Financial Cycles with Heterogeneous Intermediaries

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Goal of the paper

Provide a framework to understand credit booms and analyse jointly monetary policy and financial stability (systemic risk)

- Credit booms and low credit spreads forecast crises
- Macro finance literature has not focused on boom phase
- Risk concentration on some balance sheets important to understand systemic risk
- Dynamic Macro Model with financial intermediary heterogeneity needed
- Generates time variation in systemic risk and risk-premia
- Generates fluctuations in cross-sectional patterns of leverage as in the data.
Related Literature (subset!)


- **Risk taking channel:** Borio and Zhu (2008), Bruno and Shin (2014); Jimenez et al. (2014); Miranda-Agrippino and Rey (2015); Morais et al. (2015), Dell’ Arricia et al. (2013), Challe et al. (2013)
Model

Intermediaries

- Have limited liability and heterogeneous value-at-risk constraints.
- Collect deposits from households and invest in risky capital or invest in a constant return to scale storage technology.
- Leveraged intermediaries can default in equilibrium.

Households

- Cannot invest directly in risky projects. Can have deposits or invest in storage technology.

Official sector

- Government guarantee deposits. Lump sum tax.
- Monetary authority provides wholesale funding (affects average cost of funds.)
Model

Production Function

- Output $Y_t$ is produced according to:

\[ Y_t = Z_t K_{t-1}^{\theta} L_t^{1-\theta}, \quad L_t = \bar{L} \]

\[ \log Z_t = \rho^z \log Z_{t-1} + \varepsilon_t \]

\[ \varepsilon^z_t \sim N(0, \sigma_z) \]

- Firm maximization: $W_t = (1 - \theta)Z_t K_{t-1}^{\theta}$ and returns on a unit of capital $R_t^k = \theta Z_t K_{t-1}^{\theta-1} + (1 - \delta)$. 
Households

\[
\max_{\{C_t,S_t^H,D_t^H\}_{t=0}^{\infty}} \quad E_0 \sum_{t=0}^{\infty} \beta^t u(C_t^H) \quad \text{s.t.}
\]

\[
C_t^H + D_t^H + S_t^H = R_{t-1}^D D_{t-1}^H + S_{t-1}^H + W_t - T_t
\]

- Households have deposits \(D_t^H\) (return = \(R_t^D\)) or invest in storage technology \(S_t^H\) (return = 1).

\[
   u(C) = \frac{C^{1-\psi} - 1}{1 - \psi}
\]

- Intertemporal consumption saving decision.
At the center of the model are financial intermediaries

- Two-period OLG structure (no bequests)
- Born with an endowment of equity $\omega_t = \omega$
- When young, buy $k_{it}$ shares in the aggregate capital stock using equity and possibly deposits $d_{it}$ at interest rate $r_t^D$
- When old, consume net worth and die
- Risk neutral, have limited liability and are subject to a VaR constraint
  - Constrained maximal probability of incurring losses: $\alpha^i$
  - Heterogeneous across intermediaries: $G(\alpha^i)$
The financial intermediary

Intermediary balance sheets

The intermediary balance sheet:

<table>
<thead>
<tr>
<th>Assets</th>
<th>Liabilities</th>
</tr>
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<tbody>
<tr>
<td>$k_{it}$</td>
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</tr>
<tr>
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</tr>
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</table>

Net cash flow after returns are realized:

\[
\pi_{i,t+1} = R^K_{t+1} k_{it} + s_{it} - R^D_t d_{it}
\]
Intermediary problem

The maximization program:

$$\max \ E_t c_{i,t+1}$$

s.t. \( \Pr(\pi_{i,t+1} < \omega^i_t) \leq \alpha^i \)

\( k_{it} + s_{it} = \omega^i_t + d_{it} \)

\( \pi_{i,t+1} = R^K_{t+1} k_{it} + s_{it} - R^D_t d_{it} \)

\( c_{i,t+1} = \max(0, \pi_{i,t+1}) \)
An intermediary may invest or not in risky assets; may leverage using deposits or not.

