Macro-Financial Feedbacks in Stress Testing

Joint IMF-EBA Colloquium
New Frontiers on Stress Testing
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Financial Sector Assessments/Policies
Monetary and Capital Markets Department, IMF

Macro-financial Approaches under Development at the Fund

Macro-Financial feedback through the Credit Channel

Contingent Claims Analysis: Banks & Sovereigns/ Systemic CCA

Structural Approach using Agent-based Modeling

Systemic Risk and Economic Activity

Solvency and Liquidity Models

Outline

- Part I – Macro-financial Feedback Loops through the Credit Channel
- Part II – A Structural Approach using Agent Based Modeling
- Part III – Banking, Macro and Sovereign Feedbacks using Contingent Claims Analysis and Other Approaches

The views expressed in this presentation are those of the authors and should not be attributed to the IMF, IMF policy or IMF Board.

Part I

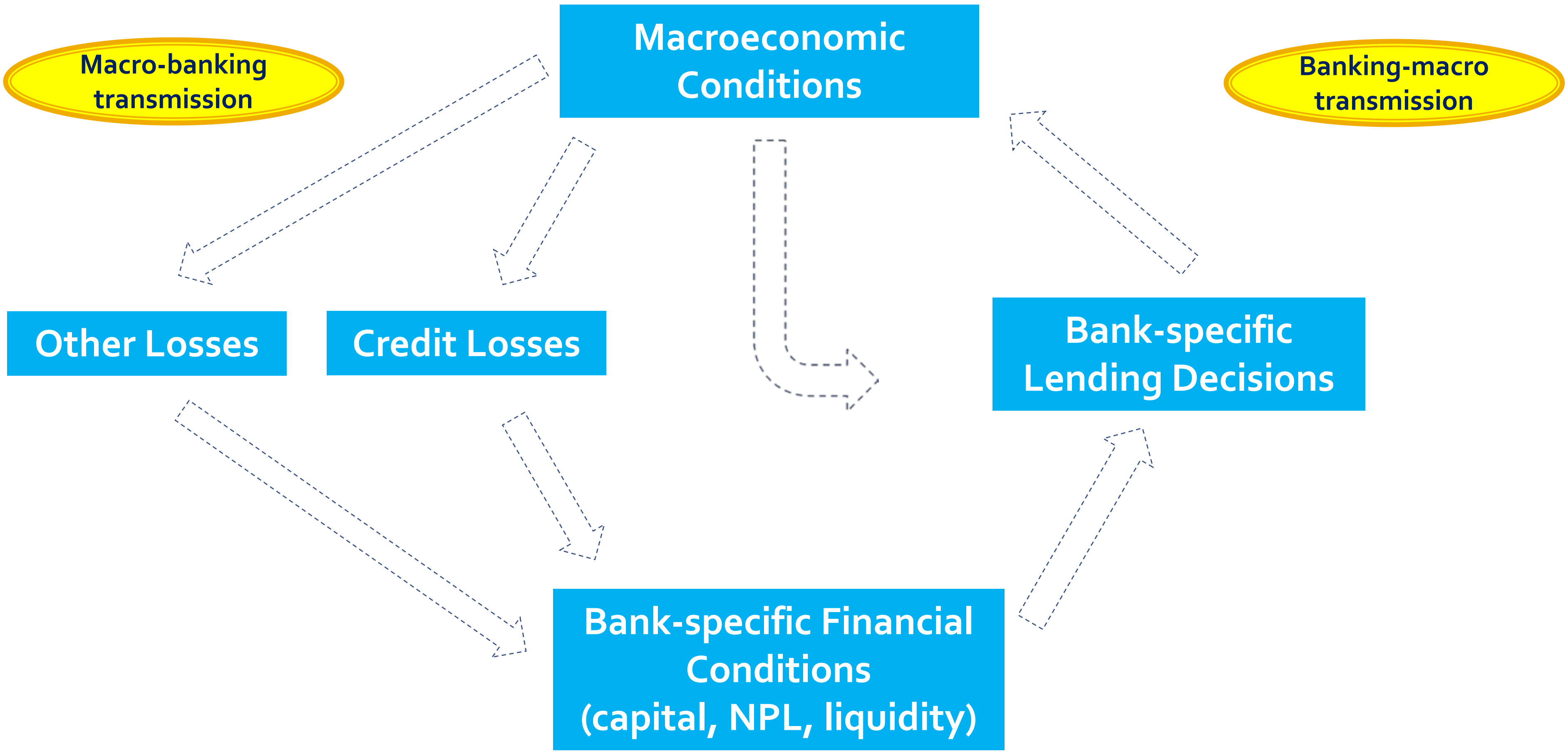
Macro-financial Feedback Loops through the Credit Channel

(Mario Catalán and TengTeng Xu)

Motivation

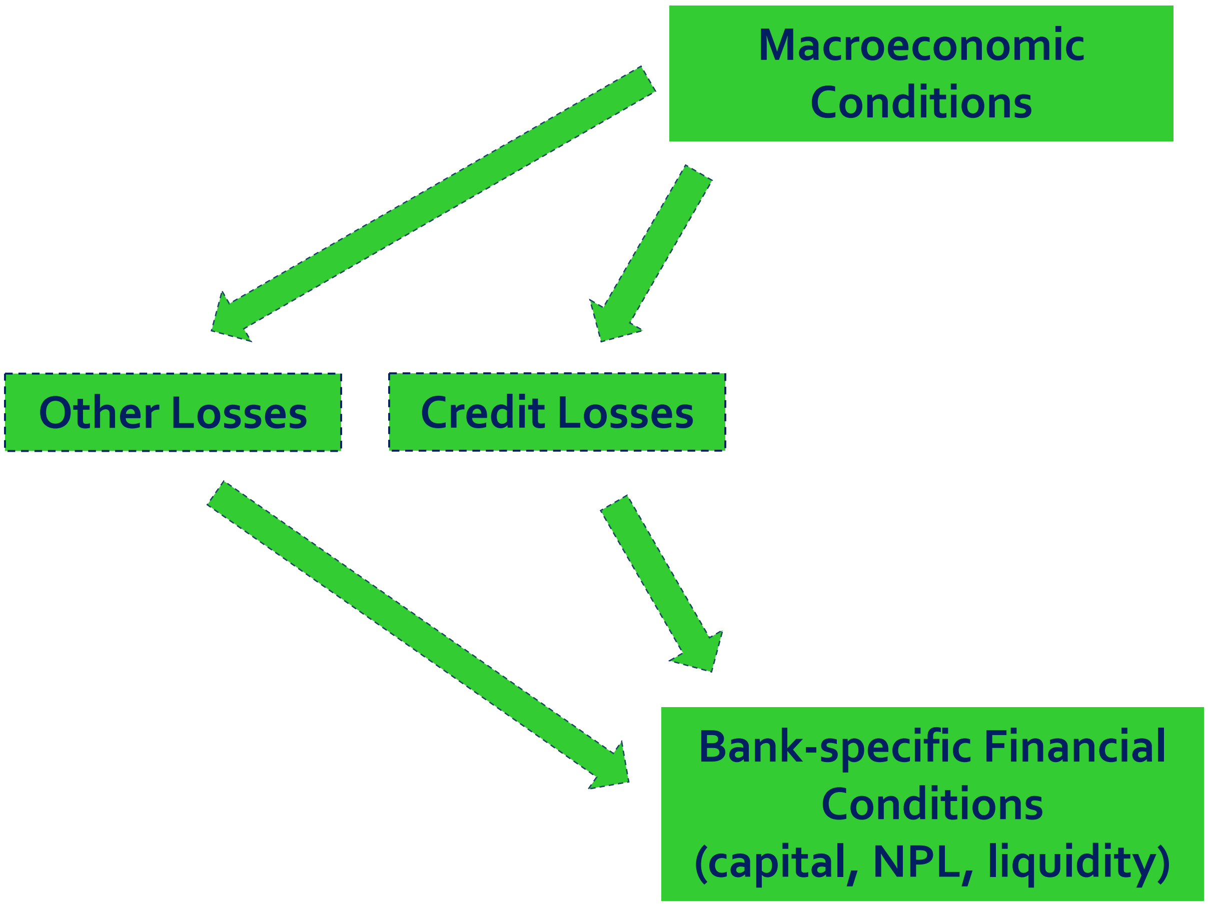
- Criticism of banking sector stress tests often centers on their failure to account for key macro-financial feedback loops
- This drawback *could* result in underestimation of capital losses and systemic risk

