The views expressed in this presentation are our own and do not necessarily reflect those of the Board of Governors of the Federal Reserve System
Motivation

- Recent wave of financial crises has put financial stability at the forefront of policy discussions

- Need for models that can account for financial crises, and that can be used for analysis of financial stability policies

- A desirable feature of such models is that they be consistent with key stylized facts regarding financial crises

- Two salient facts:
  1. Characterized by strongly non-linear dynamics
  2. Often preceded by credit booms
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Corporate Spread (%)
Figure 2: Excess Bond Premium (EBP), Economic Growth, and the Labor Market

Note: The left (right) chart in the middle panel depicts the relationship between year-ahead 4-quarter real GDP growth and negative (positive) quarterly changes in the EBP in quarter t. The left (right) chart in the bottom panel depicts the relationship between year-ahead 4-quarter change in the unemployment rate and negative (positive) quarterly changes in the EBP in quarter t.

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Domestic Bank Credit (% of GDP)

Emerging Economy Banking Crises Events

Events included: 1997 banking crises in Indonesia, Korea, Malaysia, Thailand, the Philippines; and 1994 banking crises in Mexico. Event definition is from Laeven and Valencia (2010).

Advanced Economy Banking Crises Events

Events included: 2008 banking crises in Austria, Belgium, Denmark, France, Germany, Greece, Iceland, Ireland, Netherlands, Portugal, Spain, Switzerland; 2007 banking crises in the UK and the US; and 1991 banking crises in Norway and Sweden. Event definition is from Laeven and Valencia (2010).
Credit Boom-Bust Events

Panel A. Domestic credit (percent of GDP)

Graphs by region and crisis type

Crisis year + T

Source: Gourinchas and Obstfeld (2011)
Foreign Borrowing and EME Financial Crises

Events included: 1997 Financial Crises in Korea, Indonesia, Malaysia, Thailand and Philippines.
Objective

- Develop a macroeconomic model with financial intermediaries, consistent with these two facts
- Use the model for analysis of financial stability policies
What We Do

- Develop a SOE model in which banks’ balance sheet constraints are occasionally binding, and in which banks raise equity endogenously.
  - Balance sheet constraints arise endogenously due to an agency problem, as in Gertler and Kiyotaki (2010).

- Unlike GK:
  - Banks may or may not be credit constrained.
  - Strength of banks’ balance sheets reflects not only the accumulation of retained earnings, but also banks’ endogenous decision for equity issuance.
What We Do (cont’d)

- Illustrate quantitative properties of the model
  - Constraint induces nonlinearity and state-dependence in the economy’s response to shocks
  - Model generates endogenous state-dependent probabilities of future financial crises
  - Low country interest rates lead to a credit boom and to increased probability of a financial crisis, consistent with the data
  - Model produces infrequent financial crises with features consistent with crises in the EMEs and AEs

- Use the model for analysis of macroprudential policy
Related Literature

- Financial Accelerator models with or w/o financial intermediaries

- Non-linear macro models featuring systemic risk
Model
Model

- Foreign Banks
- Domestic Households
- Agency problem
- Banks
- Nonfinancial Firms

The diagram illustrates the relationships between foreign banks, banks, and nonfinancial firms, with domestic households and an agency problem linking these entities.
Households

- Within each household, $1 - f$ “workers” and $f$ “bankers”.

- Workers supply labor and return wages to the household.

- Each banker manages a financial intermediary and also transfers earnings back to the household.

- Perfect consumption insurance within the family.

- Bankers have finite survival probability $\sigma$ (average survival time $\frac{1}{1-\sigma}$). Starting bankers receive startup transfer equal to fraction $\xi$ of previous period assets.
Households: Objective

\[ \text{Max} \quad \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \frac{\left( C_t - \chi \frac{L_t^{1+\epsilon}}{1+\epsilon} \right)^{1-\gamma} - 1}{1 - \gamma} \]

subject to

\[ C_t + B_t \leq W_t L_t + R_{t-1} B_{t-1} + \Pi_t \]

where

- \( B_t \) short term bonds (intermediary deposits and government debt)
- \( \Pi_t \) payouts to the household from firm ownership net the transfer it gives to its new bankers
Banks: Period-\(t\) Timeline

- Beginning-of-period net worth \(n_t\)
- \(Q_t s_t \leq n_t + d_t\)

- \(\theta Q_t s_t\) (\& exit)

- Exit shock realized

- Survive (prob. \(\sigma\))
  - Raise equity \(e_t\)
  - Pay cost \(C(e_t, Q_t s_t)\)

- Exit (prob. \(1 - \sigma\))

- Pay household \(R_{K,t+1} Q_t s_t - R d_t\)

\[ n_{t+1} = R_{K,t+1} Q_t s_t - R d_t + e_t \]
Banks: Balance Sheet and Net Worth

- Balance Sheet

\[ Q_t s_t \leq n_t + d_t \]

where

\[ d_t = b_t + b_t^* \]

- Evolution of Net worth

- Surviving Banks: \[ n_t = R_{K,t} Q_{t-1} s_{t-1} - R_{t-1} d_{t-1} + e_{t-1} \]

- Exiting Banks: \[ n_t = R_{K,t} Q_{t-1} s_{t-1} - R_{t-1} d_{t-1} \]
Banks: Agency Problem

- After the banker/intermediary borrows funds at the end of period $t$, it may divert a fraction $\theta$ of assets back to its family.

