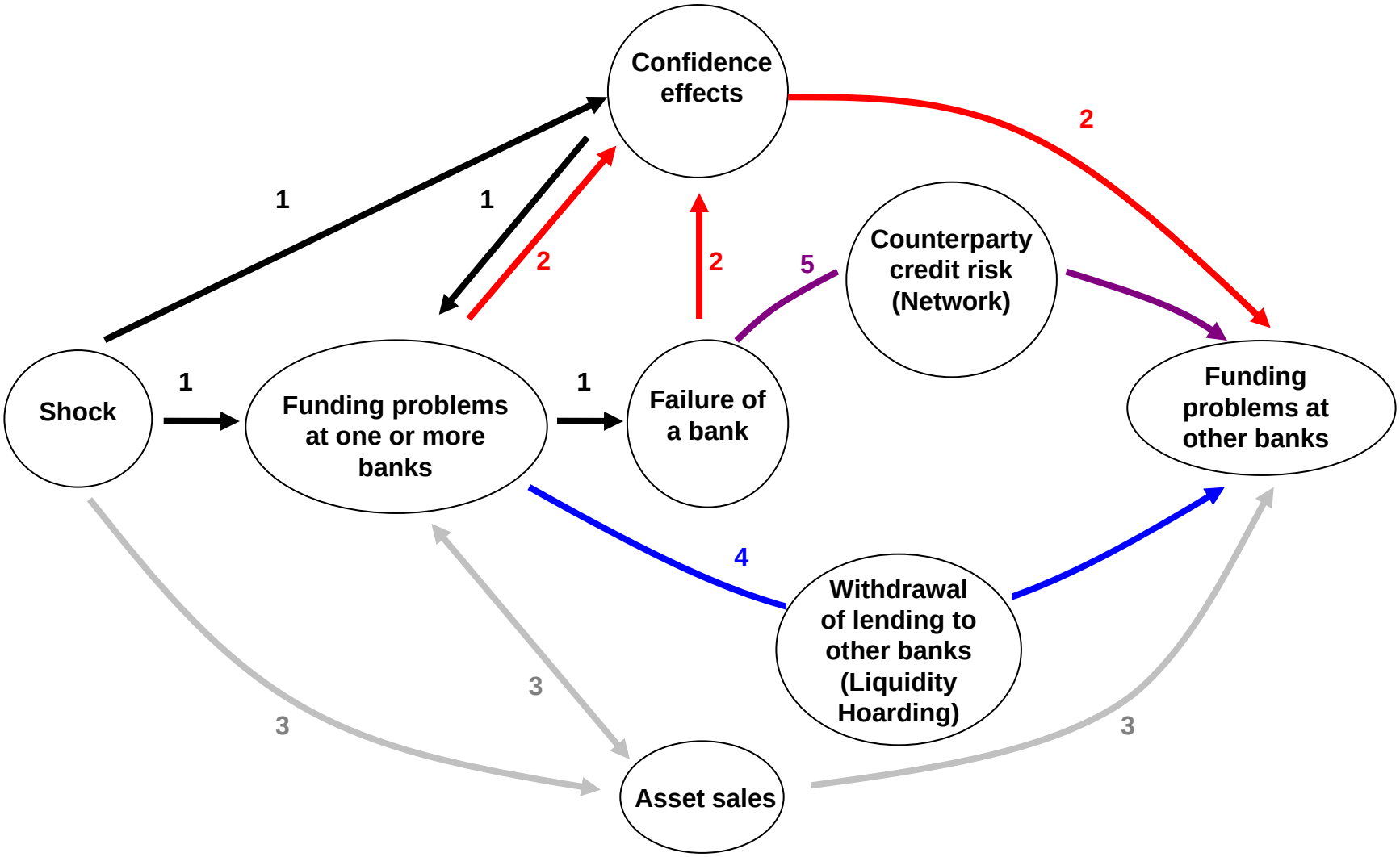
- Failed in May 1984 after wholesale run.
- Funding position had been under stress since the middle of 1982.
- Solvency concerns much more important for Continental than for Northern Rock

Continental Illinois: Danger Zone Scores



Funding Crises in a System-Wide Context



Banks' Defensive Actions

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Options for dealing with liquidity shortage:

1. Drawing on committed lines (?)
2. Expanding funding from other markets which the bank normally accesses (if available)
3. Repoing or selling highly liquid 'safe' assets