Macro-financial Loop of Interest



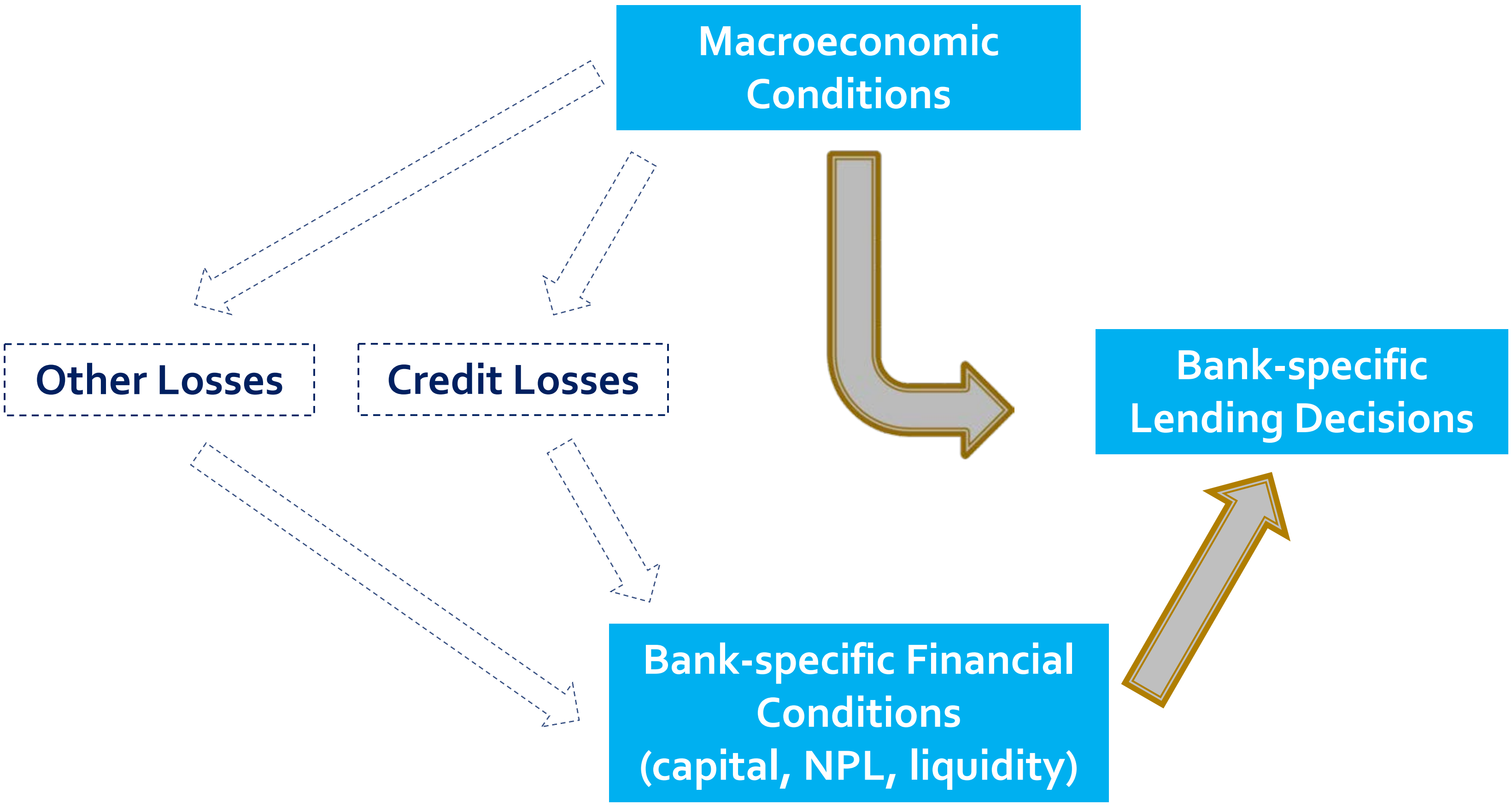
Relevance for systemic risk analysis: time dimension

Building Block #1



#1. Traditional (one round) Stress Testing

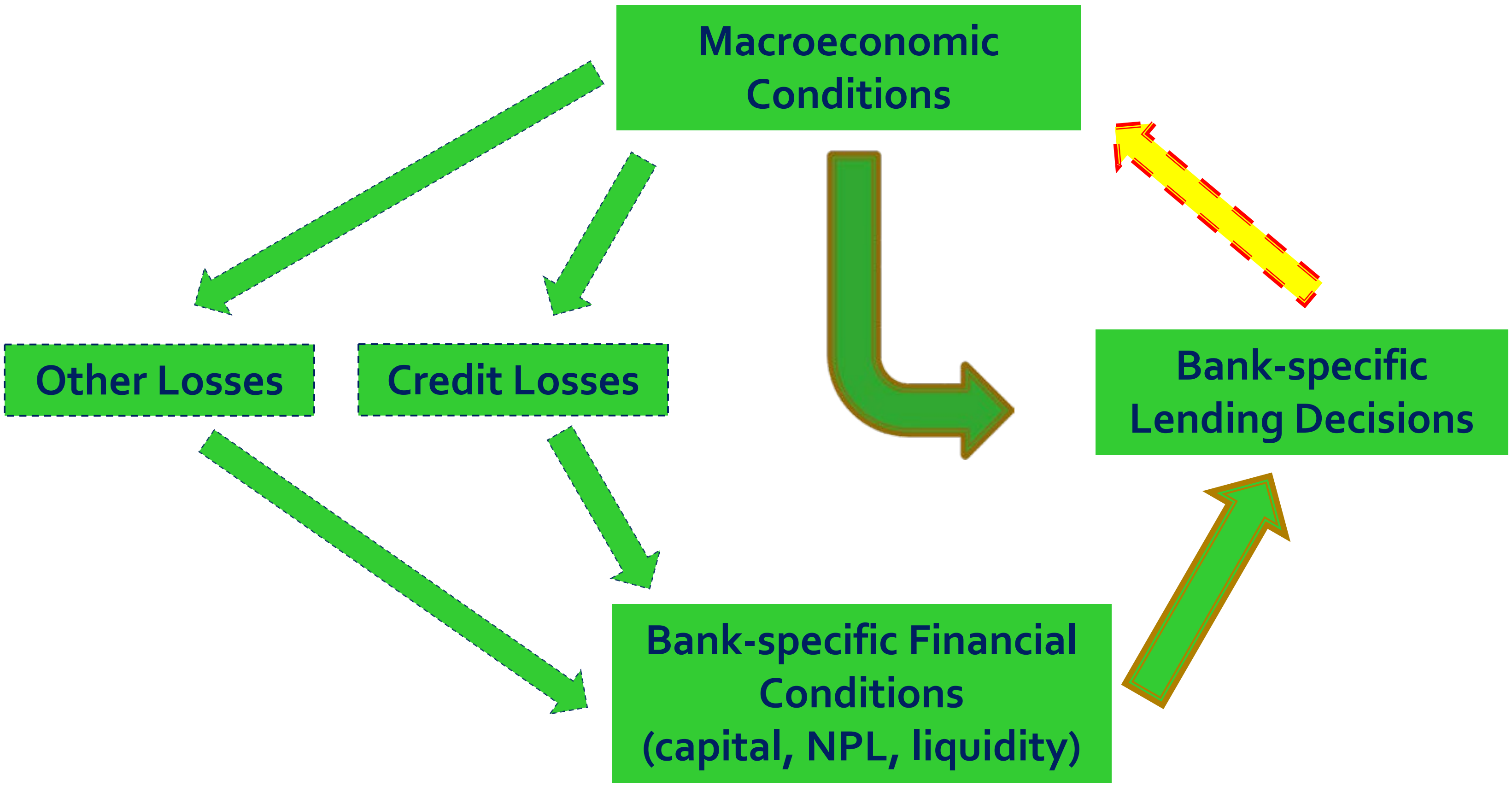
+ Building Block # 2



#2. Behavioral (Lending) Responses of Banks

Forthcoming IMF Working Paper (April 2017)

+ Building Block # 3



#3. Integration into a Macro Model to Close the Loop

IMF Working Paper and Operational Guidance Note to be Published Later in 2017

Macrofinancial Feedbacks via Credit Channel

- It consists of 3 Blocks of Equations

"Macro" Block

$$\boldsymbol{y}_t = \boldsymbol{A}_0 + \boldsymbol{A}_1 \cdot \boldsymbol{y}_{t-1} + \boldsymbol{A}_2 \cdot \boldsymbol{y}_{t-2} + \ldots + \boldsymbol{B}_1 \cdot l_{t-1} + \boldsymbol{B}_2 \cdot l_{t-2} + \ldots + \boldsymbol{\varepsilon}_t^y$$

SVAR Model

"Profit and Loss" Block

$$PD_{i,t} = \alpha + \mu_i + \lambda \cdot PD_{i,t-1} + \boldsymbol{\beta} \cdot \boldsymbol{y}_t + \boldsymbol{\gamma} \cdot \boldsymbol{X}_{i,t-1} + \varepsilon_{i,t}^p$$

Dynamic Panel Data Model/s

"Lending" Block

$$\Delta l_{i,t} = \xi_i + \lambda \cdot \Delta l_{i,t-1} + \boldsymbol{\delta}_1 \cdot \Delta \boldsymbol{y}_{i,t-1} + \boldsymbol{\delta}_2 \cdot \Delta \boldsymbol{y}_{i,t-2} + \ldots + \boldsymbol{\rho}_1 \cdot \Delta \boldsymbol{x}_{i,t-1} + \ldots + \varepsilon_{i,t}^l$$

