

Banks, Liquidity Management and Monetary Policy

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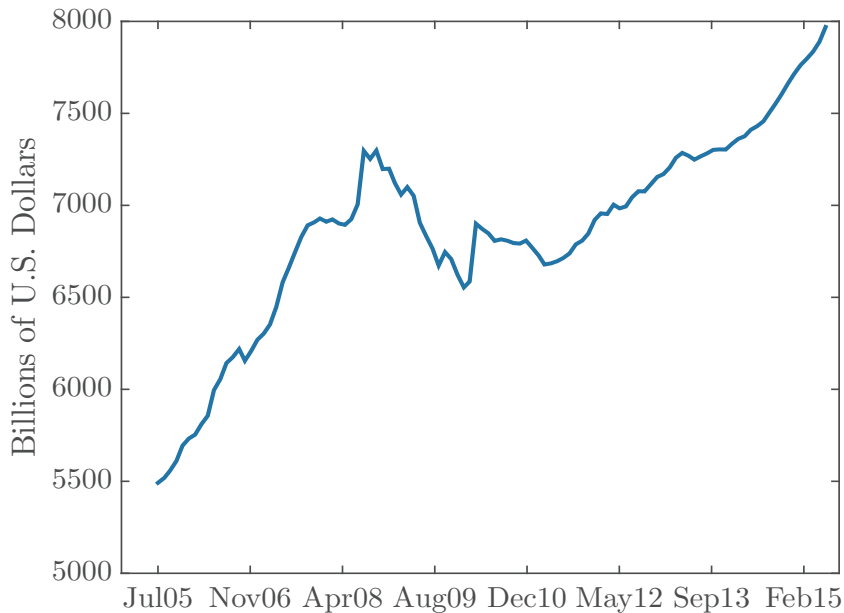
Motivation

- Financial crisis raised unprecedented challenges for central banks:
 - Worst recession since Great Depression
 - Persistently low inflation
- Despite aggressive monetary policy
 - Weak economic recovery
 - Depressed bank lending

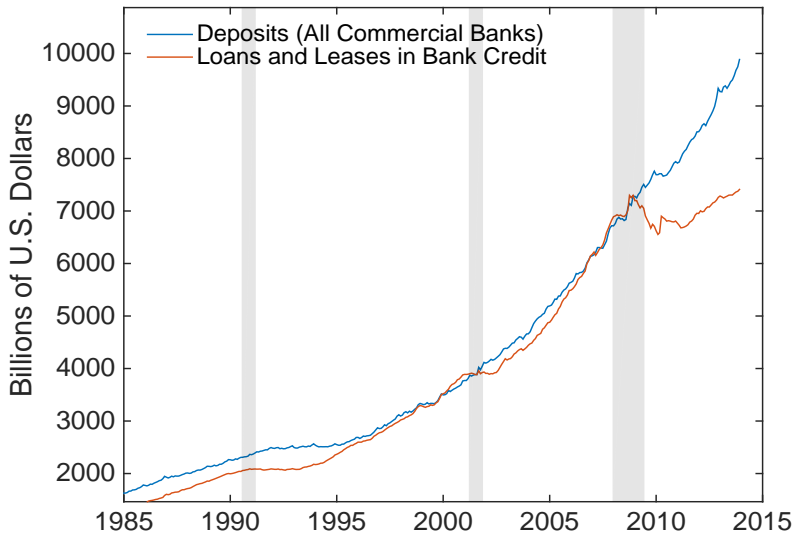
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 - Depressed bank lending
- Center of debate: banks' reaction to monetary stimulus
 - Why are banks **not lending**?
- Unfortunate divorce between Money and Banking

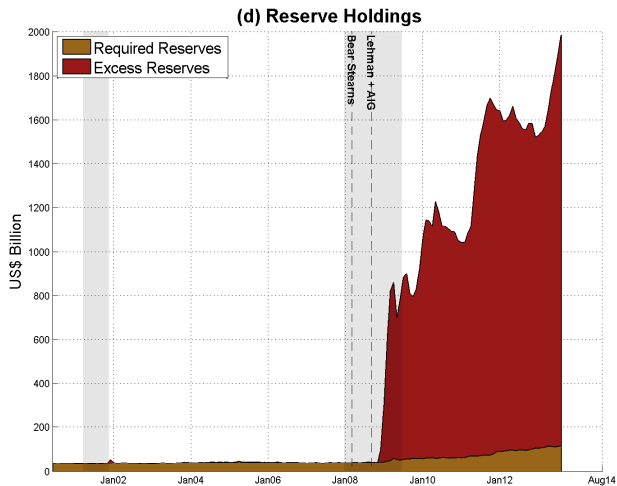
Bank Lending



Bank Lending and Deposits



Excess Reserves



This Paper

- ★ A micro-founded dynamic quantitative model of banks' liquidity management and monetary policy

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- Classic Liquidity Management
 - (+) Profit on Loans
 - Spread between loans and deposits
 - (-) Illiquidity Risk
 - After deposits transfers, bank may be short of reserves/liquid assets

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- ★ GE model with endogenous liquidity premium & money multiplier
- ★ Credit channel of monetary policy

Model Overview

1. Bank individual decision problem:

- Loan issuances, liquid assets, deposit creation, retain earnings
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★ Tractability

Application

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 5. Interest on Excess Reserves (Feldstein, Hall)