- If the bank does not honor its debt, creditors can liquidate it and obtain the remaining of assets they initially funded.

- Banks’ incentive constraint: $V_t \geq \theta Q_t s_t$
Banks: Objective

\[ V_t(n_t) = \max_{s_t, d_t, e_t} (1-\sigma)\mathbb{E}_t (\Lambda_{t,t+1} \bar{n}_{t+1}) + \sigma \{ \mathbb{E}_t \Lambda_{t,t+1} [V_{t+1}(n_{t+1}) - e_t] - C(e_t, Q_t s_t) \} \]

subject to

\[ Q_t s_t \leq n_t + d_t \]

\[ n_{t+1} = R_{K,t+1} Q_t s_t - R_t d_t + e_t \]

\[ V_t(n_t) \geq \theta Q_t s_t \]

where \( \Lambda_{t,\tau} \equiv \) household’s stochastic discount factor

and \( \bar{n}_t = R_{K,t} Q_{t-1} s_{t-1} - R_{t-1} d_{t-1} \)
Bank: Value Function

One can show

\[ V_t(n_t) = \mu_{K,t} Q_t s_t + \nu_t n_t + \sigma [\nu_{e,t} e_t - C(e_t, Q_t s_t)] \]

with

\[ \mu_{K,t} = \mathbb{E}_t [\Lambda_{t,t+1} \Omega_{t+1} (R_{K,t+1} - R_t)] \]
\[ \nu_t = \mathbb{E}_t [\Lambda_{t,t+1} \Omega_{t+1}] R_t \]
\[ \nu_{e,t} = \mathbb{E}_t [\Lambda_{t,t+1} (\alpha_{t+1} - 1)] \]

where \( \Omega_{t+1} \) is the shadow value of a unit of net worth at \( t + 1 \):

\[ \Omega_{t+1} = (1 - \sigma) + \sigma \alpha_{t+1} \]
\[ \alpha_{t+1} = V'_{t+1}(n_{t+1}) \]
Define $x_t \equiv \frac{e_t}{Q_t s_t}$.

The equity cost:

$$C(e_t, Q_t S_t) = c(x_t) Q_t s_t$$

$$c(x_t) = \frac{\kappa}{2} x_t^2$$

Optimality condition for new equity issuance:

$$\nu_{e,t} = \kappa x_t$$
Banks: Credit Spreads

- The value function becomes

\[ V_t(n_t) = \mu_t Q_t s_t + \nu_t n_t \]

where \( \mu_t \equiv \mu_{K,t} + \sigma \frac{k}{2} x_t^2 \) is the “total” excess return on assets.

- When the constraint does not bind, \( \mu_t = 0 \).

- When the constraint binds, \( \mu_t > 0 \).
Banks: Binding Incentive Constraint

- Re-writing Incentive Constraint:

\[ \mu_t Q_t s_t + \nu_t n_t = \theta Q_t s_t \]

- Endogenous Leverage Constraint:

\[ Q_t s_t = \phi_t n_t \]

with

\[ \phi_t = \frac{\nu_t}{\theta - \mu_t} \]

- Maximum Leverage Ratio = \( \phi_t \)
Banks: Normal Times vs Financial Crises

- In normal times,
  - $\mathbb{E}_t (R_{K,t+1} - R_t)$ small
  - Banks are unconstrained
  - New equity issuance is low
  - Behavior of the economy is similar to frictionless neoclassical environment

- In a financial crisis,
  - $\mathbb{E}_t (R_{K,t+1} - R_t) \uparrow \uparrow$
  - Banks’ Incentive Constraints bind
  - Nonlinear financial accelerator effect: with constraint binding, $\downarrow N \rightarrow \downarrow I$ and $Q \rightarrow \downarrow N$
SOE pays a small debt-elastic interest rate premium, following SGU (2003).

\[ R_t = \frac{1}{\beta} + \varphi (e^{B_t^*} - \bar{b} - 1) + e^{R_t^* - 1} - 1 \]

where \( R_t^* \) is the country interest rate such that:

\[
\log(R_t^*) = \rho_R \log(R_{t-1}^*) + \epsilon_{R,t} \\
\epsilon_{R,t} \sim N(0, \sigma_R)
\]
Nonfinancial Firms

Capital firms

- Purchase capital goods from capital producers (price $Q_t$) and rent it to final goods firms.

$$R_{K,t} = e^{\psi_t} \frac{\alpha Y_t}{e^{\psi_t} K_{t-1}} + (1 - \delta) Q_t$$

Final goods firms

- Production function:

$$Y_t = (e^{\psi_t} K_{t-1})^\alpha L_t^{1-\alpha}$$

- Optimality Condition for labor

$$(1 - \alpha) \frac{Y_t}{L_t} = W_t$$
Capital Producers

- Capital producers make new capital using input of final output and are subject to adjustment costs. They sell new capital to firms at the price $Q_t$.