Dynamic Panel Data Model/s

In Our Framework … algorithmic quarter-by-quarter approach

Step 1: obtain $\boldsymbol{y}_1$ using the "macro" block

Step 2: calculate credit $PD_{i,1}$ (and other) losses using the "profit and loss" block

Step 3: calculate $l_{i,1}$ using the "lending" block

Step 4: calculate bank capital ratios at end-period

$$k_{i,1} = \frac{\text{Capital}_{i,1}}{RWA_{i,1}} = \frac{\text{Capital}_{i,0} - \text{Credit and other losses}_{i,1}}{RWA_{i,1}}$$

$\boldsymbol{x}_{i,1}$, $\boldsymbol{X}_{i,1}$

Iterate over steps 1-4 to obtain quarter-by-quarter results

Part II

A Structural Approach using Agent Based Modeling[1]

(Laura Valderrama)

Valderrama, L. (2017), "Agent-Based Modeling for Stress Testing", IMF WP (forthcoming)

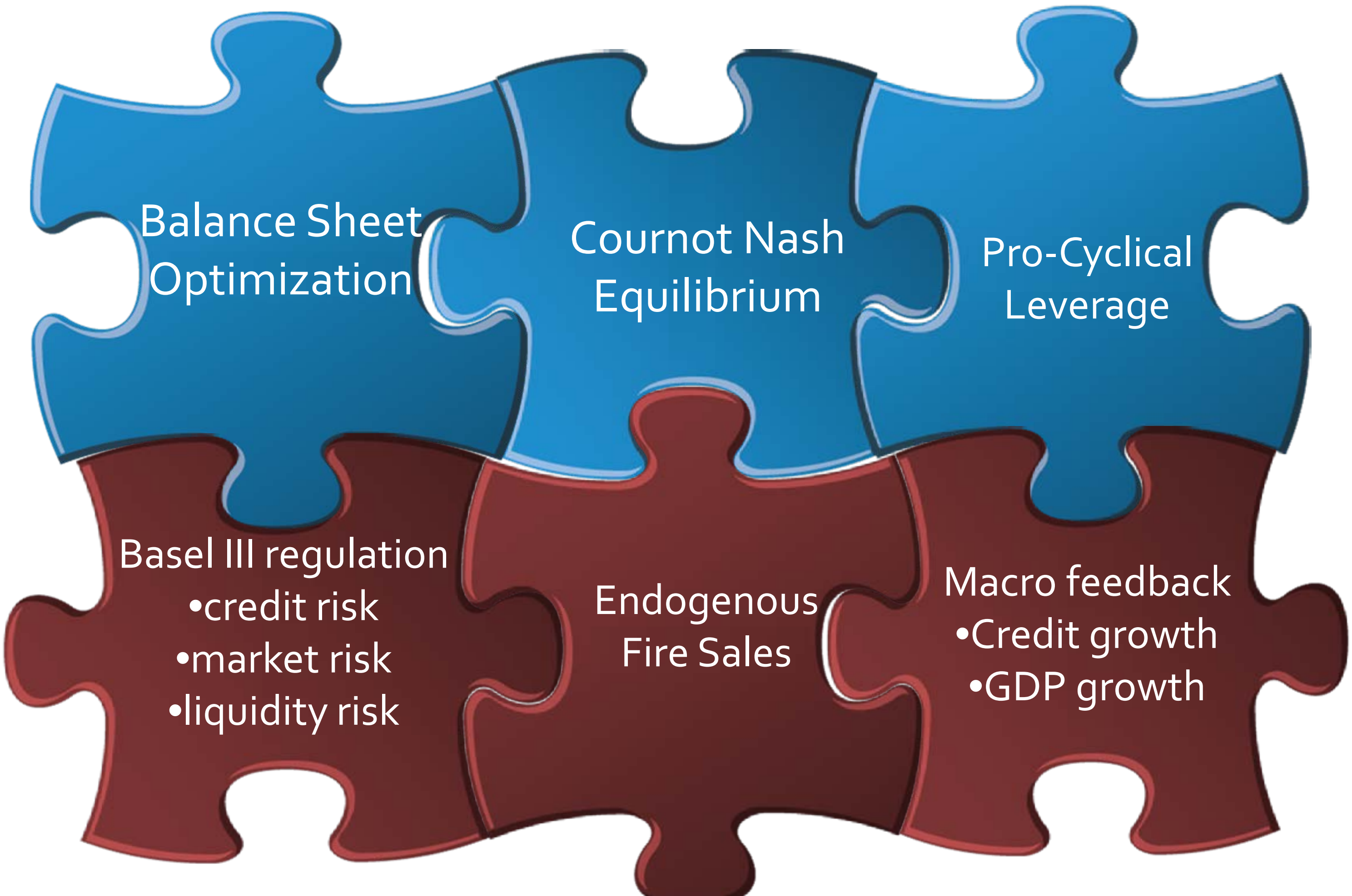
Realistic Complexity

- Heterogeneous agents
  - Explicitly accounts for interactions with each other and their environment
- Dynamics
  - Economies are highly non-linear, no steady state equilibrium conditions are imposed
- Macro patterns
  - Emerge from micro behaviors and interactions
- Financial stability
  - Well suited to explore impact of tail risk (stress test)

Key Features

- Incorporates behavioral response of financial agents (banks, noise traders, investors)
- Examines interaction of risks (credit risk, market risk, liquidity risk)
- Endogenizes funding access (leverage), fire sales (portfolio rebalancing), capital process (equity injections)
- Allows assessing the effect of unintended consequences of multiple regulations
- Suited to policy simulations
  - Macroprudential policy (regulatory constraints)
  - Banking sector structure (competition)

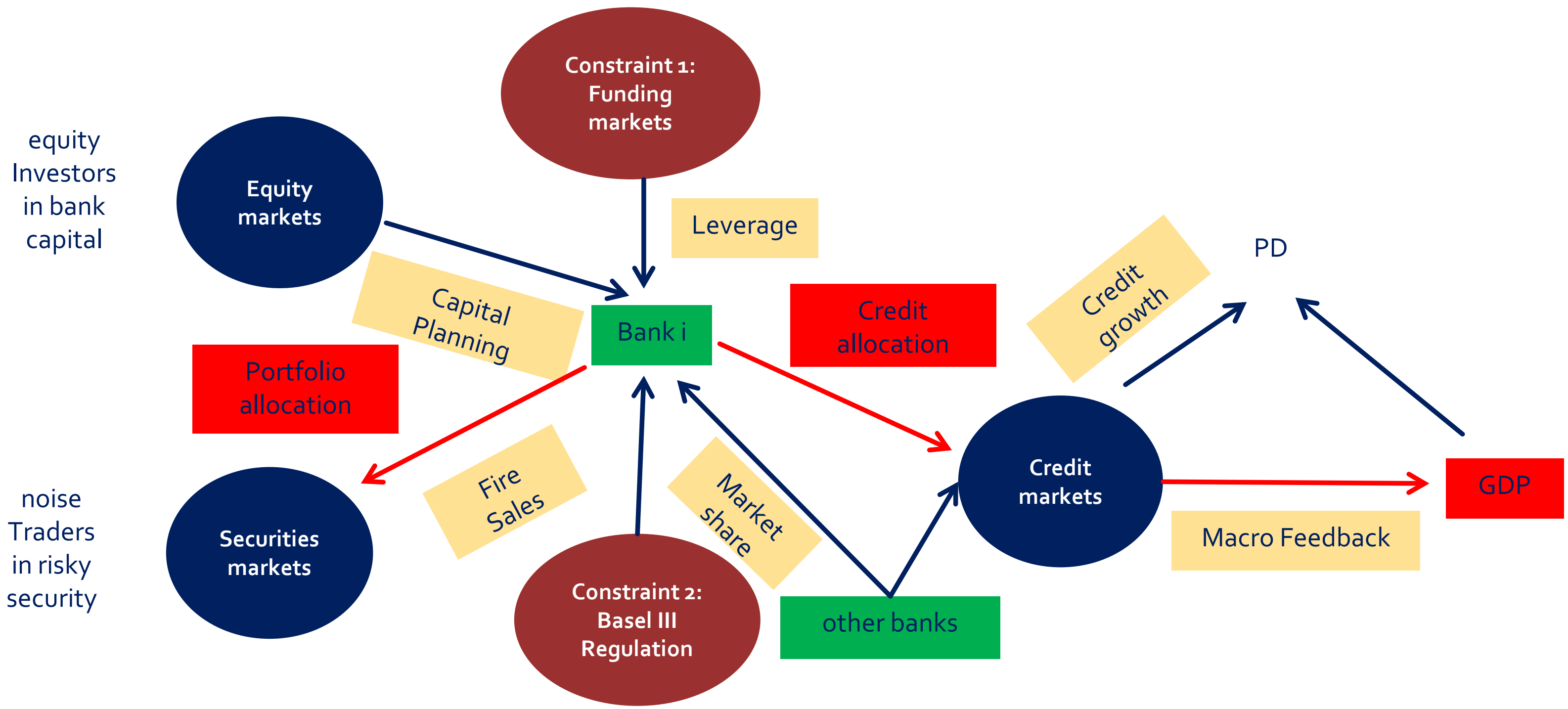
Ingredients



Agents

- **Banks (regulated entities)**:
  - Credit allocation to maximize expected value of future cash-flows net of expected losses discounted by required ROE
  - Rebalance **securities** portfolio to exploit mispricing (value investors)
  - Capital structure pinned down by regulation
  - Subject to:
    - **Funding** constraint (leverage)
    - Basel III regulatory constraints (credit risk, market risk, liquidity risk)
- **Noise traders (asset managers)**:
  - Invest in **securities** to clear the market
  - Stochastic process subject to redemption pressures (Thurner et al, 2012)
- **Investors (buy-side)**:
  - Capital injection in banks as a function of banks' realized excess return relative to benchmark (Thurner et al, 2012)
  - Provide **funding** as a function of banks' portfolio volatility

