Financial Cycles with Heterogeneous Intermediaries

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Goal of the paper

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

- Financial intermediary heterogeneity is a key ingredient
- Changes in the cost of funding generates entry and exit
- Generates time variation in systemic risk, leverage and risk-premia
- Explain some cross-sectional patterns of leverage in data
Contribution

- Dynamic macroeconomic model with financial intermediaries that are heterogeneous in their Value-at-Risk constraints
  - Can generate a meaningful tradeoff between monetary expansion and financial stability
  - Heterogeneity is key in determining asset prices, investment and systemic risk
  - Flexible framework that can be integrated in complex recursive macroeconomic models
  - Opens the door for combining panel data on financial intermediation and theoretical models of financial constraints
Non-monotonic effects of policies that reduce the cost of funding for intermediaries

- Sign of the effect on systemic risk depends on the level of interest rates
  - High level: systemic risk falls due to entry of less risk-taking intermediaries
  - Low level: rise in systemic risk as less risk-taking intermediaries are priced out by more risk-taking ones

- Interaction between the fall in the cost of funding and the fall on asset returns due to leverage increases
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)
Model

Main ingredients

- Heterogeneous intermediaries collect deposits from households and invest in risky capital or invest in a constant return to scale storage technology
- Aggregate production function with decreasing returns to capital
- Households cannot invest directly in risky projects. They can have deposits or invest in storage technology.
- Government guarantee deposits. They tax (lump sum) households.
- Monetary authority provides wholesale funding (affects the cost of funds)
Heterogeneity in Value at risk constraints

- At least two possible interpretations:
- Differentiated demand by investors
- Regulatory constraints implemented differently across intermediaries. Basel Committee on Banking Supervision provided a test portfolio to a cross section of banks.
- Median implied capital requirements calculated by the banks was about 18 million euros. The minimum was 13 million euros and the maximum was 34 million euros.
Model

Production Function

- Output $Y_t$ is produced according to:

$$Y_t = Z_t K_{t-1}^\theta$$

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

$$\varepsilon_t^z \sim N(0, \sigma_z)$$

where $Z_t$ is total factor productivity. $\theta$ is the capital share, $\varepsilon_t$ is the shock to the log of exogenous productivity with persistence $\rho^z$ and standard deviation $\sigma_z$.

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

At the center of the model are financial intermediaries

- Endowment of equity $\omega_t = \omega$ every period
- Buy $k_{it}$ shares in the aggregate capital stock using equity and deposits $q_t^D d_{it}$
- Have limited liability and are subject to a VaR constraint
  - Constrained maximal probability of incurring losses: $\alpha^i$
  - Heterogeneous across intermediaries: $G(\alpha^i)$
Financial intermediaries
Role of frictions

- Interaction of **limited liability** with different probabilities of default leads to different willingness to pay for risky financial assets

- Due to **deposit guarantees**, depositors do not discriminate based on intermediary default risk
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>
<td>$\omega$</td>
</tr>
<tr>
<td></td>
<td>$q_t^D d_{it}$</td>
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</table>

Net cash flow after returns are realized:

$$\pi_{it} = R^K_{t+1} k_{it} - d_{it}$$
The maximization program:

\[
\max \mathbb{E}_t^i \left[ R_{t+1}^K k_{it} - d_{it} \right] \\
\text{s.t. } \Pr(R_{t+1}^K k_{it} - d_{it} < \omega) \leq \alpha^i
\]

- $\mathbb{E}_t^i$ is indexed by $i$ because of limited liability. This truncates the profit function at zero, generating an option value of default that intermediaries can exploit.
Intermediary problem

- An intermediary may participate or not in the market for risky assets. The outside option is the safe storage technology.
- A participating intermediary may use deposits and be levered (value function $V_{it}^L$)
  \[ V_{it}^L = E_t[\max(0, R_{t+1}^K k_{it} - d_{it})] \]
- A participating intermediary may also be non-levered (value function $V_{it}^N$).
  \[ V_{it}^N = E_t[\max(0, R_{t+1}^K k_{it})] \]
- A non-participating intermediary will use the storage technology yielding $\omega$. 
Entry conditions: an intermediary takes as given the price of deposits $q_t^D$, the aggregate capital stock $K_t$, the expected productivity $Z_t^e$ and compares the value of entering the market to its outside option, subject to its value-at-risk constraint.

