Banks, Liquidity Management and Monetary Policy

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Introduction

- Last 5 years, Central Banks facing unprecedented challenges
  - Equity losses
  - Collapse in interbank lending
  - Increased loan spreads, weak lending

- Monetary policy has been changing in response...

- Center of debate: *banks’ reaction to monetary stimuli*
  - Why are banks holding on to so many liquid reserves and lending so little?
Our View

- **Want:** model of banks’ liquidity management in monetary policy transmission

- **Why:** monetary policy implemented through the banking system
  - Understand banks’ reactions to stimuli
  - Understand effects under special conditions

- No coincidence that debates occur *post*
  - Interbank-market freeze
  - Bank equity losses

- Bank Equity
1. Liquidity Management Trade-Off
   - (+) Profit on Loans
     - Spread between loans and deposits
   - (-) Illiquidity Risk
     - After deposits transferred, bank may be short of reserves

2. Monetary Policy
   - Illiquidity Risk: precautionary holdings of central bank reserves
   - Policy Instruments: operate through this tradeoff

3. Tractability
Why are banks stockpiling reserves instead of lending?

Four Hypothesis

1. Equity Losses
2. Interbank Uncertainty
3. Capital Requirements
4. Weak Loan Demand

Approach

- Illustrate effects of shocks and contrast with data patterns (today)
- Estimate shocks (in progress)
- Evaluate relative importance of shocks and policy (in progress)
Literature Review

- Call for studying banks in transmission of MP in Macro:
  - Woodford (2010, JEP), Mishkin (2012, JEP), Greenwood & Stiglitz (2003),

- Closest Papers

- Other papers studying implementation of monetary policy
  - Afonso & Lagos (2012a,b),

- Empirical Work
  - Kashyap & Stein (1998), Krishnamurthy & Vissing-Jorgenson (JPE 2012a, 2012b),

- Influential Work
  - Reserve Management: Frost (JPE, 1971), Bolton et al. (2012), Saunders et al. (2011)
  - Payments: Freeman (AER, 1996), Cavalcanti et al. (1998)
  - Monetary Economics: CIA, Money-Search, Kiyotaki and Moore (2012)
Model
Model - Environment

- **Time:** \( t=1,2,3,\ldots \)
  - **Two stages:** \( s=l,b \)
    - Lending stage (l) and balancing stage (b)

- Continuum of Heterogeneous Banks \( z \in [0,1] \)

- **Utility function:** Concave utility \( U \) over dividends \( \text{div}_t \)
Bank’s State Variable - Bank Balance Sheet

- Liabilities:
  - $D_t$ demand deposits (*numeraire*)

- Assets:
  - $C_t$ reserves (only traded among banks or with FED)
  - $B_t$ loans

- Equity
  - $N_t = B_t + C_t - D_t$
Liquidity Management

Figure: Bank Balance Sheet
Liquidity Management

Liquid Assets
Regulated Reserves

Illiquid Assets
Expertise
Adverse-Selection
Maturity

Reserves
Deposits
Loans
Equity

Medium of Exchange

Figure : Bank Balance Sheet
Loans $B_t$

- Loans: perpetual securities (long maturity)
  - Decaying-coupon Consol
Loans $B_t$

- Loan contract specifies:
  1. price $q_t^l$
  2. loan size face value $I_t$
  3. $q_t^l I_t$ checks given to firms or households
  4. $I_t$ payments owed

- Repayment:
  - $I_t (1 - \delta) \delta^n$ in period $n \geq 0$ after loan
  - Introduces maturity (beyond 1 period, not essential)
Loans \( B_t \)

- Recursively, bank loans l.o.m.:

\[ B_{t+1} = \delta B_t + I_t \]

- Loan is **illiquid**:
  - Lending stage: Loans **can** be sold
  - Balancing stage: Loans **cannot** be sold
Loans $B_t$

- Where’s $q$ coming from?
- Downward (weakly) sloping curve
  - $I_t^d = \Theta_t (q_t^l) \in$

To Derivation
Liquidity Management

Figure: Bank Balance Sheet
Deposits $D_t$ - Lending Stage: ______________

- Deposits change because:
  - Lending $qI_t$
  - Paying Dividends $DIV_t$
  - Purchasing Reserves $\varphi_t$

- Decreases Deposits through
  - Inflow of loan coupons

- Leverage Constraint:
  - $D_t \leq \kappa N_t$ (only during lending stage)
Deposits $D_t$ - Balancing Stage

- $\omega \in (-\infty, 1]$ random fraction of $D_t$ leaves bank
  - Randomness in payments system

- Withdrawal, pay other bank with reserves
  - $\omega \sim F_t(\omega)$
  - $E(\omega) = 0$ - deposits don’t leave banking system

