Measuring and Monitoring Financial Systemic Risk

Presentation to G-20 Conference on “Financial Systemic Risk” September 27-28 2012

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The views expressed in this presentation are those of the authors and should not be attributed to the International Monetary Fund, its Executive Board, or its management.
Outline of Presentation

I. Systemic Risk Monitoring

II. Information Sources and a Taxonomy of Systemic Risk Models

III. Using Contingent Claims Analysis (CCA) for Financial, and Sovereign, Systemic Risk Analysis
A PRACTICAL APPROACH TO SYSTEMIC RISK MONITORING*
– IMF Monetary and Capital Markets Department

Motivation:

Need to know *when to act*

No magic bullet (single model) to monitor SR

Many tools/approaches developed over time (~60-70), but only some suitable for Systemic Risk Monitoring

Increasing need to make the toolkit understandable and usable

A practical user guide (not an academic survey)

- Which best tools and combinations of tools
- For which types of risks?
- In which country categories?
- For measuring which phase of risk—early warning, impact of crisis, amplification

*Systemic Risk Monitoring Report will be published in October 2012; it was prepared by IMF MCM staff—Nicolas Blancher, Srobona Mitra, Hanan Morsy, Akira Otani, Tiago Severo and Laura Valderrama.
21 different tools mapped to six key questions

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<th>Key Questions</th>
<th>2-page templates to describe each tool:</th>
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<td>What is the Probability of a Systemic Crisis?</td>
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Toolkit Coverage:

- Types of risks: credit, liquidity, market risks;
- Types of tools: single risk indicators, macro-financial, network, market-based, hybrid and structural models;
- Impact of shocks;
- Long-term build up in balance sheet vulnerabilities;
- Spillovers across financial entities, especially using high-frequency market price-based tools;
- Cross border contagion between banking systems.
Key Findings: How to Use Tools

A combination of tools should be used

The selection of tools is country-specific

Tools for different phases in systemic risk:

- The slow buildup of risk (e.g., through combinations of balance-sheet and slow-moving indicators).

- The identification of weak points and potential adverse shocks (e.g., stress tests to detect weak financial institutions, asset price deviation from fundamentals).

- The fast unfolding of crisis, including through amplification mechanisms (e.g., high frequency market-based spillover measures).

Longstanding data gaps remain an obstacle
Key Findings: Limitations

Early warning. The forward-looking properties of systemic risk measures are generally weak, even though some measures appear relatively promising.

Thresholds. More work needed on clear and reliable signals indicating when “to worry” and take action.

System’s behavior. The capacity to model aggregate agent behaviors is limited, for instance as regards how banks internalize the materialization or increasing likelihood of systemic risk; potential reverse feedbacks and multi-round effects (i.e., “perfect storms”); and, nonlinear risk correlations during periods of financial distress.

(See summary of tools: coverage, inputs, outputs, applicability, bibliography in Appendix to this presentation)
II. Information Inputs; Towards a Taxonomy of Risk Models

Risk models use Different Sources of Information:

- Accounting balance sheet information
- Equity market (levels, returns, option prices)
- Bond and CDS spreads
- Interbank network linkages
- Exposure data
- Value-at-Risk
- Other
Relationships between Risk Models for Individual Institutions Using Accounting and Market Information

**Accounting Balance Sheet**
- Traditional Balance Sheet Indicators
- Contingent Claims Analysis (CCA); MKMV
- Advanced CCA - with Govt contingent liabilities
- CDS/spread implied PoD

**Market Equity-based**
- Equity levels and returns,
- Equity option implied volatility and skew
- Distress Insurance Premium

**Market Debt-based**
- CDS or Bond implied Probability of Default (PoD)
- (CDS & bond spreads)
Systemic Risk Models for Multiple Entities

- **Accounting Balance Sheet**
  - Aggregate FSIs

- **Systemic CCA**
  - CDS/spread implied JPoD
  - CDS CoRisk
  - CDS –Joint Probability of Distress (CoPoD, BSI)

- **Market Debt-based**
  - (CDS & bond spreads)

- **Market Equity-based**
  - Equity Joint Tail Risk (from returns- SES and MES)
  - Equity option implied joint risk

- **Network**
  - Interbank Exposures
  - Lo –Sherman model

The diagram illustrates various models for systemic risk, including accounting balance sheet, systemic CCA, market debt-based, and market equity-based approaches. Each approach is connected to different risk measures and methodologies. The diagram highlights the interconnections and overlaps between these models, reflecting the complex nature of systemic risk assessment in the financial industry.
III. Using Contingent Claims Analysis (CCA) for Financial, and Sovereign, Systemic Risk Analysis