When $\mathbb{E}_t \left[ R^K_{t+1} \right] \geq 1$, we can show there is a cutoff $\alpha^L_t$ above which financial intermediaries enter the market for risky projects and lever up to their constraints.

Below the cutoff $\alpha^L_t$ intermediaries enter the market for risky projects but do not lever up.
Intensive margin: Heterogeneous leverage

For levered intermediaries ($\alpha^i > \alpha^L$), leverage is given by:

$$\lambda_t^i \equiv \frac{k_{it}^L}{\omega} = \frac{r_t^D}{r_t^D - \theta Z_t^{\rho z} K_t^{\theta-1} F^{-1}(\alpha^i) + \delta}$$

Conditional on participation, $\lambda_t^i$ is:

- Increasing in intermediary risk-taking $\alpha^i$
- Decreasing in cost of leverage: $r_t^D$
- Increasing in expected returns: $\theta Z_t^{\rho z} K_t^{\theta-1} - \delta$
Aggregate Leverage

Asset weighted leverage. Bankscope data
Leverage quantiles
Bankscope data

Negative correlation between top and median/bottom quantiles!
Systemic Risk

The model allows a precise definition of systemic risk

- We can quantify systemic risk as the probability that a certain fraction of intermediaries defaults or in terms of a fraction of the assets held by intermediaries in default.

- We define **systemic crisis** as a state of the world where all levered intermediaries are unable to repay in full their stakeholders (deposits and equity)

- **Systemic risk** is defined by the probability of a systemic crisis occurring and is therefore equal to $\alpha^L_t$. The higher $\alpha^L_t$ the more likely a small shock will trigger a crisis.
Partial Equilibrium

Cross-sectional distribution of leverage

Interest Rates
- High
- Medium
- Low

\[ \lambda_{it} - 1 \]

\[ \alpha \quad \alpha^L \quad \alpha^i \quad \bar{\alpha} \]
Cut-off and aggregate capital as a function of deposit rates.

- **Macroeconomic variables** (K, C, Y) are smooth but the underlying financial structure supporting aggregate outcomes can be very different.
IRFs to a 100 bp shock to deposit rates (% changes)

\[ R_t = \bar{R}^{1-\nu} R_{t-1}^\nu \varepsilon_t^R \]
Financial stability versus economic activity

Economic intuition can be understood by looking at a fall in interest rates in two different extreme cases.

- An inelastic capital stock: $K_t = \bar{K}$
  - Riskier intermediaries can buy more as the constraint relaxes, so some less risky intermediaries must exit the market. Price adjusts and the cutoff rises ⇒ *Trade-off always present.*

- A perfectly elastic capital stock: $E[R_{t+1}^K] = \bar{R}^K$
  - Since expected returns remain unchanged, a decrease in the cost of leverage will always lead to entry. Capital stock grows and the cutoff falls ⇒ *Trade-off never present.*
General Equilibrium

- Partial eq: $r_t^D$ assumed to be exogenous
- General eq: $r_t^D$ is the price that clears the market for funds
  - Household program defines a deposit supply schedule
  - Financial sector block defines a deposit demand schedule
  - In equilibrium $D_t^H = \int d_i t dG(\alpha^i)$

- Households are assumed to be able to both invest in deposits and storage
  - ...but not directly in the capital stock
  - Also provide a fixed supply of labour and pay lumpsum taxes
General equilibrium