System Interactions



- At each time step, banks optimize their balance sheet.
- Implications for credit risk, asset volatility, capital buffers, credit growth, GDP growth

$$Max_{c_t^i} \sum_{s=1}^{w} \frac{(i_l - i_d(1-cap_t) - ROE \cdot cap_t)}{(1+ROE)^s} \cdot c_t^i - \frac{PD_t \cdot LGD \cdot c_t^i}{(1+ROE)^w}$$

Credit allocation

- **Cournot competition**: Each bank maximizes net discounted value of expected future cash-flows subject to balance sheet capacity and Basel III regulation

$$Max_{c_t^i} \sum_{s=1}^{w} \frac{E_t\left[i_l - i_d \cdot (1-cap_t) - coe \cdot cap_t\right]}{(1+ROE)^s} \cdot c_t^i - \frac{E_t\left[PD_t\left(c_t^i, \sum_{j \neq i} c_t^j, g_t\left(c_t^i, \sum_{j \neq i} c_t^j\right)\right)\right] \cdot LGD \cdot c_t^i}{(1+ROE)^w}$$

Balance sheet capacity

$$s.t. \quad c_t^i + cs_{t-1} \cdot \delta + Q_t^b \cdot p_t \leq K_t\left(c_t^i\right) \cdot \mu_t^{\max}$$

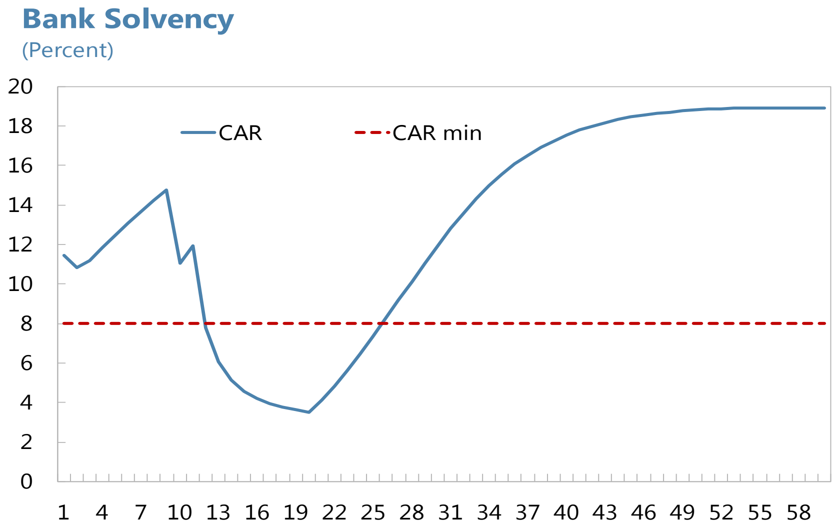
$$\mu_t^{\max} = \frac{\mu^{\max} + \varepsilon_t^{\lambda}}{1 + \kappa \cdot \sigma_t^2\left(c_t^i, p_t\right)}$$

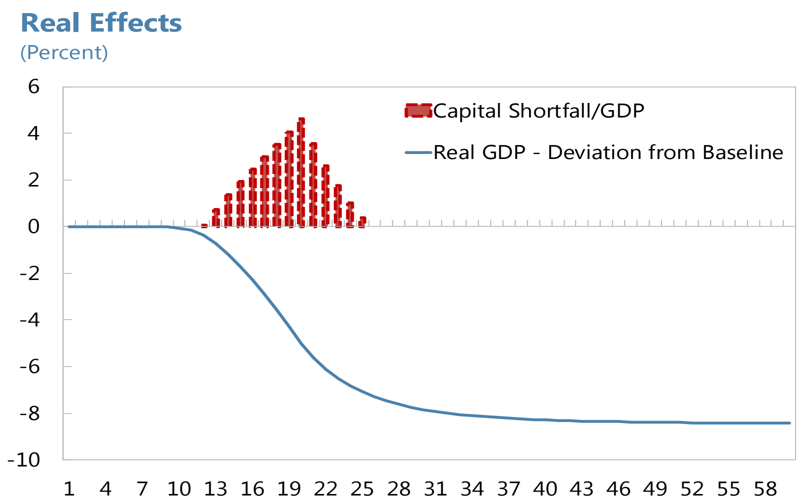
Basel III Regulation

$$cap_t = f\left(PD_t\left(c_t^i, \sum_{j \neq i} c_t^j, g_t\left(c_t^i, \sum_{j \neq i} c_t^j\right)\right)\right)$$

$$Q_t^b \cdot p_t \geq runoff_t \cdot D_t\left(K_t\left(c_t^i\right)\right)$$

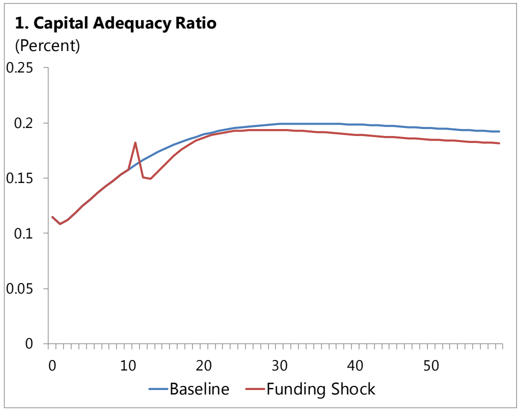
GDP shock

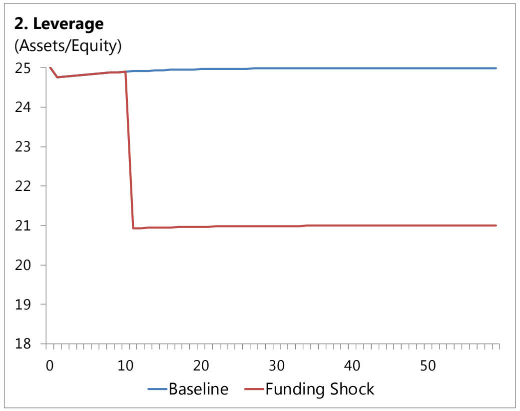


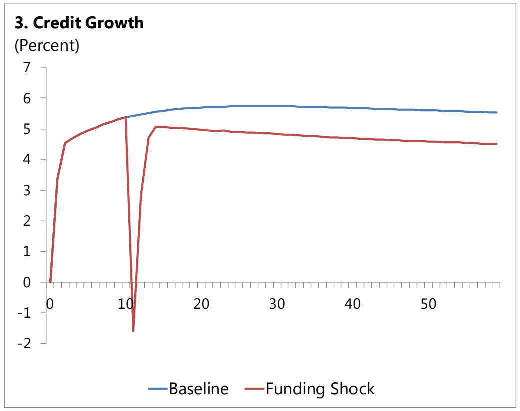


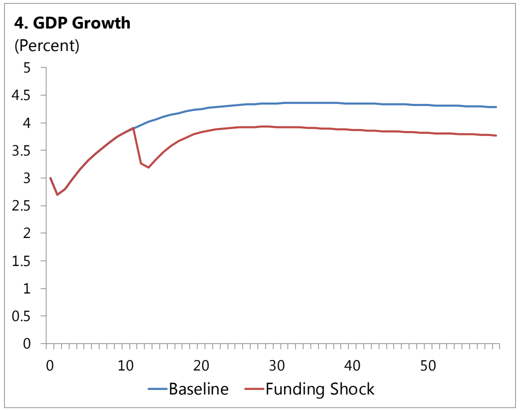
- GDP PROJECTIONS ARE **ENDOGENOUS** TO BANKS' REACTION TO STRESS
- DESPITE RECOVERY IN BANKS' CAPITAL RATIOS, **PERMANENT** REAL EFFECTS
- RECESSIONS **DEEPER** AND MORE **PERSISTENT** WHEN SECOND-ROUND EFFECTS ARE INCLUDED
- BANK **RECAPITALIZATION** PEAKS AT 5 PERCENT OF NOMINAL GDP
- OVER 5-YEAR, CUMULATIVE **REAL GDP** DECLINES BY 8 PERCENT RELATIVE TO BASELINE