4. Hoarding liquidity
5. Selling illiquid or 'risky' assets

6. Obtaining funding from markets that the bank does not normally access (if available)
7. Reducing lending to the non-bank sector
8. Increasing retail deposit interest rates

Network Model – December 2005

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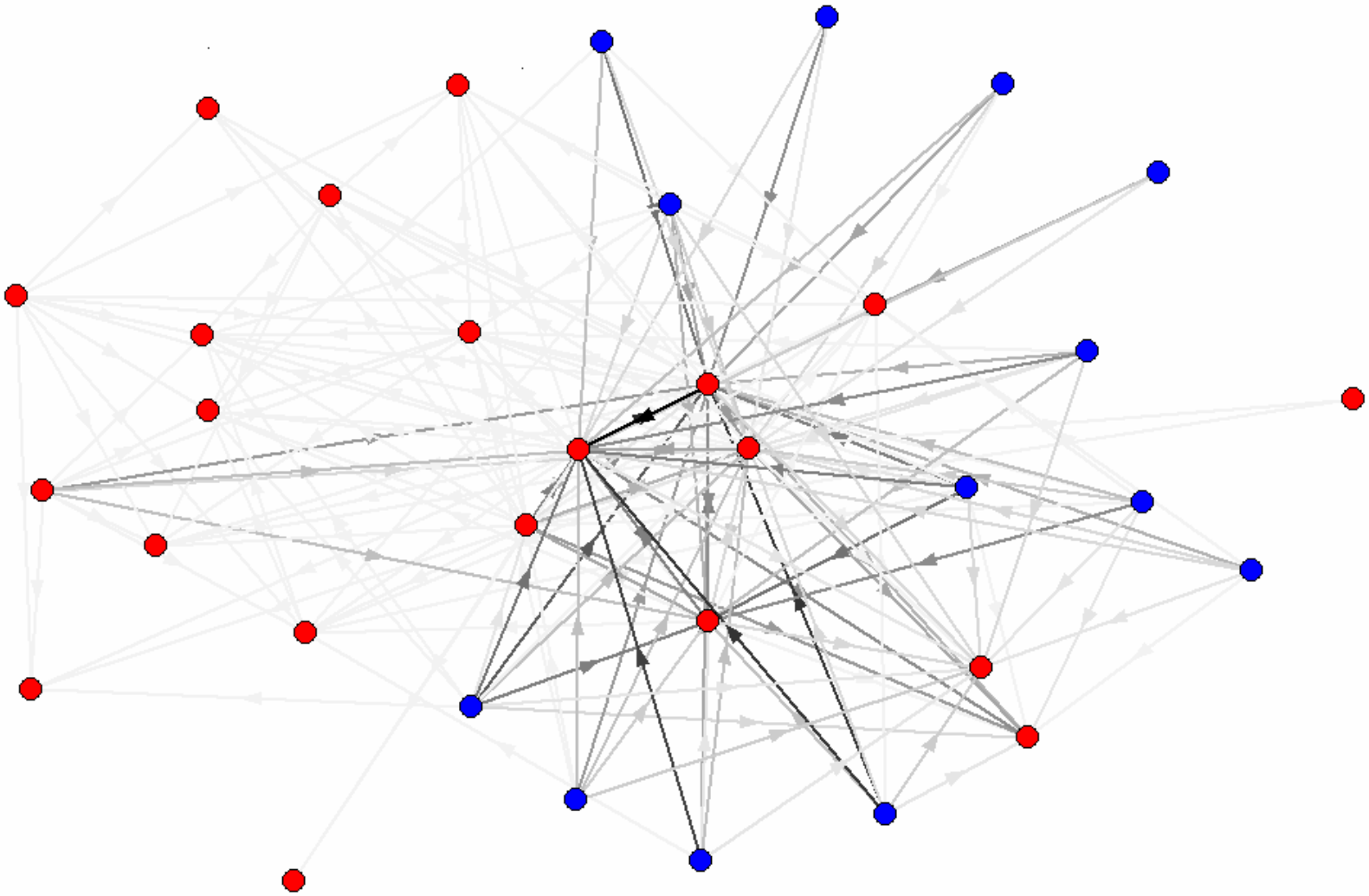