Core Concept of Contingent Claims Analysis (CCA): Merton Model

Assets = Equity or Jr Claims

Assets = Equity + Risky Debt

Assets = Equity + Default-Free Debt – Expected Loss

Assets = Implicit Call Option + Default-Free Debt – Implicit Put Option

• Value of liabilities derived from value of assets.
• Liabilities have different seniority.
• Randomness in asset value.
CCA is Generalization of Black, Scholes, Merton Option Pricing Theory

- Liabilities derive their value from assets;
- Asset value is stochastic, changes in future asset value, relative to the promised payments on debt are the driver of forward-looking values of equity and risky debt;
- Risky debt is default-free debt value minus the expected loss value (ELV) due to default;
- It helps explain complex risk transmission and amplifications;
- If volatility is set to zero, result is the accounting balance sheet, default/credit risk measure is lost.
CCA Framework has Several Benefits

Tools and techniques for calibrating CCA balance sheets of corporates and financial institutions are decades old. Commercial and academic daily models available.

CCA is useful for modeling bank funding cost and can account for government guarantee impacts on bank funding cost or spillovers from high sovereign spreads.

Combining individual institution expected losses into system-wide joint expected losses is useful for analysis of financial systemic risk, government contingent liabilities, sovereign risk interactions and frequently leads GDP.
Key CCA Risk Indicators for Financial Institutions

Expected Default Frequency (EDF, 1 yr in %)

Expected Loss Value (ELV=implicit put option value $)

Expected Loss Ratio (EL, in basis points)
\[ E \text{L}V/\text{Default Barrier}=\text{RNDP} \times \text{LGD}_{\text{sector}} \]

Fair Value Spread (in basis points)
\[ \text{FV Spread}=-(1/T) \times \ln(1-\text{EL}) \]

Ratio of Market Capitalization/Assets
(CCA Capital Ratio, in %)
Typical Bank – Non-linear Relationships Between CCA Capital Ratio, EL, EDF and Fair-Value Spreads

Low Risk Zone: CCACR>2.5%, EDF<1.5%, EL<1800 bps, FVSpread<380 bps

Based on Moody’s KMV CreditEdge data and IMF calculations
CCA provides Estimates of “Market-Implied” Government Contingent Liability (Citigroup example 2007-2011)

CCA-based FV credit spreads greater than observed CDS spreads (in bps)

Estimated “market implied" government contingent liability (billion US $)
Systemic CCA: Measuring And Stress Testing
Financial Sector Tail-risk Losses and Contingent Liabilities

Beginning with CCA models of individual banks, expected losses and market implied 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 dependence

(iii) measures of financial sector tail risk (95% VaR or Expected Shortfall)

(iv) macro-factor model linked to CCA to stress test systemic tail risk.

(See Gray and Jobst 2009, 2010, 2011, and forthcoming)
Extreme Tail Risk – US Financial System -Joint Total Expected Loss Value including dependence structure, 36 largest US financial institutions, 95th percentile

Just after Lehman there was a 5% chance of $3 trillion losses in financial system over a one year horizon!
Extreme Tail Risk – US Government Contingent Liabilities including dependence structure, 36 largest financial institutions, 95th percentile

(Contributions of individual institutions can also be measured.)
Systemic CCA Shows Nonlinearities of Asset Volatility, Market Capital/Assets, Fair Value Credit Spreads, and Joint Losses – for individual institutions and for the system as a whole (illustrated below)

Jobst and Gray (2012)
Spillovers from the Sovereign to the Banks and Banks to Sovereigns

**DOMESTIC**

- A. Mark-to-market fall in value of govt bonds held by local banks
- B. Increase in bank funding costs
- C. Erosion in potential for official support
- E. Similar sovereigns come under pressure
- I. Increase in contingent liabilities of govt.

**FOREIGN**

- D. Mark-to-market fall in value of govt. bonds held by foreign banks
- F. Contagion channels (A, B, & C as above)
- G. Rise in counter-party credit risk
- H. Withdrawal of funding for risky banks
- I. Increase in contingent liabilities of govt.
Measuring Bank, Sovereign, Corporate, Macro, Risk Spillovers in EU Using CCA-GVAR Framework

(Ongoing joint work with three ECB staff (Marco Gross, Matthias Sydow, and Joan Paredes); Forthcoming Working Paper)

Framework for analysis the interactions of banking sector risk, sovereign risk, GDP growth, stock markets, and other macro variable for 15 EU countries plus the US.