Funding shock



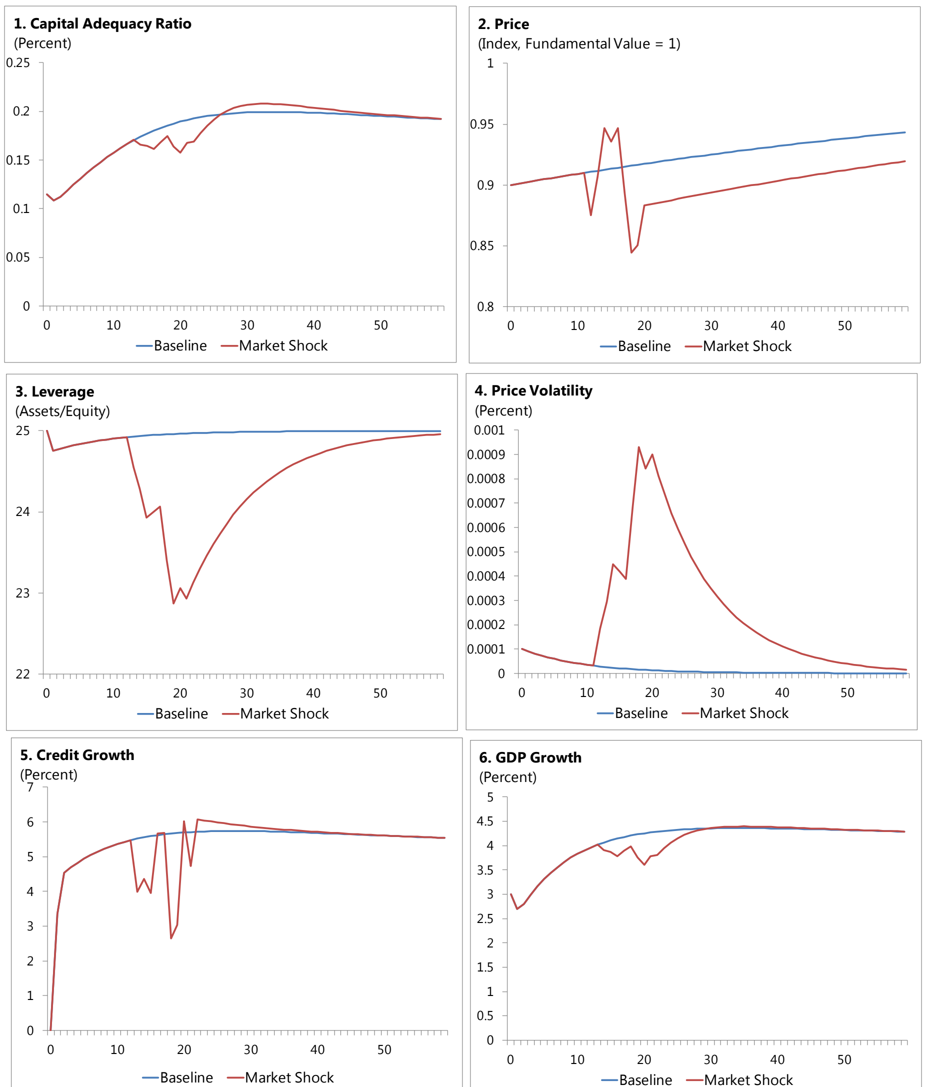






- BANK DELEVERAGING HAS AN INITIAL POSITIVE IMPACT ON BANKS' CAPITAL RATIOS
- EVEN IF BANKS' CAPITAL POSITION STABILIZES, REAL EFFECTS BECOME PERMANENT
- OVER 5-YEAR, CUMULATIVE REAL GDP DECLINES BY 2 PERCENT RELATIVE TO BASELINE

Market shock



- A **MARKET SHOCK** (REDEMPTIONS FROM NOISE TRADERS) MORPHS INTO…
- …A **LIQUIDITY SHOCK** (THROUGH LEVERAGE CONSTRAINT) AND…
- …A **CREDIT SHOCK** (THROUGH BANKS' BEHAVIORAL RESPONSE)…
- … INCREASING **DEFAULT RISK** (THROUGH SECOND-ROUND EFFECTS)…
- …SLOWING DOWN **ECONOMIC GROWTH**…
- …CUMULATIVE **REAL GDP** DECLINES BY 1 PERCENT RELATIVE TO BASELINE

Part III

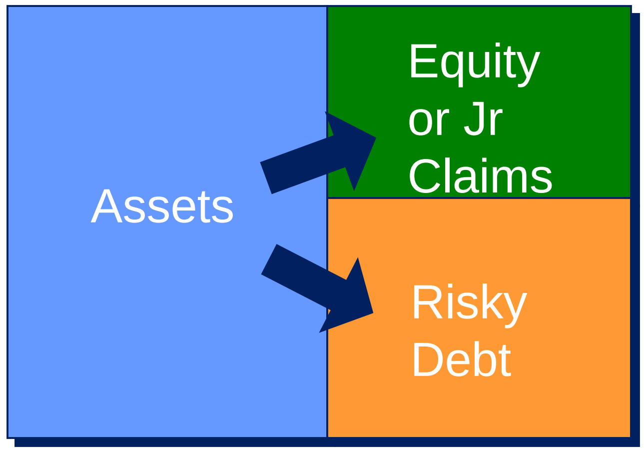
Banking, Macro and Sovereign Feedbacks using Contingent Claims Analysis

(Dale Gray)

Integrated Solvency and Liquidity Models

(Fabian Lipinsky)

Core Concept: Risk Adjusted Balance Sheet Based on Contingent Claims Analysis (CCA)



- Value of liabilities derived from value of assets
- Uncertainty in asset value

Assets = Equity + Risky Debt

= Equity + PV of Debt Payments – Expected Loss due to Default

= Implicit Call Option + PV of Debt Payments – Implicit Put Option

CCA Risk Indicators

Merton-type model uses equity value and volatility with balance sheet debt data to estimate several key risk indicators:

- *Expected Default Frequencies (EDFs)* for banks and corporates
- Associated *expected losses* to bank creditors (i.e. implicit put option value)
- Associated *credit spreads* consistent the default probabilities and expected losses --- called, fair-value credit default swap (FVCDS) spreads.

CCA Risk Indicators (cont.)

- For large banks the CCA based credit spread (FVCDS) is higher than the observed bank CDS spread
- This is due to the depressing effect of implicit or explicit guarantees on bank debt
- CCA is used to back out the market's view of government contingent liabilities to banks
- CCA models of banks and sovereigns are used to model *feedbacks between bank and sovereign risks*

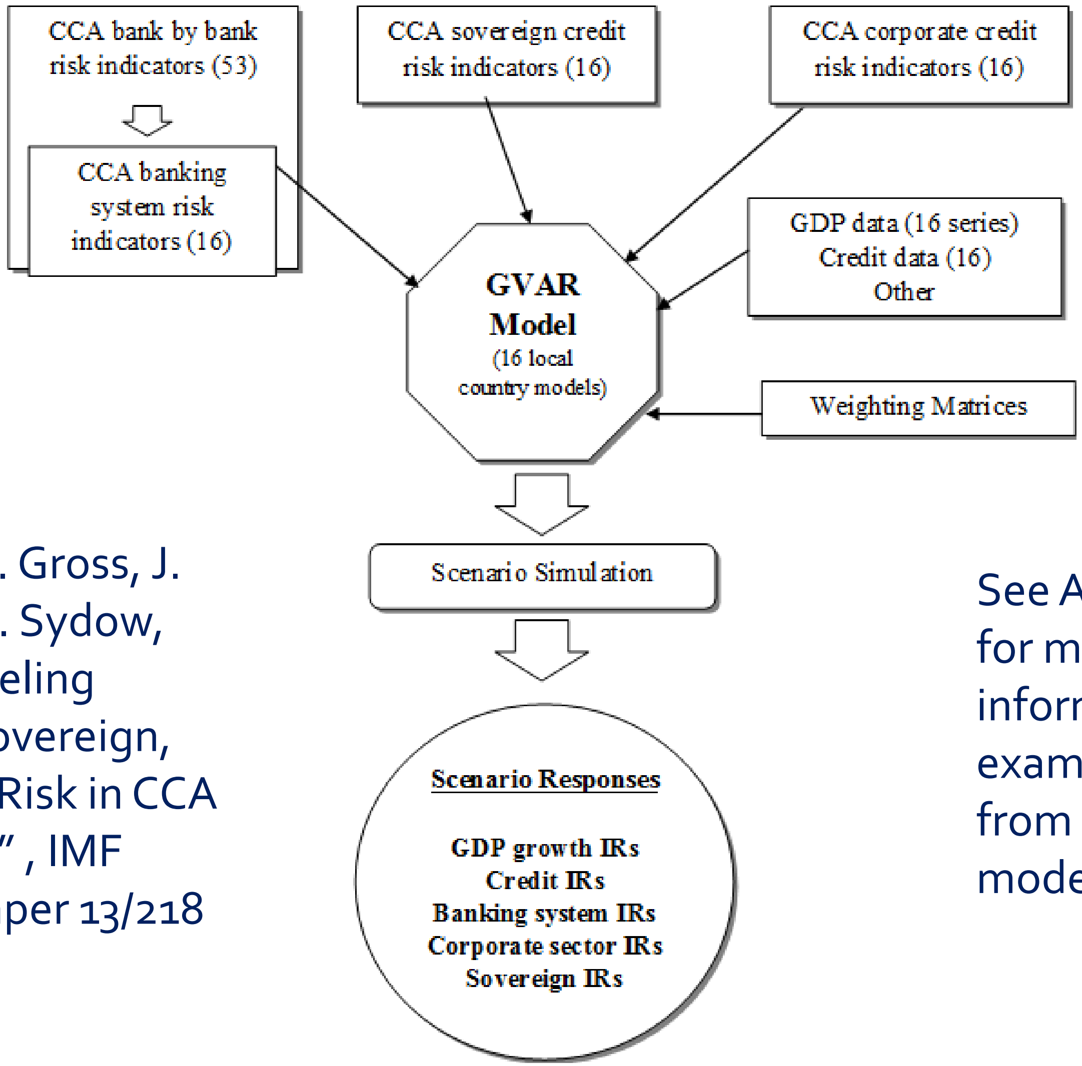
Approach 3 – Systemic CCA Framework – Used in FSAP Stress Tests (Gray and Jobst, 2013, "Systemic Contingent Claims Analysis –Estimating Market-Implied Systemic Risk" IMF Working Paper 13/54)