Households

$$\max \left\{ C_t, S_t^H, D_t^H \right\}_{t=0}^{\infty} E_0 \sum_{t=0}^{\infty} \beta^t u(C_t^H) \quad \text{s.t.}$$

$$C_t^H + D_t^H + S_t^H = R_{t-1}^D D_{t-1}^H + S_{t-1}^H + W_t - T_t \quad \forall t$$
Monetary policy: Intermediaries now have also access to wholesale funding $l_{it}$ at rate $R^L_t$

$$k_{it} = \omega + d_{it} + l_{it}$$
Monetary policy

**Assumption 1:** Up to $\chi$ units of wholesale funding per unit of deposits $d^i$

$$l_{it} = \chi d_{it}$$

**Assumption 2:** Wholesale funds are provided at a spread from deposit rates

$$R_t^L = (1 - \gamma_t)R_t^D$$

**Assumption 3:** Deep-pocketed monetary authority

- Internal asset management not modelled
- Can always fund wholesale funding
- Interest differential is deadweight loss/gain
### Monetary policy

#### Intermediary balance sheets

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Monetary policy
Intermediary balance sheets

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# Monetary policy

Intermediary balance sheets

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with

$$R_t^F = \frac{1 + \chi(1 - \gamma_t)}{1 + \chi} R_t^D$$

$$f_{it} = d_{it}(1 + \chi)$$

Intermediary problem is then the same, but now there is a wedge

- Between deposit rates and the cost of funding
- Between total deposits and total funding
Monetary policy and systemic risk

We now compare the IRFs at 3 different parts of the state space:

- **Scenario 1**: Starting with large $K \Rightarrow ”low”$ $R^D$
- **Scenario 2**: Starting with $K = \bar{K} \Rightarrow ”average”$ $R^D$
- **Scenario 3**: Starting with low $K \Rightarrow ”high”$ $R^D$
General Equilibrium: IRF to monetary policy shock

Monetary policy: affects cost of wholesale funds; changes average cost of funds.

Output \( (\Delta \%) \)

Cutoff \( \alpha^L (\Delta \%) \)

Leverage active banks \( (\Delta \%) \)

- High \( K_0 \)
- Low \( K_0 \)
- \( K_0 = \bar{K} \)
Monetary Policy in General Equilibrium

- Monetary policy affects composition of financial sector.
- Monetary policy affects risk-shifting.
- Credit booms due to monetary policy loosening are associated with decreases in risk premium.

⇒ There is a meaningful tradeoff for some values of the interest rate between monetary policy and financial stability policy.
Monetary policy: Cross-sectional implications

Bankscope data: cross section of bank balance sheets worldwide during 1993-2015. We compute leverage as the ratio of assets to equity. The model has the following properties:

1. Leverage quantiles respond differently to monetary policy. ⇒ When $R$ is low, leverage is higher for highly levered intermediaries but not necessarily for the bottom quantiles Data

2. Skewness is monotonically decreasing with $R$ ⇒ When $R$ is low, capital will be even more concentrated on the upper range of the risk-taking distribution Data

3. More leveraged intermediaries take on more macro risk and make more profit (pre-crisis) ⇒ Betas, leverage and profits are correlated Data
Systemic crises and efficiency losses: costly default

- When intermediaries cannot repay their deposits:
  - Government taxes households
  - Repays deposit insurance

- We assume that ROA of distressed intermediaries suffer an efficiency loss $\Delta$

- Crisis might also affect productivity in following periods
  - Poisson shock $\xi$ determines if economy remains distressed
  - If yes, productivity loss is proportional to the mass of capital held by defaulting intermediaries $\mu_t^D$
  - Scaled by the maximal loss: $\bar{\Delta}$
Systemic crises and productivity shocks

We now compare the IRFs of 3 scenarios:

- **Scenario 1**: Largest negative productivity shock that doesn’t trigger defaults

- **Scenarios 2 and 3**: Smallest negative shock such that all leveraged intermediaries default
  - **Scenario 2**: Crisis does not carry on: $\xi_t = 0$
  - **Scenario 3**: Crisis last for 5 periods: $\xi_s = 1$, $\forall s \in [t, t+3]$
IRF to large productivity shocks

Key variables

Output (Δ%)

Cutoff $\alpha^L$ (Δ%)

Leverage active banks (Δ%)

