A Framework to Analyze the Sovereign Credit Risk Exposure of Financial Institutions

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Motivation

• Evaluate the nexus between sovereign debt sustainability and the stability of the financial sector.
  – Is there any relationship between the sustainability of a country’s debt profile and the stability of the financial sector?
  – Can we systematically measure the exposure of the banking system to an implicit or explicit default on sovereign debt?
Research Objectives

• Develop integrated model of debt dynamics and the stability of the financial sector

• Use model to explore the impact of shocks to the macro economy on the stability of the financial sector

• Evaluate impact of such shocks on the credit risk exposure of the financial sector
The relationship between banking fragility and government fragility... arises because the operations of both entities are intricately intertwined...
What we already know from the data...
Fragility measures (the risk of insolvency) can be derived for both banks and governments using Contingent Claims Analysis (CCA) techniques.

We can evaluate this relationship over time by evaluating scatterplots of the relative fragility of banks and the relative fragility of the government over time.

The assessment can lead to some interesting results... when we evaluate monthly data for the Government of Jamaica (GOJ) and the aggregate banking system in Jamaica for a ten year period as we will soon see....
Fragility of the Banking Sector

- Strong Banks but Weak Government
- Weak Government and Weak Banks
- Strong Government but Weak Banks
- Macro-Financial Stability
Between 2000 and 2010 both the banking system and the Government of Jamaica have experienced both relative stability as well as periods of “joint-heightened fragility”
But how does an economic system transition from relative stability into a "crisis-mode" of operation?
To evaluate this we must understand how shocks are transmitted within the economic system.

To do this we will need a structural macro-financial risk model.
Scope of the Framework

The systemic risk cube:

Source: de Bandt, Hartmann and Peydró (2009) and ECB (2010a)
The framework allows for the assessment of contagion and spill-over risks, the endogenous build-up and unravelling of widespread imbalances using a macro-stress testing approach. It does not focus on idiosyncratic risks.
The Methodology (General)

• **Focus of analysis:** Extreme Outcomes
• **Forecast Technique:** Simulation with stress tests
• **Simulation Methodology:** System Dynamics
• **Calibration Techniques:** Monte-Carlo Techniques, Logistic Regressions, Expert Judgement
Method of Analysis: Results
Twin Sovereign Debt and Banking Crisis (Reference Modes)

Sovereign: $PD > PD^*$

Banking Sector: Credit Exposure $> \text{Capital}$
Stress Testing Framework

Dynamic Behavioural Risk Model

Stress Test Scenario -> Data generating Process -> Exposure and Risk Measures
Interaction between each Agent

Backward Looking – Boundedly Rational

Government Sector

Rating Agency assesses Gov’t performance
Rating Impact Debt Raising Activities

Credit Rating Agency
Output of Rating Agency Informs Credit Risk Exposure of Banks

Financial Sector

Both Gov’t and Banks Interact via Domestic and Int’l Capital Mkt's

Forward Looking – Perfect Foresight
Key Decisions for each Agent

• Government Agent – How do I finance my activities?

• Credit Rating Agent – How do I assign a rating score to reflect capacity of government to repay its obligations?

• Banking Agent – How do I invest customer deposits in loans and government securities?
And now... some equations!!!
Credit Rating Agent
Indicators of Debt Servicing Capacity

- Total debt to GNP ratio \((EDTGNP)\) \((+ve)\)
- Reserves to Debt stock ratio \((RESEDT)\) \((-ve)\)

- Net government deficit to GNP ratio \((DEFGNP)\) \((+ve)\)
- Interest payments to exports ratio \((INTXGS)\) \((+ve)\)

- Past episodes of default \((SIG)\) \((+ve)\)

Solvency Measures

Liquidity Measures

Reputational Risk Measure

\[ PD = f(EDTGNP, INTXGS, RESEDT, DEFGNP, SIG) \] (1)
Argentina
Which is evaluated by estimating using a logistic regression:

\[
PD_{(t+1)} = \frac{EXP(C+Xb)}{1+EXP(C+Xb)}
\]  (2)

where \(C\) is a constant and \(Xb\) represents the linear combination of each ratio and its corresponding weight \((w_i's)\) placed on each ratio evaluated by the Credit Rating Agent.
Logistic Regression Results

• There are 106 sovereign default episodes which is 20.7 per cent of the sample.

• On average countries that default have external debt to gni ratios of 68.0 per cent, external interest expense of 17.0 per cent, very high likelihood of having default in the past 3 years (76.0 per cent) and reserves to external debt of 18.0 per cent.

• On average countries that do not default have debt to gni ratios of 55.0 per cent, external interest expense to exports of 11.0 per cent, low likelihood of having defaulted in the previous 3 years (25.0 per cent) and reserves to external debt of 25.0 per cent.