- Reserve requirements $\rho_t \in [0, 1]$
- Reserve Deficit: $x = \rho_t D_t - C_t$
- Penalty for insufficient reserves: $\chi_t(x_t)$:

\[
\chi_t(x) = \begin{cases} 
\chi_t x & \text{if } x \leq 0 \\
\frac{1}{\chi_t}x & \text{if } x > 0 
\end{cases}
\]
Detour - Derivation of $\chi_t$

- FED chooses corridor system rates: $r^l_t > r^b_t$
- Mass (normalized) of reserve deficits and surpluses:

\[ M^- \text{ and } M^+ \]

- Probability of match:

\[ \gamma^- = \min \left(1, \frac{M^+}{M^-}\right) \text{ and } \gamma^+ = \min \left(1, \frac{M^-}{M^+}\right). \]

- Bargaining Problem of dollar in surplus and deficit:

\[ \max_{r^{FedFunds}} \left( r^l_t - r^{FedFunds} \right) \xi \left( r^{FedFunds} - r^b_t \right)^{1-\xi} \]

- Spline penalty function:

\[ \chi_t = \gamma^+ \left(1 + r^{FedFunds}\right) + \left(1 - \gamma^+\right) \left(1 + r^b_t\right) \]

for dollar in surplus and for dollar in deficit

\[ \bar{\chi}_t = \gamma^- \left(1 + r^{FedFunds}\right) + \left(1 - \gamma^-\right) \left(1 + r^l_t\right). \]
Reserves $C_t$

- Fixed Aggregate Supply determined by FED: $M0_t$

- Transferred across banks
  - Loan withdrawal
  - Interbank purchases $\varphi_t$

- Precautionary saving
  - Avoid penalty $\chi$
Figure: Bank Balance Sheet - Liquid Assets
Liquidity Management

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Liquidity Management

After Liquidity Shock

Figure: Bank Balance Sheet - Liquid Assets
The Aggregate State

- Governments Policy Path \( \{ \rho_t, M_0, D_{t}^{\text{FED}}, B_{t}^{\text{FED}}, \kappa_t, \chi_t, \overline{\chi}_t \} \) \( t \geq 0 \)

- \( \Theta_t \) is the slope of demand curve.

- \( F_t \) process for withdrawal risk

- Potentially: Distribution of Bank state variables
  - Only one endogenous state variable \( E_t \)

- Aggregate State: \( X_t \)
  - Model recursive in \( X_t \)
Value Function - Lending Stage

\[ V^l(C, B, D; X) = \max_{I, \varphi, \tilde{DIV}} u(DIV) + \beta E\omega'[V^b(\tilde{C}, \tilde{B}, \tilde{D}, \omega'; X)] \]

\[ \tilde{D} = D + qI + DIV + \varphi(1 + r) - B(1 - \delta) \]

\[ \tilde{C} = C + \varphi \]

\[ \tilde{B} = \delta B + I \]

\[ \tilde{D} \leq \kappa(\tilde{B}q + \tilde{C}(1 + r) - \tilde{D}), \tilde{D} \geq 0. \]
Value Function - Balancing Stage

\[ V^b (C, D, B, \omega; X) = \beta \mathbb{E}[V^l (C', B', D'; X')] \]

subject to

\[ C' = C - \omega D \]
\[ D' = D - \omega D + \chi (\rho D (1 - \omega) - C') \]
\[ B' = B \]
One Value Function

\[ V^l(C, B, D; X) = \max_{\{I, DIV, \tilde{C}, \tilde{D}\} \in \mathbb{R}^4} \ U(DIV) \ldots \]

\[ + \beta \mathbb{E} \left[ V^l(\tilde{C} - \omega' \tilde{D}, \tilde{B}, \tilde{D}(1 - \omega') + \chi(\rho \tilde{D} - (\tilde{C} - \omega' \tilde{D})); X')|X \right] \]

\[ \tilde{D} = D + qI + DIV + \varphi(1 + r) - B(1 - \delta) \]

\[ \tilde{B} = \delta B + I \]

\[ \tilde{C} = \varphi + C \]

\[ \tilde{D} \leq \kappa(\tilde{B}q + \tilde{C}(1 + r) - \tilde{D}), \tilde{D} \geq 0. \]
Characterization
Characterization

1. Single endogenous state

2. Portfolio Separation Theorem
   - Dividend-Savings independent of Portfolio Weights

3. Analysis of the Power of Monetary Policy
Solution

- Law of motion for deposits

\[ \tilde{D} = D + q \underbrace{I}_{\tilde{B} - \delta B} + DIV + (1 + r) \underbrace{\varphi}_{\tilde{C} - C} - B(1 - \delta). \]