Network Model: Data

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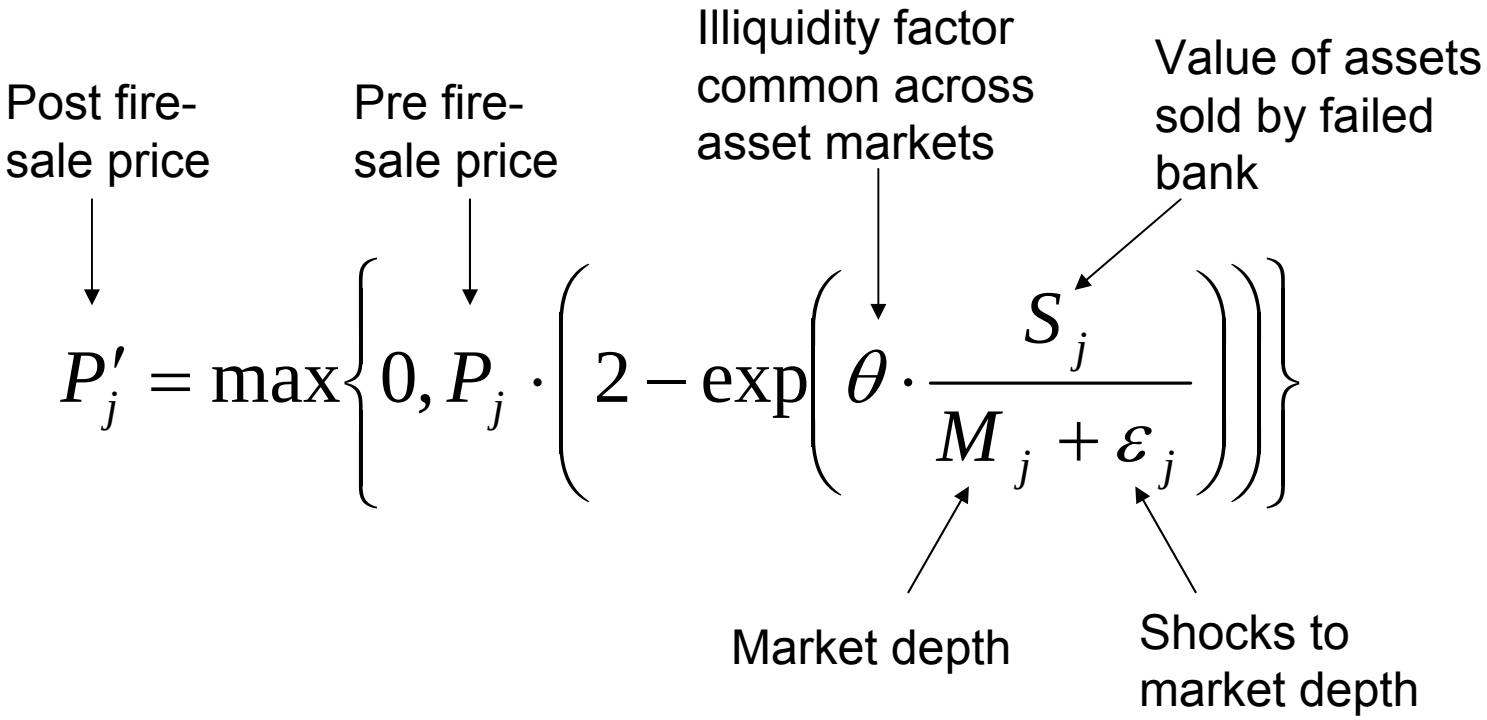
	UK Banks	LCFIs / Other Foreign Banks	Total Interbank Assets
UK Banks	**A**	**B**	**R**
LCFIs / Other Foreign Banks	**C**	**D**	**S**
Total Interbank Liabilities	**P**	**Q**	

- Entry *ij* refers to what column institution *j* owes row institution *i*.

- Use maximum entropy techniques to estimate the structure of interbank linkages in areas C and D.

Asset Fire Sale Equation



Asset Fire Sales: Calibration

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- Paucity of data. Illiquidity factor (theta) is calibrated for a case study (US convertible bonds, Mitchell et al , AER 2007: ≈ 5% of the market sold, price impact ≈ 3% in 2005.)

- Given theta, derive 'implied' market depths (M's) that generate 2%, 4% and a 5% price fall for equities, corp. bonds and ABS, respectively, when the major UK bank with the largest holdings of these assets sells all of its holdings.

- Market depths for each bank are not perfectly observable since information about banks' asset holdings is not sufficiently granular.

- Price falls informed by case studies (Coval and Stafford ('07), Mitchell et al, Pulvino ('98)).