• The default threshold (P*) is chosen in such a way as to minimize the incidence of both Type 1 and Type 2 errors.

• The probability default threshold of 15.0 per cent probability such that the probability of a Type 1 error (rejecting the truth - missed crisis) is 22.6 per cent and the probability of a Type 2 error (accepting the false - false alarm) 25.9 per cent.
The Banking Agent
Banking Agent Investment Decision Rules

\[ GS_j = GS_j(0) + \int_0^t AGS_j(s) - MGS_j(s) - SWR_j(s) \, ds \quad j \in e, i \]  

where

\[ GS_j(0) = \text{the initial holding of securities}, \quad AGS_j(s) = \text{the rate of acquisition of new government securities}, \quad MGS_j(s) = \text{the rate at which existing securities mature and} \]

\[ SWR_j(s) = \text{the write-off rate of government securities} \]

\[ AGS(t) = (TGS(t) - GS_i(t))/tags_i \]  

The banking agent rebalances its portfolio towards its target holdings \((TGS(t))\) until the target growth rate, \(g^*\), is reached over the period, \(tags_i\).

\[ TGS(t) = f(g^*(t)) = g(TPPC, THRC, TPT, PD, DDF) \]  

\[ g^*(t) = g(i) \times \rho_1(PD_{t+1}) \times \chi(DDF) \]  

where \(\rho_1(PD_{t+1}) < 0\) and \(\chi'(DDF) > 0\).
The transfer of funds ($TRA(s)$) into the capital base of the agent is governed by a decision rule that adjusts the existing capital base ($CAP$) towards a target regulatory required capital base ($TCAP$).

$$TCAP = rwa \, \gamma_1(\pi) \, LN$$  \hspace{1cm} (8)

where

- $rwa = \text{risk weighted assets}$,
- $\gamma_1(\pi) = \text{reaction to profitability}$,
- $LN = \text{stock of loans}$

and $\gamma'_1(\pi) > 0$
Banking Agent Decision Rules governing Write-offs:

**Condition 1**

\[ SWR_j = IF(PD > PD^*, CLPE_j, 0) \]; where \( CLPE_j = GS_j \times LGD \)  

where

\( SWR_j \) = write-off government securities, \( PD^* \) = Threshold Probability of Default  
\( GS_j \) = Government Securities; \( LGD \) = Loss Given Default

**Condition 2**

\[ LWR(s) = pswr(t) \times \rho_3(PD) \times \omega_1(\text{ir}_{LN(t)}) \]  

where

\( LWR(s) \) = Loan Write-off Rates; \( pswr = \) Private Sector Credit Default Rate;  \( \text{ir}_{LN(t)} = \) interest rates on loans

where \( \rho_3(PD) > 0 \) and \( \omega_1(\text{ir}_{LN(t)}) > 0 \)
The Government Agent
Government Agent Decision Rules
governing Borrowing:

The government agent continues to adjust its borrowing requirement until the
difference between its target cash balance (DGCB) equates with its cash balances (GCB)
over the period, dft.

\[
DDF = \text{MAX}[0, (DGCB - GCB)]/dft \quad (11)
\]

The agent defines its cash needs as a function of its average historical expenditure
rate, a coverage period for the funds (gcbct) and as a function of the profitability of
the banking sector, \( \omega(\pi) \).

\[
DGCB = (\overline{MGS}(t) + \overline{IREP}(t) + \overline{PSW}(t)) \times \text{gcbct} \times \omega(\pi) \quad (12)
\]

The government’s cash balance will therefore be increasing in tax revenues and
borrowing and decreasing in expenditures and debt servicing.

\[
GCB = GCB(i) + \int_0^t REV(s) + DR(s) - EXP(s) - DSP(s) \, ds \quad (13)
\]

\[
DR = DDF(t) \times \rho_5(PD_{t+1}) \times \psi_1(TDS) \quad \text{where } \rho'_5(PD_{t+1}) < 0, \psi'_1(TDS) < 0. \quad (14)
\]
This formulation is capable of capturing behaviour over time observed in the data.

Persistent fiscal deficit performances versus projections....
The Financial Market
The Impact of the Sovereign Bond Market

**Interest Rates**

\[
ir_e = ir_i \rho_4(PD) \tau_1(FP); \quad ir_i = (ir_e + \theta) \rho_5(PD) \tau_2(FP)
\]  

(14)

where

- \( ir_e \) is the initial external interest rate,
- \( ir_i \) is the initial domestic interest rate,
- \( \theta \) is the foreign exchange risk premium,
- \( \rho_4,5(PD) > 0 \) and \( \tau_1,2(FP) > 0 \)

**Maturity Profile**

\[
ADM_e = MGS_e \rho_6(PD) \tau_3(FP); \quad ADM_i = MGS_i \rho_7(PD) \tau_4(FP)
\]  

(15)

where

- \( MGS_e \) = Average Maturity of External Bonds, \( ADM_i \) = Average Maturity of Domestic Bonds, and \( \rho_6,7(PD) < 0, \ \tau_3,4(FP) < 0 \).
The Impact of the Sovereign Bond Market
(Cont’d)

The currency composition of the debt financing acquired by the government agent will be determined as a function of an initial ratio of domestic debt financing, $irho$, the total supply of debt raised by the government agent ($CFR$) and the impact of the credit risk exposure of the government agent.