- and substitute for \( I \) and \( \varphi \)...

\[ \tilde{D} = D + q(\tilde{B} - \delta B) + DIV + (\tilde{C} - C)(1 + r) - B(1 - \delta) \]

- and rearrange terms to obtain...

\[ DIV + (1 + r)\tilde{C} + q\tilde{B} - \tilde{D} = C(1 + r) + (q\delta + (1 - \delta)) B - D. \]

- We can collapse all state-variables into one: \( E! \)
Solution

Proposition (Single-State)
We have
\[ V^l(C, B, D; X) = V^l(E; X) \]
\[ E \equiv C(1 + r) + q\delta B + B(1 - \delta) - D. \]

Proposition (Homogeneity and Separation)
With CRRA,
\[ V^l(E; X) = v^l(X) E^{1-\gamma} \]
where:
\[ v^l(X) = \max_{\text{div} \in \mathbb{R}^+} \text{div}^{1-\gamma} + \beta \mathbb{E} [v^l(X') | X] (\Omega(X)(1 - \text{div}))^{1-\gamma} \]
where \( \Omega(X) \) is Return to Bank Portfolio.
Bank Portfolio Problem

- Four Returns:
  - Return on Loans:
    \[ R^B_t \equiv \frac{\delta q_{t+1} + (1 - \delta)}{q_t}, \]
  - Return on Reserves:
    \[ R^C_t \equiv \left( \frac{1 + r_{t+1}}{1 + r_t} \right) \]
  - Return on Deposits:
    \[ R^D_t (\omega') \equiv 1 + r_{t+1} \omega' \]
  - Liquidity Cost:
    \[ R^x (w_d, w_c, \omega') \equiv \chi \left( (\rho + \omega') w_d - \frac{w_c}{1 + r} \right) \]
Bank Portfolio Problem

- Effects of MP captured by $\Omega(X)$
- $\Omega(X)$ certainty equivalent portfolio:

$$\max_{\{w_b, w_d, w_c\} \in \mathbb{R}^3_+} \left( \mathbb{E}_{\omega'}[(R^B w_b + R^C w_c - R^D w_d - R^x(w_d, w_c))^{1-\gamma}] \right)^{\frac{1}{1-\gamma}}$$

subject to,

$$1 = w_b + w_c - w_d$$

$$w_d \leq \kappa (w_b + w_c - w_d)$$

- Original Policies: $[\tilde{D}, \tilde{B}, \tilde{C}] = [w_d, w_b, w_c] \cdot E \cdot (1 - \text{div})$
Figure: Portfolio Problem
Liquidity Management and Monetary Policy

- Monetary Policy Instruments
  - Discount window: $\chi_t$
  - Reserve requirements $\rho_t$
  - Long-Term Loans: $M0_t$
  - Open-market operations: $(b_t, c_t)$
Liquidity Management

Figure : Portfolio Problem
Liquidity Management

Figure: Portfolio Problem
## Calibration

<table>
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<tr>
<th>Parameter</th>
<th>Value</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital requirement</td>
<td>$\kappa = 17$</td>
<td>6% Tier-2 Capital</td>
</tr>
<tr>
<td>Discount factor</td>
<td>$\beta = 0.99$</td>
<td>Return on Equity=8%</td>
</tr>
<tr>
<td>Risk aversion</td>
<td>$\gamma = 1$</td>
<td>Benchmark</td>
</tr>
<tr>
<td>Loan Maturity</td>
<td>$\delta = 0.5$</td>
<td>Residual duration + buy-backs</td>
</tr>
<tr>
<td>Interest rate (annualized)</td>
<td>$r = 4%$</td>
<td>LIBOR</td>
</tr>
<tr>
<td>Liquidity Requirement</td>
<td>$\rho = 0.10$</td>
<td>Res. Req.</td>
</tr>
<tr>
<td>Loan Demand Elasticity</td>
<td>$\epsilon = 8.0$</td>
<td>-</td>
</tr>
<tr>
<td>Penalty</td>
<td>$\chi^L = 0.0%$</td>
<td>FedRate</td>
</tr>
<tr>
<td>Penalty</td>
<td>$\chi^H = 3.2%$</td>
<td>Liquidity Ratio</td>
</tr>
<tr>
<td>Withdrawal-shock volatility $F_t$</td>
<td>Non-Param</td>
<td>Data</td>
</tr>
</tbody>
</table>
Figure: Cross-Sectional Distribution of Deviation from Cross-Sectional Average Growth Rates
Calibration of Dispersion

Figure: Key Historical Ratios
Why are banks stockpiling cash rather than lending?

