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
- Structural Approach using Agent-based Modeling
- Systemic Risk and Economic Activity
- Contingent Claims Analysis: Banks & Sovereigns/ Systemic CCA
- 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)
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.
Relevance for systemic risk analysis: time dimension
Building Block #1

- Macroeconomic Conditions
- Other Losses
- Credit Losses
- Bank-specific Financial Conditions (capital, NPL, liquidity)

#1. Traditional (one round) Stress Testing
#2. Behavioral (Lending) Responses of Banks
+ Building Block #3

Macroeconomic Conditions

Other Losses
Credit Losses
Bank-specific Financial Conditions (capital, NPL, liquidity)
Bank-specific Lending Decisions

#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**

\[ y_t = A_0 + A_1 \cdot y_{t-1} + A_2 \cdot y_{t-2} + \ldots + B_1 \cdot l_{t-1} + B_2 \cdot l_{t-2} + \ldots + \epsilon_t^y \]

**“Profit and Loss” Block**

\[ PD_{i,t} = \alpha + \mu_i + \lambda \cdot PD_{i,t-1} + \beta \cdot y_t + \gamma \cdot X_{i,t-1} + \epsilon_{i,t}^p \]

**“Lending” Block**

\[ \Delta l_{i,t} = \xi_i + \lambda \cdot \Delta l_{i,t-1} + \delta_1 \cdot \Delta y_{i,t-1} + \delta_2 \cdot \Delta y_{i,t-2} + \ldots + \rho_1 \cdot \Delta x_{i,t-1} + \ldots + \epsilon_{i,t}^l \]
In Our Framework …
algorithmic quarter-by-quarter approach

Step 1: obtain \( y_{1} \) 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

\[
k_{i,1} = \frac{\text{Capital}_{i,1}}{\text{RWA}_{i,1}} = \frac{\text{Capital}_{i,0} - \text{Credit and other losses}_{i,1}}{\text{RWA}_{i,1}}
\]

\( x_{i,1}, X_{i,1} \)

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

A Structural Approach using Agent Based Modeling¹
(Laura Valderrama)

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)
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

Suites to policy simulations
  - Macrophyudential policy (regulatory constraints)
  - Banking sector structure (competition)
Ingredients

- Balance Sheet Optimization
- Cournot Nash Equilibrium
- Pro-Cyclical Leverage
- Basel III regulation
  - credit risk
  - market risk
  - liquidity risk
- Endogenous Fire Sales
- Macro feedback
  - Credit growth
  - GDP growth

Macro feedback
- Credit growth
- GDP growth
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
At each time step, banks optimize their balance sheet.

Implications for credit risk, asset volatility, capital buffers, credit growth, GDP growth
Credit allocation

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

\[
\text{Max}_{c_i^j} \sum_{s=1}^{w} \left( i_i - i_d \left( 1 - \text{cap}_i \right) - \text{ROE} \cdot \text{cap}_i \right) \cdot c_i^j - \frac{PD_t \cdot LGD \cdot c_i^j}{(1 + \text{ROE})^w}
\]

**Balance sheet capacity**

\[
s.t. \quad c_i^j + c_{s-1} \cdot \delta + Q_t \cdot p_i \leq K_t(c_i^j) \cdot \mu_i^{\text{max}}
\]

**Basel III Regulation**

\[
cap_i = f\left( PD_t\left( c_i^j, \sum_{j \neq i} c_i^j, g_t\left( c_i^j, \sum_{j \neq i} c_i^j \right) \right) \right)
\]

\[
Q_t^b \cdot p_i \geq \text{runoff}_t \cdot D_t\left( K_t(c_i^j) \right)
\]

\[
\mu_i^{\text{max}} = \frac{\mu_i^{\text{max}} + \varepsilon_i^t}{1 + \kappa \cdot \sigma_t^2(c_i^j, p_i)}
\]
GDP shock

**Bank Solvency**

(Percent)

- **CAR**
- **CAR min**

**Real Effects**

(Percent)

- **Capital Shortfall/GDP**
- **Real GDP - Deviation from Baseline**

- 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)
Assets = Equity + Risky Debt

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

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

• Value of liabilities derived from value of assets
• Uncertainty in asset value
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.
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*.
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).*
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


See Annex slides for more information and example outputs from CCA GVAR model.
Approach 5: Integrated Solvency and Liquidity Models

**Purpose**

- 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 Part I


REFERENCES Part II

REFERENCES Part III – Contingent Claims Analysis Applications


## Annex Slides Part II: Structural Approach Agent-Based Modeling

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

- **Macroprudential Policy**
  - **Bank Solvency**
    - **Funding Constraints**
      - **Credit Risk**
        - **Market Risk**
          - **Credit, securities allocation**

- **Endogenous Process**
  - **Highly Non-Linear**

- **Real Economy**

- **Credit, securities allocation**
  - **Evolves with credit growth (lending standards) and GDP growth (income gearing)**
  - **Evolves with market price of securities (mark-to-market) and asset volatility (Value-at-Risk)**
  - **Credit frictions**

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

- **Banking regulation**
  - **Banking concentration**

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

$$FVCDS = -\frac{1}{T} \ln \left( 1 - \text{LGD}_{\text{Banking Sector}} \times EDF_{Risk-Neutral} \right)$$

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

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
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