An intermediary will participate in the market for risky assets iff $V_{it}^L \geq \omega$ or $V_{it}^N \geq \omega$ and its value-at-risk constraint is satisfied.
Extensive margin

- When \( \mathbb{E}_t [ R_{t+1}^K ] \geq 1 \):
- There is a cutoff \( \alpha_t^L \) above which financial intermediaries enter the market for risky projects and lever up to their constraints (Risky Business Model).
- Above this cutoff more risk-taking financial intermediaries are all in the market and lever up to their constraints.
- Below the cutoff \( \alpha_t^L \) participating intermediaries enter the market for risky projects but do not lever up (Safe Business Model).
- Non-levered financial intermediaries invest \( \omega \) unless their value-at-risk constraint binds in which case they invest an amount \( \omega \geq k_{it} \geq 0 \).
Intensive margin

- Intermediary $i$ with **risky business model** ($\alpha^i \geq \alpha^L_t$):

$$k_{it}^L = \omega \frac{1/q_t^D - 1}{1/q_t^D - (1 - \delta) - \theta Z_t^\rho \theta^{-1} K_t F^{-1}(\alpha^i)}$$

- Intermediary $i$ with **safe business model**:
  - Unconstrained: $\alpha^i \in [\alpha^N_t, \alpha^L_t]$, with $\alpha^N = \Pr(R_{t+1}^K \omega \leq \omega)$
    $$k_{it}^N = \omega$$
  - Constrained: $\alpha^i < \alpha^N_t$
    $$k_{it}^N \in [0, \omega]$$ given by VaR condition without leverage
Heterogeneous leverage

For participating intermediaries with a risky business model, leverage is given by:

\[ \lambda_{it} \equiv \frac{k_{it}^L}{\omega} = \frac{1}{q_t^D} - 1 \]

\[ \frac{1}{q_t^D} - (1 - \delta) - \theta Z_t^{\rho^z} K_t^{\theta-1} F^{-1}(\alpha^i) \]

Conditional on participation, \( \lambda_{it} \) is:

- Increasing in intermediary risk-taking \( \alpha^i \)
- Decreasing in cost of leverage: \( 1/q_t^D \)
- Increasing in expected returns: \( \theta Z_t^{\rho^z} K_t^{\theta-1} + (1 - \delta) \)
Financial market equilibrium

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

\[ K_t = \int_{\alpha_t}^{\bar{\alpha}} k^N_{it} \, dG(\alpha^i) + \int_{\alpha_t}^{\bar{\alpha}} k^L_{it} \, dG(\alpha^i) \]  

(4)

- The financial block is described by the joint dynamics of \((\alpha^L_t, q_t, Z^e_t, K_t)\).
- Taking \(q^D_t\) as given, we can solve for the equilibrium aggregate capital stock and the cut off.
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.

- For example the cutoff $\alpha^L$ gives the probability that the entire leveraged part of the financial system incurs in losses at a point in time.
Partial Equilibrium

Cross-sectional distribution of leverage
Partial equilibrium

Cut-off and aggregate capital as a function of deposit costs
Partial Equilibrium

IRFs to a 100 bp shock to deposit rates (% changes)

\[ R_t = \bar{R}^{1-\nu} R_{t-1}^\nu \varepsilon_t^R \]
Monetary policy

Monetary policy affects composition of financial sector

- Cheap credit lines reduce static risk of default
  ⇒ *But allow each intermediary to lever more*
- And also affects the extensive margin
  ⇒ *More intermediaries start leveraging*
  ⇒ *Or stop if marginal returns decrease a lot*
- Impacts ability and willingness of intermediaries to lend
- Affects the risk premium and risk-shifting

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

The model has the following properties:

1. Aggregate leverage is monotonically decreasing with $R$
   - And so is its derivative
   $\Rightarrow$ When $R$ is low, leverage is higher

2. Skewness is monotonically decreasing with $R$
   - And again so is its derivative
   $\Rightarrow$ When $R$ is low, capital will be even more concentrated on the upper range of the risk-taking distribution

3. More leveraged intermediaries are more risk-taking
   $\Rightarrow$ Profit volatility, betas and leverage are correlated
Cross-sectional implications and evidence

1. Aggregate leverage and $R$
Cross-sectional implications and evidence

2. Cross-sectional skewness and $R$

Skewness in the model as a function of the cost of leverage $(1/R)$:
Cross-sectional implications and evidence

2. Cross-sectional skewness and $R$

Cross-sectional skewness of leverage and Fed Funds Rate
Cross-sectional implications and evidence

3. Profit volatility, market betas and leverage
General Equilibrium

- Partial eq: $q^D_t$ assumed to be exogenous
- General eq: $q^D_t$ is the price that clears the market for funds
  - Household supply of deposits used to pin down $q^D$ in equilibrium