Four Hypothesis

1. Equity Losses
2. Capital Requirements
3. Uncertainty in Interbank markets
4. Weak Loan Demand
Deterministic Transitional Dynamics

Steady-state:
- Fix \( \{ \rho_t, M0_t, \kappa_t, \underline{X}_t, \overline{X}_t \} \) \( \geq 0 \)
- Find \((q,r)\) such that equity doesn’t grow
- Solve for E: financial sector size

Transitional Dynamics: one shock at a time
- Find \((q_t, r_t)\), consistent with equity growth and convergence
Equity Loss- $\downarrow E_0$ by 4 percent
Eq. loss

Equity

Total Lending

Return on Loans

Total Cash

51
Eq.loss

- Lending Rate (b)
- Reserve Rate (c)
- Dividend Rate (div)
- Portfolio Value (Ω)
- Bank Value
- Liquidity Risk
Permanent Rise in Capital Requirements - (AR-1 process, extra 2.5 % capital)
Perman. Rise in Cap. Requirements

Equity

Total Lending

Return on Loans

Total Cash
Permanent Rise in Cap. Requirements
Shock to probability of bank-run (AR-1 process, initial increase is 10 percent)
Bank-run Risk

Equity

Total Lending

Return on Loans

Total Cash
Bank-run Risk

Lending Rate (b)

Reserve Rate (c)

Dividend Rate (div)

Portfolio Value ($\Omega$)

Bank Value

Liquidity Risk

Bank-run Risk
Loan Demand Shock - $\downarrow \Theta_t$ (AR (1) process, 20 percent initial decrease)
Demand Shock

**Equity**

**Total Lending**

**Return on Loans**

**Total Cash**
Demand Shock

- Lending Rate (b)
- Reserve Rate (c)
- Dividend Rate (div)
- Portfolio Value (Ω)
- Bank Value
- Liquidity Risk

Graphs showing the impact of a demand shock on various economic indicators such as lending rates, reserve rates, dividend rates, portfolio values, bank values, and liquidity risks.
Transitory Reduction in $\chi$ (20% initial reduction, AR-1 process)
Transitory Reduction in $\chi$
Transitory Reduction in $\chi$
Transitory Reduction in $r$ (50 % initial reduction, AR-1 process)
Transitory Reduction in \( r \)
Transitory Reduction in $r$
Summary

- **Equity Losses and Capital Requirements**
  - Similar Effects
  - Expect High Marginal Returns - contraction of Loan Supply
  - Drop in Reserves
  - Dividends Accumulation

- **Withdrawal Uncertainty**
  - Explain initial spike in cash not persistence

- **Seems that Best fit is via Loan Demand**
  - Consistent with decline in lending, profits
  - High dividend rate
  - At ZLB can explain big part of FED’s Balance Sheet

- **Caveat**: Feed-back effect (credit quality vs. actual demand)
End
Liquidity Management

Figure: Bank Balance Sheet
Loan Demand

- Risk-Neutral Workers
- Risk-Neutral Entrepreneurs
  - Cannot prepay debt
  - Borrow to purchase hours from workers
  - Hold debt and deposits to repay debt

Liquidity Management

Figure: Bank Balance Sheet
Liquidity Management

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Figure: Bank Balance Sheet
Fact 1 - Disruption in Fed-Funds Market

Figure: Fed Funds Rate 2002-2012
Fact 1 - Disruption in Fed-Funds Market and ZLB

Figure: Fed Funds Rate 2008-2012
Fact 2 - Unconventional Policy

Figure: Fed Balance Sheet 2002-2012: Total Assets
Fact 2 - Unconventional Policy: Open Market Ops

Figure: Fed Balance Sheet: Treasuries, Gov Secs, MBS
Fact 2 - Unconventional Policy: OMO + Lending

Figure: Fed Balance Sheet: OMO
Fact 2 - Unconventional Policy: OMO + Lending

Figure: Fed Balance Sheet: OMO
Fact 3 - Required Reserves

Figure: Required Reserves at Commercial Banks
Fact 3 - Required vs. Excess Reserves

Figure: Required vs. Excess Reserves at Commercial Banks
Fact 4 - Bank Lending

Figure: Lending of Commercial Banks
Fact 4.b - My McGrattan Prescott Slide

Figure: Liabilities of Corporations
Figure: Liabilities of Non-Corporate Sector
Fact 5 - Banks Not Issuing Liabilities

Figure: Total Liabilities of Commercial Banks
Fact 4 & 5 - Drop in Money Multiplier

Figure: Total Liabilities of Commercial Banks
Fact 6 - Bank Equity Losses

Figure: Bank Equity