Legend:
- Red: No crisis
- Blue: Short crisis
- Black: Long crisis
Conclusion

A new tractable framework with heterogeneous financial intermediaries

- Time variation in leverage, risk-shifting and systemic risk (default of intermediaries)
- Can generate credit booms associated with low risk premia
- Trade-off between monetary policy and financial stability (but only when rates are low)
  - Risk taking channel of monetary policy.
- Fits time variation in cross-sectional patterns of leverage
- Paper also looks at productivity shocks and crisis dynamics
- Versatile: potential applications include international capital flows; real estate markets.
Additional Slides
Changes in assets due to changes in equity and/or debt

Source: Bankscope, billions of dollars
Intermediary problem

The maximization program:

\[
\begin{align*}
\text{max} \quad & \mathbb{E}_t c_{i,t+1} \\
\text{s.t.} \quad & \Pr(\pi_{i,t+1} < \omega^i_t) \leq \alpha^i \\
& k_{it} + s_{it} = \omega^i_t + d_{it} \\
& \pi_{i,t+1} = R^K_{t+1} k_{it} + s_{it} - R^D_t d_{it} \\
& c_{i,t+1} = \max(0, \pi_{i,t+1})
\end{align*}
\]
Heterogeneous leverage and second derivatives

We also have that a fall in rates:

- Has a larger effect on leverage, the more risk-taking is the intermediary: \( \frac{\partial^2 \lambda_i^t}{\partial r_t^D \partial \alpha^i} < 0 \)

- And a larger effect on leverage, the lower are rates to begin with: \( \frac{\partial^2 \lambda_i^t}{\partial (r_t^D)^2} > 0 \)
Financial market equilibrium

To close the financial market equilibrium, we need to use the market clearing condition.

$$K_t = \int_{\alpha_t^L}^{\alpha_t^N} k_{it}^N dG(\alpha^i) + \int_{\alpha_t^L}^{\bar{\alpha}} k_{it}^L dG(\alpha^i)$$

- The financial block is described by the joint dynamics of $(\alpha_t^L, r_t^D, Z_t^e, K_t)$.
- Taking $r_t^D$ and $Z_t^e$ as given, we can solve for the equilibrium aggregate capital stock and the cut offs.
Cross-sectional implications and evidence

1. Aggregate (asset weighted) leverage and the Fed Funds Rate $R$ as a proxy for the cost of funds

![Graph showing mean leverage and Fed Funds Rate (FFR) over time from 1995 to 2015. The graph displays two lines: one for mean leverage (blue) and another for FFR (RHS). The x-axis represents the years 1995 to 2015, and the y-axis represents values from 0 to 30.]
Cross-sectional implications and evidence

1. Leverage quantiles and $R$

![Graphs showing cross-sectional implications and evidence with quantiles for Top 1% and Median, along with FFR (RHS) for both Top 1% and Bottom 1% categories.](graph.png)
Cross-sectional implications and evidence

2. Skewness of participating intermediaries (model and data) and interest rates
Cross-sectional skewness and $R$
Cross-sectional skewness and real $R$
Leverage and market betas

![Graph showing the relationship between average pre-crisis leverage and average pre-crisis beta for various banks. The graph includes points for Barclays, Commerzbank, Societe Generale, UBS, Dexia, Deutsche Bank, Lloyds, BNP, Credit Suisse, BBVA, Santander, Societe Generale, BNY Mellon, Citigroup, Goldman Sachs, JP Morgan, Morgan Stanley, State Street, Well Fargo, RBS, Unicredit, State Street, HSBC, BBVA, Santander, Bank of America, and Nordea.]
Returns and market betas

The scatter plot illustrates the relationship between average pre-crisis Beta and average return pre-crisis (pp) for various banks. The line indicates a positive correlation, where higher betas are associated with higher returns. The banks are represented as blue dots, with labels for clarity.
General equilibrium

**Financial sector equilibrium**
- We first solve for the financial sector equilibrium on a grid of $(r, Z^e)$.

**General equilibrium block**
- First we discretize the state space using a Tauchen-Hussey procedure for the AR(1) processes $(Z, \gamma)$
- Guess $r_0^D$ and set storage policy function $S_0 = 0$
- Obtain capital and deposits from the financial sector block
- Update prices using the consumer Euler Equation and storage using the household budget constraint.
- Iterate until convergence
Calibration
Calibrating the process for $\gamma_t$, $\lambda_t$ and $\omega$

To calibrate the process of $\gamma_t$, we fit an AR(1) in logs to the difference between the FFR and $1/\beta$, the long-run deposit rate.