- CCA models of individual banks, expected losses and market-implied government contingent liabilities are estimated.
- Multivariate extreme value dependence model is then used to calculate the multivariate density of: (i) the banking system expected losses and (ii) government's contingent liabilities accounting for the *time-varying and non-linear* dependence (correlation *becomes exceedingly unreliable in the presence of "fat tails"*).
- Provides estimates of *joint losses* for the banking system and *joint government contingent liabilities* and *contribution* of various bank to systemic risk at different percentile levels (and at each point in time) e.g. 50th percentile or 95th percent VaR.
- Dynamic macro factor model projects average and 95 percent VaR tail risk losses and contingent liabilities for various scenarios.
- **Used in numerous FSAPs (US,UK, Sweden, Germany, Netherlands, Israel, Spain, Hong Kong and others).**

Approach 4-Time Series of CCA Risk Indicators and Macro Variables can be used in VAR or Global VAR (GVAR) models

- VAR – For a single country the time series of individual bank (or banking system), corporate sector and sovereign Expected Loss Ratios and GDP, Credit, other variables can be used in a VAR.
- Then shocks produce outputs, which incorporate feedbacks. impulse response
- The Expected Loss Ratio outputs can then be converted to credit spreads, EDFs or total expected losses for each bank and related to 'safe zone' levels (e.g. investment grade).
- Global VARs can be used for multiple countries.

Approach 4 (cont.): Modeling Banking, Sovereign and Macro Risk in CCA GVAR



Gray, D., M. Gross, J. Paredes, M. Sydow, 2013, "Modeling Banking, Sovereign, and Macro Risk in CCA Global VAR" , IMF Working Paper 13/218

See Annex slides for more information and example outputs from CCA GVAR model.

Approach 5: Integrated Solvency and Liquidity Models

Purpose

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- Better capture the interactions between solvency and liquidity risks and their joint impact on financial stability.

Methodologies

- General equilibrium model, where model parameters are estimated with Bayesian techniques;
- Capture joint dynamics of bank solvency and liquidity and their impact on the real economy, embedding Basel III regulation.
- Extending "global games" framework to account for solvency-liquidity interactions over short-time horizons (i.e. weeks or months), from a conceptual and hands-on perspective. (being developed by Fabian Lipinsky)

References

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Annex Slides Part II: Structural Approach Agent-Based Modeling

	Balance Sheet Composition	Balance Sheet Capacity
Banks	Manage actively their balance sheet: optimize credit allocation rebalance their securities' portfolio Subject to Basel III banking regulation: capital regulation (IRB): - credit risk - market risk liquidity regulation (LCR) Subject to market constraints: maximum leverage (time-varying)	P&L receive interest income (loans/securities) incur expenses from interest payments hit by loan impairment charges gains/losses on securities at fair value Capital management actions: receive equity injections payout dividends Maximum leverage (portfolio variance; pro cyclical): volatility of expected payoff of loans volatility of securities' returns
Noise Traders	Stochastic downward sloping demand curve for securities Mean-reversion towards fundamental value Hit by liquidity shocks (redemption flows)	Fluctuations in prices feed into: P&L (mark-to-market valuation) RWAs (market risk) maximum leverage
Investors	Inject/withdraw capital from banks Behavior governed by banks' excess return over benchmark Provide funding as a function of current leverage	Capital Planning Process Funding Risk Profile

Annex Slides Part II: Structural Approach Agent-Based Modeling

Endogenous Process

Highly Non-Linear

Macroprudential Policy

- Banking regulation
- Banking concentration

Bank Solvency

- Capital position evolves with net interest income, fair value gains/losses of securities, loan loss provisioning, credit risk migration, capital injection/withdrawal, RWAs.

Funding Constraints

- Asset variance (debt)
- Excess bank returns over benchmark (equity)

Leverage constraint

Credit Risk

- Evolves with credit growth (lending standards) and GDP growth (income gearing)

Market Risk

- Evolves with market price of securities (mark-to-market) and asset volatility (Value-at-Risk)

Credit, securities allocation

- Credit frictions → **Credit growth, GDP growth**

Real Economy

Annex Slides Part III on CCA: Relationship of EDF (Expected Default Frequency), Risk-neutral EDF, FVCDS (Fair-value CDS) and Expected Loss Ratio with Examples

Risk-Neutral EDF is derived from EDF, Global Market Sharpe Ratio (SR), correlation ρ of asset return with market return.

$$EDF_{Risk-Neutral} = N\left[N^{-1}(EDF) + \rho_{A,Mkt} SR\sqrt{T} \right]$$

Using Risk-Neutral EDF and Loss Given Default (Banking Sector LGD) the FVCDS can be calculated. The Expected Loss Ratio is equal to the EDF risk-neutral* LGD and equal to the implicit put option/default barrier present value.

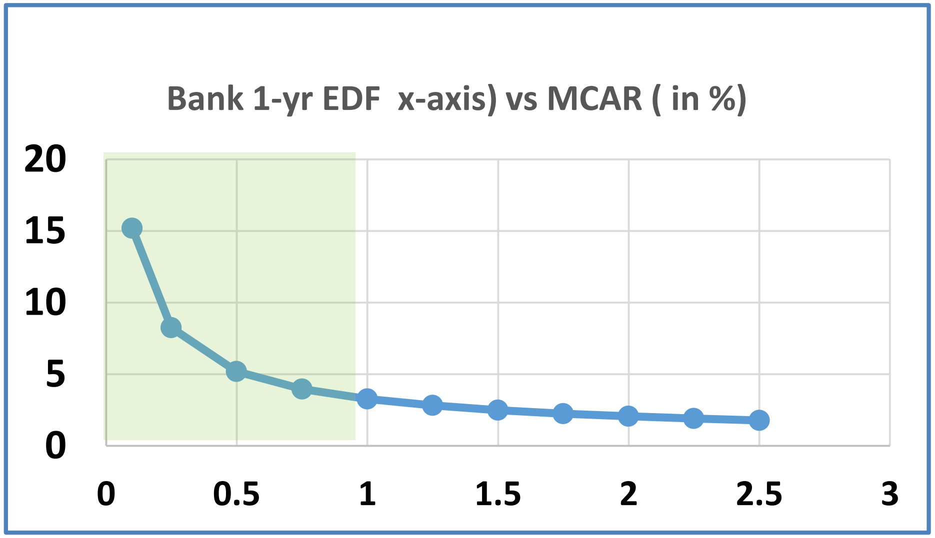
$$FVCDS = -\frac{1}{T}\ln\left(1 - LGD_{Banking\ Sector} * EDF_{Risk-Neutral}\right)$$

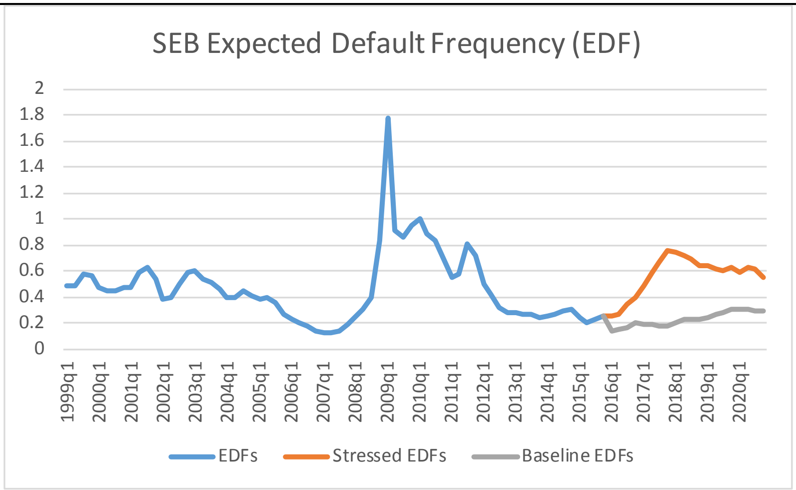
$$= -\frac{1}{T}\ln\left(1 - \frac{Put\ Option}{PV\ Default\ Barrier}\right) = -\frac{1}{T}\ln\left(1 - Expected\ Loss\ Ratio\right)$$