Quantum of Funds Raised Domestically

\[ DR_i = irho \rho_8(PD) CFR \quad (16) \quad \rho'_8(PD) < 0 \]

where

$irho$ is the initial proportion of funds raised domestically, $\rho_8(PD) = \text{impact of credit rating on proportion}$, and $CFR = \text{total supply of funds to finance government activity}$

Quantum of Funds Raised Externally

\[ DR_e(t) = (1 - irho) \rho_8(PD) CFR \quad (17) \]
Stress Testing Framework
The Application
Univariate Stress Tests
Specification of Univariate Shocks

Each shock is implemented at the beginning of 2007 and the impact on macro-financial stability is evaluated for the four year period up to 2011.

1. **Foreign Exchange Rate Shock**: involves an increase in the rate of depreciation to 10.0 per cent per year for a period of one year.

2. **Reserves Shock**: rapid loss in the net international reserves (NIR) of the sovereign nation of US$0.5 billion for a period of one year starting at the beginning of 2007 and then declines by US$0.7 billion for the following year.

3. **Exports Shock**: significant decline in exports of US$2.0 billion for a period of one year starting 2007. As a result export earnings decline to US$3.7 billion in 2007.

4. **External Interest Rate Shock**: an increase in external interest rates for a period of one and half years at the start of 2007. External interest rates on bonds peak at 11.0 per cent by mid-2007.
Exploration of Findings of the Univariate Shocks
Simulated Impact of Univariate Stress Tests on the Probability of Sovereign Default
Simulated Impact of Univariate Stress Tests on the Sovereign Credit Loss Exposure to Capital Base of the Banking System

![Graph showing the simulated impact of stress tests on capital base over time.](graph.png)
Multivariate Stress Tests
(Simulated Crisis)
Impact of Global Financial Crisis on Jamaica

The stylized simulated shocks are calibrated as follows:

1. **External Interest Rate Shock**: increase in the indicated external interest rate by 15.0 per cent in 2007.

2. **Foreign Exchange Rate Shock**: increase in the rate of depreciation in the foreign exchange rate to 18.0 per cent in 2008 for one year.

3. **Reserves Shock**: decline in the net international reserves (NIR) of 11.0 per cent and 22.0 per cent in 2008 and 2009, respectively.

4. **Exports Shock**: reduction in the exports of goods and services of 27.0 per cent in 2009.

5. **Fiscal Shock**: increase in the rate of employment of public sector workers to 8.0 per cent in 2007.
Exploration of Findings of the Dynamic Simulation Framework
Simulated Impact of the Global Financial Crisis on Macro-Financial Stability in Jamaica as measured by the Probability of Sovereign Default

![Graph showing Sovereign Default Probability (PD t+1) over time from 2006 to 2013. The graph compares baseline, simulated crisis, and default threshold scenarios.](image-url)
Simulated Impact of the Global Financial Crisis on Macro-Financial Stability in Jamaica as measured by Bank Capital Adequacy

Bank Regulatory Capital - Leverage Ratio

Baseline Per cent
Simulated Crisis Per cent
Simulated Twin Default

Sovereign Default Probability (PD t+1)

Bank Regulatory Capital - Leverage Ratio

Baseline
Simulated Crisis
Default Threshold

Time (Year)

Per cent
Fragility of the Banking Sector

Fragility of the Government Sector

High Fragility

Low Fragility

Macro-Financial Stability
What generates these results?
There are powerful self-reinforcing feedbacks at play in a ‘twin-crisis’

*Dynamic Behavioural Risk Model*
There are powerful self-reinforcing feedbacks at play in a ‘twin-crisis’.
Other Insights from the Framework

In the face of unanticipated shocks and heightened uncertainty

• The standard ways that banks attempt to protect themselves from increasing risk can create more risk for the entire financial system.

• Highly indebted Governments which attempt to run counter-cyclical fiscal policy to *offset* the impact of the crisis can instead exacerbate and intensify the impact of the crisis.
Insights from the Published Paper

• The importance of feedback in capturing low-frequency high-impact crises
• Comparing output of model to standard concentration risk stress-testing frameworks
• More information on calibration of model to the data

Thank you
Any Questions?
Useful References


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