To calibrate $\chi$, we use Bankscope data and target the percentage of wholesale funding in total liabilities: $\frac{\chi}{1+\chi} = 0.41$

For $\omega$, we target an average leverage at the stochastic steady-state of 7.3, the asset-weighted mean using Bankscope data for banks and a leverage of 1 for Other Financial Institutions (Global Shadow Banking Report, Financial Stability Board, 2015).
To clarify the composition effect, we assume the mass of each intermediary is constant across the distribution so:

$$\alpha^i \sim \mathbb{U}[0, \overline{\alpha}]$$

To calibrate $\overline{\alpha}$, we look at FDIC data on failed banks and find the median age of failed banks is 20.5 years. We then calibrate $\overline{\alpha}$ to 0.1 such that the median bank ($\alpha^i = \overline{\alpha}/2$) will fail once every 20 years.
Calibration
Calibrating $G(\alpha^i)$
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>$\psi$</td>
<td>4</td>
<td>Risk aversion parameter</td>
</tr>
<tr>
<td>$\beta$</td>
<td>0.95</td>
<td>Subjective discount factor</td>
</tr>
<tr>
<td>$\rho^z$</td>
<td>0.9</td>
<td>AR(1) parameter for TFP</td>
</tr>
<tr>
<td>$\sigma_z$</td>
<td>0.028</td>
<td>Standard deviation of TFP shock</td>
</tr>
<tr>
<td>$\mu^\gamma$</td>
<td>0.023</td>
<td>Target spread over deposit rates</td>
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<tr>
<td>$\rho^\gamma$</td>
<td>0.816</td>
<td>Spread persistence</td>
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<tr>
<td>$\sigma^\gamma$</td>
<td>0.0128</td>
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<tr>
<td>$\chi$</td>
<td>0.41</td>
<td>Wholesale funding percentage</td>
</tr>
<tr>
<td>$\theta$</td>
<td>0.35</td>
<td>Capital share of output</td>
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<tr>
<td>$\delta$</td>
<td>0.1</td>
<td>Depreciation rate</td>
</tr>
<tr>
<td>$\omega$</td>
<td>0.51</td>
<td>Equity of intermediaries</td>
</tr>
<tr>
<td>$\bar{\alpha}$</td>
<td>0.1</td>
<td>Upper bound of distribution $G(\alpha^i)$</td>
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## Calibration with costly default

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<td>Standard deviation of TFP shock</td>
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<tr>
<td>$\mu^\gamma$</td>
<td>0.02</td>
<td>Target spread over deposit rates</td>
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<td>Spread persistence</td>
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<td>$\sigma^\gamma$</td>
<td>0.01</td>
<td>Standard deviation of spread</td>
</tr>
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<td>$\delta$</td>
<td>0.1</td>
<td>Depreciation rate</td>
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<tr>
<td>$\omega$</td>
<td>0.5</td>
<td>Equity of intermediaries</td>
</tr>
<tr>
<td>$P(\xi = 1)$</td>
<td>0.5</td>
<td>Average crisis length of 2 years</td>
</tr>
<tr>
<td>$\bar{\Delta}$</td>
<td>0.115</td>
<td>Efficiency loss of 11.5%</td>
</tr>
<tr>
<td>$\bar{\alpha}$</td>
<td>0.1</td>
<td>Upper bound of distribution $G(\alpha^i)$</td>
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