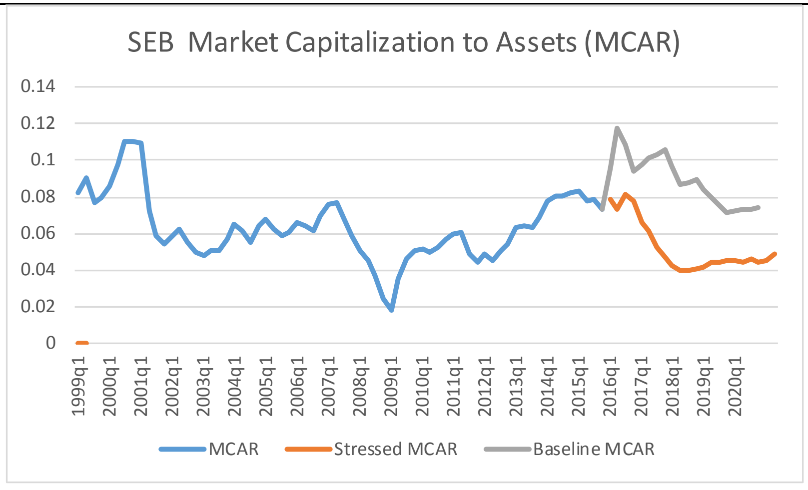
A very distressed bank example is when EDF=3.5 %, FVCDS is 700 bps, expected loss ratio is around 2700 bps and market cap to assets is 2 %
A bank in the investment grade "safe zone" has EDF=0.6 %, FVCDS = 200 bps and expected loss ratio of 950 bps and market cap to assets of 4-6 %

EDFs are tightly related to Market Cap to Assets (MCAR); Using macro factor model to project EDFs and MCARs for different scenarios

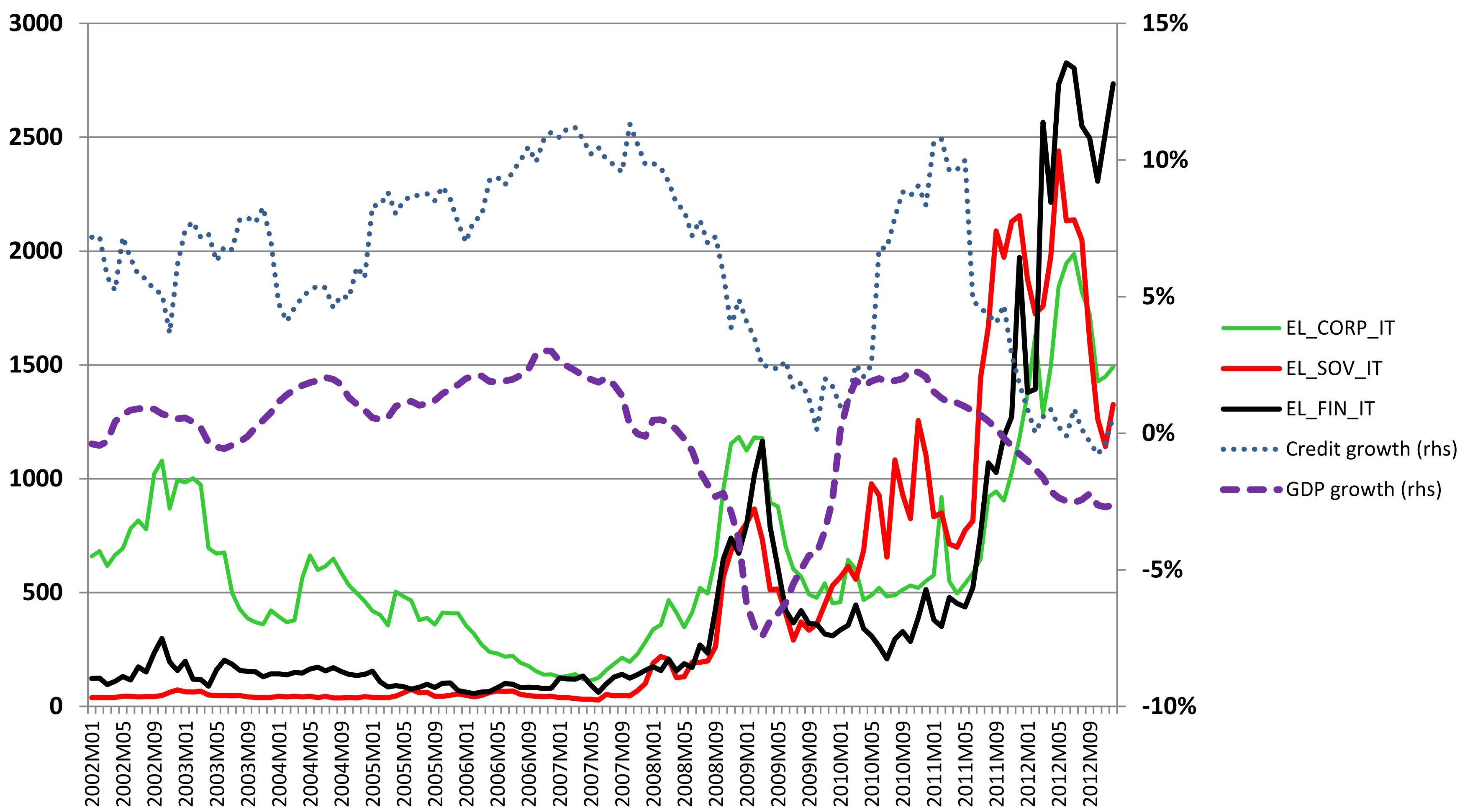
Investment Grade or Near Investment Grade Ratings have EDFs of less than about 0.8 or 0.9 percent --- in a **"safe zone"**