- The price of capital goods is equal to the marginal cost of investment goods production:

$$Q_t = 1 + \psi_I \left( \frac{l_t}{e^{\psi_t K_{t-1}}} - \delta \right)$$
Resource Constraint and Market Clearing

- Resource constraint:

$$Y_t = C_t + \left[ 1 + \frac{1}{2} \psi l \left( \frac{I_t}{e^{\psi t} K_{t-1}} - \delta \right)^2 \right] I_t + \sigma \frac{\kappa}{2} x_t^2 Q_t K_t + NX_t$$

- Balance of payments:

$$R_{t-1} B_{t-1}^* - B_t^* = NX_t$$
Computation

- Solve the model using the Parameterized Expectations method.
  - To take into account the precautionary savings behavior of risk averse banks.
  - To take into account strong nonlinearities, especially when the constraint binds.
- Method relies on approximating the expectations as a function of the state vector.
### Table: Calibration

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Value</th>
<th>Source/Target</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Conventional</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discount factor</td>
<td>$\beta$</td>
<td>0.985</td>
<td>Interest rate (6%, ann.)</td>
</tr>
<tr>
<td>Risk aversion</td>
<td>$\gamma$</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Inverse Frisch elast.</td>
<td>$\epsilon$</td>
<td>1/3</td>
<td>Frisch lab. sup. elast. (inv)</td>
</tr>
<tr>
<td>Labor disutility</td>
<td>$\chi$</td>
<td>2.8125</td>
<td>Steady state labor (30%)</td>
</tr>
<tr>
<td>Capital share</td>
<td>$\alpha$</td>
<td>0.33</td>
<td>Standard RBC value</td>
</tr>
<tr>
<td>Capital depreciation</td>
<td>$\delta$</td>
<td>0.025</td>
<td>Mendoza (2010)</td>
</tr>
<tr>
<td>Investment adj. cost</td>
<td>$\Psi_I$</td>
<td>5</td>
<td>BGG (2000)</td>
</tr>
<tr>
<td>Debt elast. of interest rate</td>
<td>$\varphi$</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>Reference debt/output ratio</td>
<td>$\bar{b}$</td>
<td>0.6</td>
<td>Steady state $B/Y$ of 60%</td>
</tr>
<tr>
<td><strong>Financial Intermediaries</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Survival rate</td>
<td>$\sigma$</td>
<td>0.95</td>
<td>Expected horizon of 5 yrs, as in GK (2013)</td>
</tr>
<tr>
<td>fraction divertable</td>
<td>$\theta$</td>
<td>0.26</td>
<td>Frequency of crises (2%)</td>
</tr>
<tr>
<td>Transfer rate</td>
<td>$\xi$</td>
<td>0.0001</td>
<td></td>
</tr>
<tr>
<td>Cost of raising equity</td>
<td>$\kappa$</td>
<td>5</td>
<td>Steady State Leverage of 3.5</td>
</tr>
<tr>
<td><strong>Shock Processes</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Persistence of interest rate</td>
<td>$\rho_R$</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>SD of interest rate innov.</td>
<td>$\sigma_R$</td>
<td>0.008</td>
<td></td>
</tr>
<tr>
<td>SD of capital quality</td>
<td>$\sigma_{\psi}$</td>
<td>0.01</td>
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### Table: Stochastic Steady State

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<tr>
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<tr>
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<td>0.8379</td>
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<td>0.8399</td>
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<td>0.6594</td>
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<td>$QK/N$</td>
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**Moments**

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**Welfare**

-213.705 -213.4275 -213.4302
Figure: Responses to Decline in Country Interest Rate

- **Output**
- **Investment**
- **Q**
- **Foreign Debt, B**
- **Net Worth, N**
- **Total Credit Q x K**

Graphs showing the percentage deviation of various economic indicators over time in response to a decline in country interest rate.
Figure: Responses to Decline in Country Interest Rate, Crisis Probabilities
Figure: Responses to Capital Quality Shocks
**Figure:** Responses to Capital Quality Shocks, Crisis Probabilities

2 Quarters Ahead

1 Year Ahead
Figure: Average Financial Crisis

![Graphs showing the effects of financial crises on various economic indicators.](image-url)
Policy Experiment

- Government sets a subsidy $\tau_s$ per unit of equity issued, financed by a tax $\tau_t$ on bank assets.

- Bank’s first order condition for equity issuance becomes:

  $$\nu_{e,t} + \tau_s = c'(x_t)$$

  → the policy induces an increase in bank capital, similar to a capital requirement.

- Balance sheet constraint is now:

  $$(1 + \tau_t)Q_t s_t \leq n_t + d_t$$
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Next Steps

- Use the model to analyze time-varying capital requirements
- Study relative merits of capital controls *vis-á-vis* capital requirements
- Develop monetary version of the model and use it to study implications of conventional monetary policy for financial stability