Uses CCA risk indicators (EL) for the banking systems and corporate sectors and sovereigns in each country,

Together with the GVAR (Global Vector Autoregression) model for each country, and weight matrices, impulse responses captures the non-linearity of changes in bank assets, equity capital, bank credit spreads, sovereign spreads and corporate credit risk.
Inputs and Scenarios/shock origins and Generalized Impulse Responses (GIRs) for Banks, Sovereign, Corporates, GDP, etc.)

CCA bank by bank risk indicators (63)

CCA sovereign credit risk indicators (16)

CCA corporate credit risk indicators (16)

GDP data (16 series)

Stock market index (16)

Other

CCA banking system risk indicators (16)

Scenarios and Shock Origins

Copula Simulation

GVAR Model (16 local country models)

Weighting Matrices

EL (l) and CDS (r) SOVEREIGNS

EL (l) and CDS (r) BANKS

EL (l) and CDS (r) CORPORATE

GDP
Scenario responses are fed into banking, sovereign, corporate modules to get secondary outputs.

**Scenario Responses**
- GDP growth IRs
- Stock market IRs
- Banking system IRs
- Corporate sector IRs
- Sovereign IRs

**Banking Module**
Banking system responses (ELs and spreads)
Bank by bank output results:
- Funding cost impacts
- Expected Losses
- Implied market capital impact
- Government contingent liabilities

**Corporate Module**
Corporate output results:
- Expected Losses
- Credit Spreads

**Sovereign Module**
Sovereign output results:
- Expected Losses
- Credit Spreads
- Other

**EU and Euro Zone**
Aggregate banking and sovereign debt expected losses
Aggregate bank capital impact

**Fiscal and Growth Module**
- Contingent liabilities
- Borrowing cost changes
- Debt to GDP changes
Ongoing Work: CCA-GVAR Risk Exposure Outputs Facilitate Analysis of a Range Risk Mitigation Policy Options to get to ‘Low Risk Zone’

- **Banks:**
  - Increase bank capital → higher assets, lower expected losses
  - Debt-to-equity conversion → lower default barrier, higher equity
  - Guarantees on bank debt → lower bank borrowing costs
  - Ring-fenced asset guarantees → Lower asset volatility

- **Sovereigns:**
  - Increase debt maturity → lower spreads
  - Fiscal adjustment → higher sovereign assets

- **Supranational:**
  - Sovereign debt purchases/guarantees by public entity (ECB, EFSF, ESM, other) → lower sovereign spreads
  - Other Monetary Policy OMT/QE purchases → lower spreads, higher GDP growth
Thank you

(Contact information: Dgray@imf.org)

Appendix

Systemic Risk Monitoring Tools and Bibliography

References for CCA/Systemic Risk Models
# Summary of tools for Systemic Risk Monitoring

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**Notes:**
- **Y** indicates applicability.
- **N** indicates non-applicability.
- **Limited** indicates limited applicability.
- **Early Warning** and **Impact of crisis** indicate whether the tool is used for early warning or impact analysis.
- **Amplification** indicates whether the tool amplifies the risk.

**Questions:**
- **CoVaR**: Does it amplify risk?
- **CoPoD/BSI**: Does it amplify risk?
- **Volatility Spillovers**: Does it amplify risk?
- **Distress Spillovers**: Does it amplify risk?
- **Market-Based Probability of Default**: Does it amplify risk?
- **Probability of Default**: Does it amplify risk?
- **DSA**: Does it amplify risk?
- **Asset Price**: Does it amplify risk?
- **Balance Sheet Analysis**: Does it amplify risk?
- **Systemic CCA**: Does it amplify risk?
- **Cross-Border Interconectedness**: Does it amplify risk?
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Bibliography of Models and Tools for Systemic Risk Monitoring

Adrian, Tobias and Markus Brunnermeier, 2010, “CoVaR,” Federal Reserve Bank of New York Staff Reports.


Bibliography (cont’d)


Bibliography (cont’d)


References on Macrofinancial risk and CCA:


Macrofinancial Risk Analysis

- Framework integrates risk-adjusted balance sheets using Contingent Claims Analysis (CCA) of financial institutions, corporates, and sovereigns together and with macroeconomic and monetary policy models

- TOOLKIT FOR MACRO RISK ANALYSIS