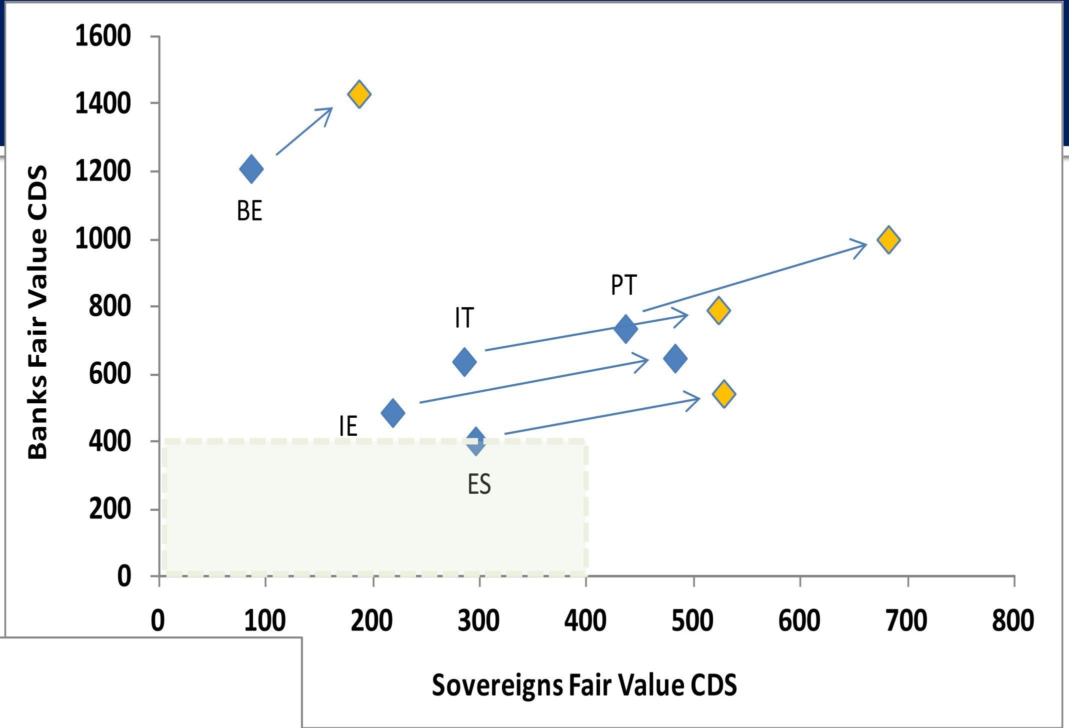




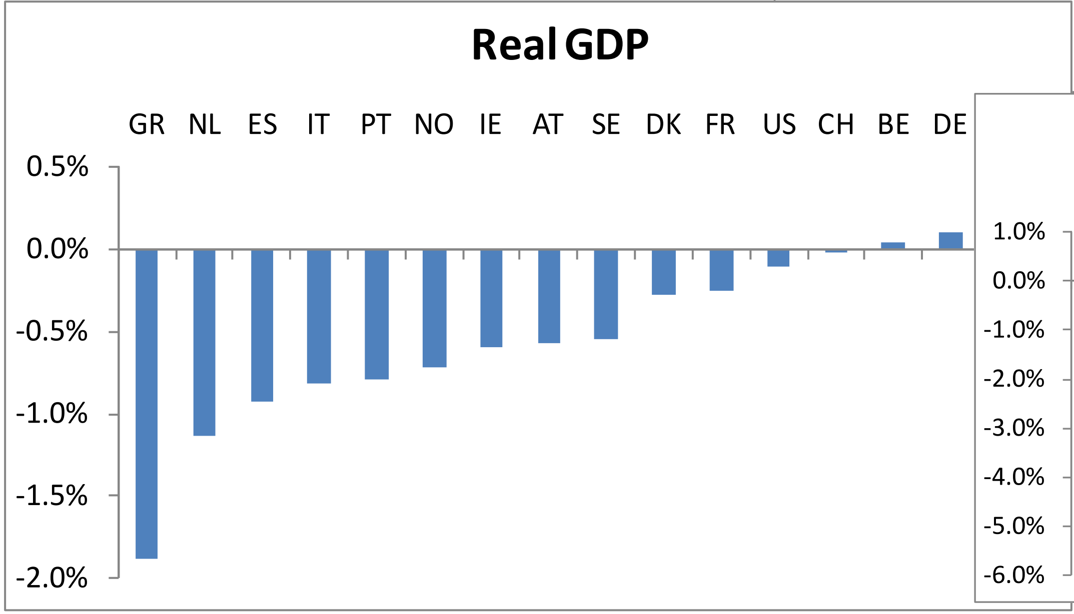
Example monthly time series data: Italy - Banking System, Corporate Sector, and Sovereign Expected Loss Ratio (all in bps, lhs), and Real GDP growth (percent, rhs) Jan. 2002–Mar. 2012

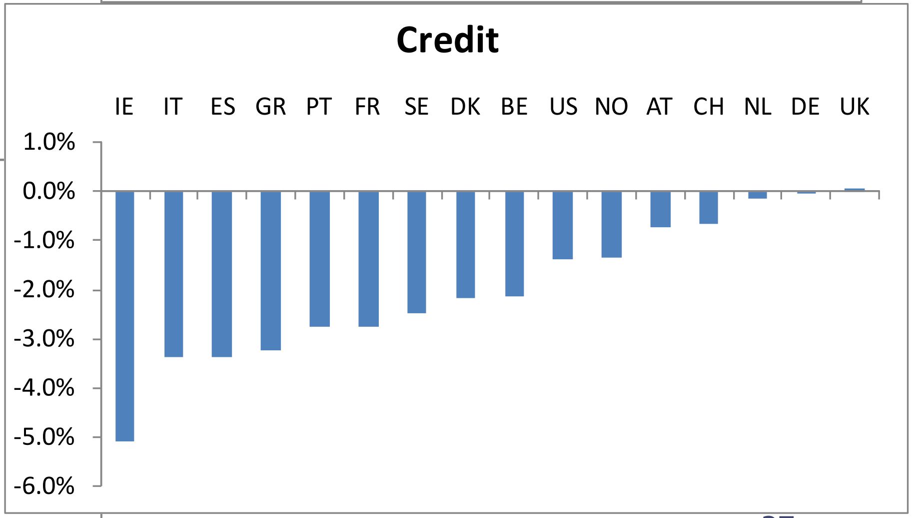


CCA GVAR Results Scenario 1



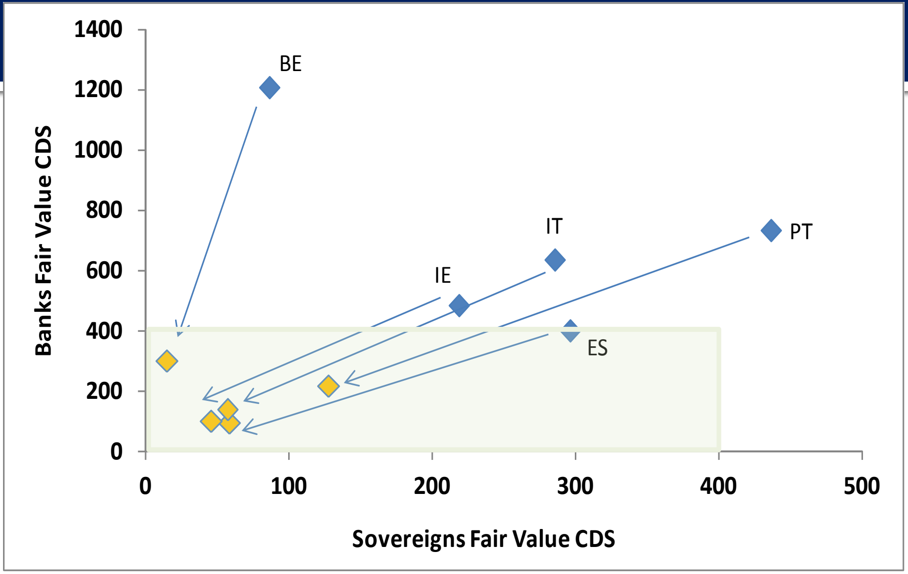
Negative Shock to Spain and Italy Sovereigns: Bank and Sovereign FVCDS increase; Real GDP growth down; Credit growth down

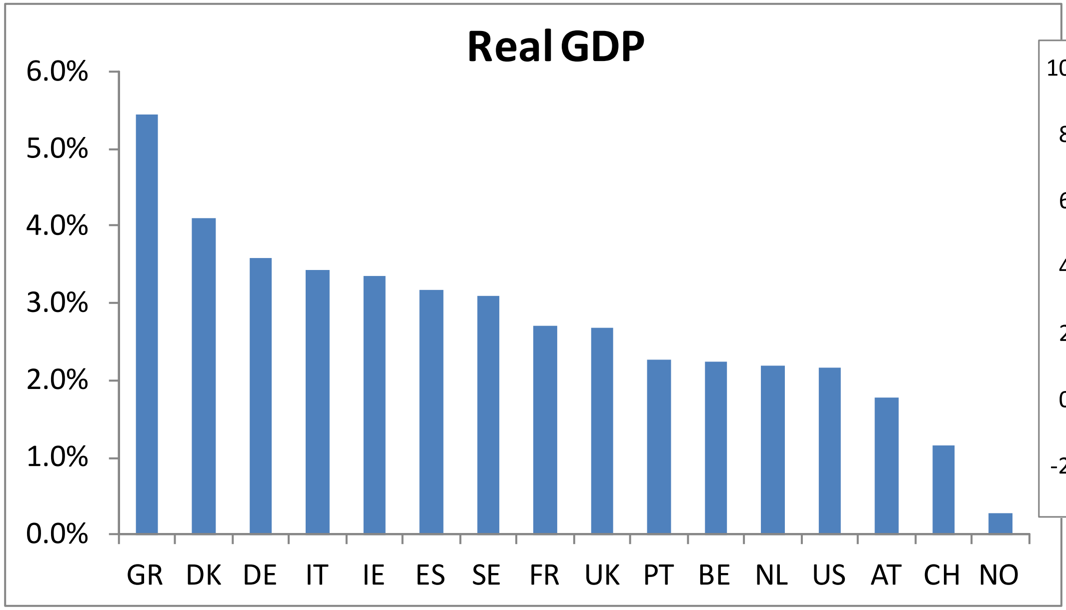


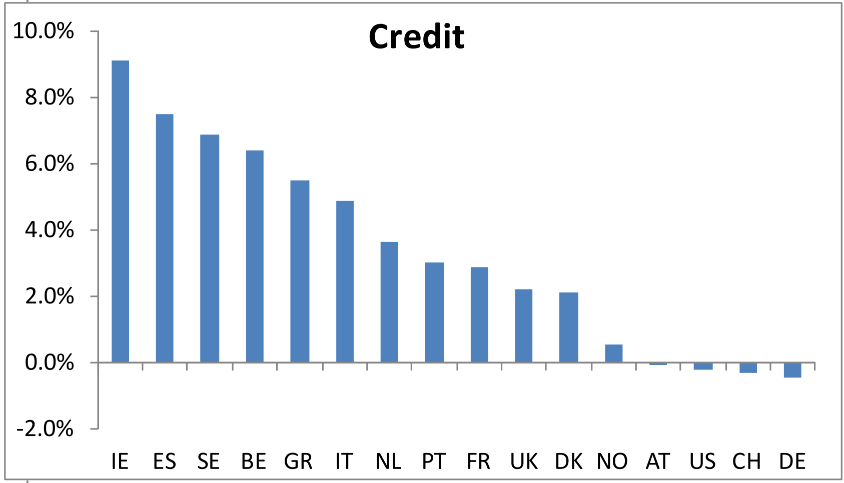


CCA GVAR Results Scenario 2

Positive Shock to Spain and Italy Sovereigns: Bank and Sovereign FVCDS to “safe zone”; Real GDP up; Credit Growth up







CCA GVAR Results Scenario 3

Negative Shock to Spain and Italy Banks: Bank and Sovereign FVCDS increase; Real GDP growth down; Credit growth down