- 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

\[ \max \{ C_t, S_t^H, D_t^H \}_{t=0}^{\infty} E_0 \sum_{t=0}^{\infty} \beta^t u(C_t^H) \quad \text{s.t.} \]
\[ C_t^H + q_t D_t^H + S_t^H = D_{t-1}^H + S_{t-1}^H + W_t - T_t \quad \forall t \]
Monetary policy: Intermediaries now have also access to wholesale funding $l_{it}$

$$k_{it} = \omega + q_t^D d_{it} + q_t^L l_{it}$$
**Monetary policy**

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

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

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

$$q_t^L = (1 + \gamma_t)q_t^D$$

**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

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Monetary policy
Intermediary balance sheets

\[
\begin{array}{c|c}
\text{Assets} & \text{Liabilities} \\
\hline
k_{it} & \omega \\
 & q_t^f f_{it} \\
\end{array}
\]

with

\[
q_t^F = q_t^D \frac{1 + \lambda (1 + \gamma_t)}{1 + \lambda}
\]

\[
f_{it} = d_{it} (1 + \lambda)
\]

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
General equilibrium

Financial sector equilibrium

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

General equilibrium block

- First we discretize the state space using a Tauchen-Hussey procedure for the AR(1) processes $(Z, \gamma)$
- Guess $q_0^D$ and set storage policy function $S_0 = 0$
- Obtain capital and deposits from the financial sector block
- Update prices using the consumer Euler Equation.
- Iterate until convergence
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 low $K \Rightarrow ”high” \ R^D$
- **Scenario 3**: Starting with $K = \bar{K} \Rightarrow ”average” \ R^D$

**Monetary policy shock of 100 basis points to subsidy $\gamma_t$**
## Calibration

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<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>
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<td>$\rho^z$</td>
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<td>AR(1) parameter for TFP</td>
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<td>$\sigma_z$</td>
<td>0.028</td>
<td>Standard deviation of TFP shock</td>
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<td>$\mu^\gamma$</td>
<td>0.02</td>
<td>Target spread over deposit rates</td>
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<td>0.24</td>
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<td>Upper bound of distribution $G(\alpha^i)$</td>
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IRF to monetary policy shock

Key variables

- **Y (%)**
- **$\alpha^L (%)$**
- **Leverage active banks (%)**

Legend:
- High $K_0$
- Low $K_0$
- $K_0 = \bar{K}$
IRF to monetary policy shock

Real variables

- **C (%)**
- **W (%)**
- **K (%)**

Graphs showing the response of real variables to a monetary policy shock, with different scenarios for $K_0$.
IRF to monetary policy shock

Financial variables

\[ R^D \text{ (bp)} \]

\[ E(R^R) - R^D \text{ (bp)} \]

\[ R^F \text{ (bp)} \]

Total leverage (%)
BVAR results

Responses to MP shock inducing 100 bp increase to FFR
Empirical evidence


- Dell Arricia et al. (2013) also finds that the more leveraged banks take the most risk when the interest rate decreases.

- This is consistent with the implications of our model.
Systemic crises and efficiency losses: costly default

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

- Now, 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 $\mu^D_t$
  - Scaled by the maximal loss: $\overline{\Delta}$
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<tr>
<td>$P(\xi = 1)$</td>
<td>0.5</td>
<td>Average crisis length of 2 years</td>
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<tr>
<td>$\Delta$</td>
<td>0.05</td>
<td>Maximum efficiency loss of 5%</td>
</tr>
<tr>
<td>$\bar{\alpha}$</td>
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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

![Graphs showing Y (%), aL (%), and Leverage active banks (%)]
IRF to large productivity shocks

Real variables

\[
\begin{align*}
C(\%) & \quad W(\%) & \quad K(\%)
\end{align*}
\]
Financial variables

IRF to large productivity shocks
Conclusion

A new framework with heterogeneous financial intermediaries

- Generates endogenous entry and exit in risky financial markets
- Time variation in leverage, risk-shifting and systemic risk
- Trade-off between monetary policy and financial stability
  - But only when rates are low.
- Fits recent cross-sectional patterns in leverage and risk-taking
- Versatile: potential applications include international capital flows; real estate markets
Additional Figures
Cross-sectional skewness and $R$ - Balanced panel

Cross-sectional skewness of leverage and Fed Funds Rate
Cross-sectional implications and evidence

1. Aggregate leverage and $R$