Literature Review

- **Reserve Management:** Poole (JF,1968),Bolton et al. (2012),
Saunders et al. (2011), Afonso & Lagos (2015)
- **Classic models of Banking:** Diamond & Dybvig (1983), Allen &
Gale (1998), Holmstrom & Tirole (1997,1998)
- **Banking in Macro:** Gertler & Karadi(2009), Gertler & Kiyotaki
(2011,2012), Curdia & Woodford(2009), Corbae & D'erasmo
(2013,2014)
- **Payments:** Freeman(AER,1996), Cavalcanti et al. (1998), Piazzesi
and Schneider (2015)
- **Money & credit:** , Wright et al. (2014), Brunnermeier & Sannikov
(2013), Williamson (2012,2016), Kiyotaki & Moore (2012)
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- **Time:** $t=1,2,3,\dots$
 - **Two stages:** $s=l,b$
 - Lending stage (l) and balancing stage (b)
- Continuum of banks with idiosyncratic liquidity shocks
- **Utility function:** Concave utility U over dividends c_t , $u(c) = \frac{c^{1-\sigma}}{1-\sigma}$

Banks' Balance Sheet ---

- Liabilities:
 - d_t demand deposits
- Assets:
 - m_t liquid assets (central bank reserves, T-bills)
 - b_t loans
- Interbank market loans f_t and discount-window loans w_t
- All assets/liabilities denominated in nominal terms

Banks' Problem (Lending Stage)_____

- Budget constraint

$$P_t c_t^j + \tilde{b}_{t+1}^j + \tilde{m}_{t+1}^j - \tilde{d}_{t+1}^j = b_t^j(1 + i_t^b) + m_t^j(1 + i_t^{ior}) - d_t^j(1 + i_t^d) - \left(1 + \bar{i}_t^f\right) f_t^j - (1 + i_t^{dw}) w_t^j - P_t T_t$$

- P_t price of goods in terms of reserves

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- P_t price of goods in terms of reserves
- Capital requirement constraint

$$\tilde{d}^j \leq \kappa \left(\tilde{b}^j + \tilde{m}^j - \tilde{d}^j \right) \quad (1)$$

Banks' Problem (Balancing Stage)_____

- Idiosyncratic withdrawal shock $\omega \in (-1, \infty], \omega \sim F_t(\omega), \quad \mathbb{E}(\omega) = 0$
- Borrow in interbank market f to satisfy res. req. (or $m_{t+1} \geq 0$)

$$d_{t+1}^j = \tilde{d}_{t+1}^j + \omega_t \tilde{d}_{t+1}^j$$

$$m_{t+1}^j = \tilde{m}_{t+1}^j + \omega_t^j \tilde{d}_{t+1}^j \left(\frac{1 + i_{t+1}^d}{1 + i_{t+1}^{ior}} \right) + f_{t+1}^j + w_{t+1}^j,$$

$$m_{t+1}^j \geq \rho d_{t+1}^j$$

$$s^j \equiv \underbrace{\tilde{m}_{t+1}^j - \omega \tilde{d}_{t+1}^j}_{\text{Reserves left}} - \underbrace{\rho \tilde{d}_{t+1}^j (1 - \omega)}_{\text{Deposits left}}$$

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Interbank Market

- “Dollar to dollar” matching (OTC markets of Atkeson et al. 2014)
- N rounds of matching
- Matching function for dollars in surplus (S^+) and deficit (S^-)
- Terminal outside options are discount window rates and interest on reserves
- Nash Bargaining
- See paper for analytical results for Fed funds rate and matching probabilities

Liquidity Cost Function χ_t ---

- Wedge in return to excess reserves and reserves deficits:
- Marginal Benefit of excess reserves:

$$\chi_t^+ = \gamma^+ \bar{i}_t^f + (1 - \gamma^+) i_t^{ior}$$

- Marginal cost of reserve deficits:

$$\chi_t^- = \gamma^- \bar{i}_t^f + (1 - \gamma^-) i_t^{dw}.$$

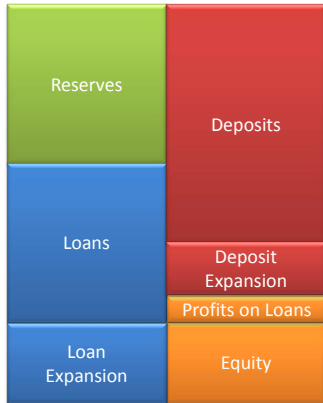
- Liquidity Cost Function:

$$\chi(s) = \begin{cases} \chi_t^+ s & \text{if } s > 0 \\ \chi_t^- s & \text{if } s \leq 0 \end{cases}$$

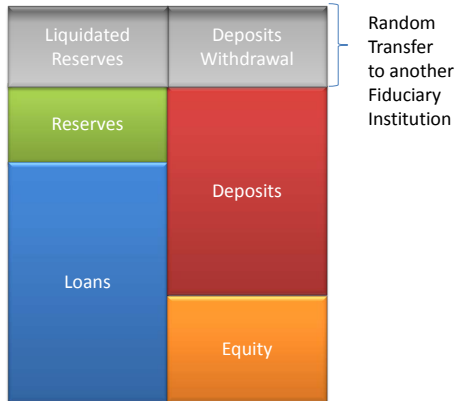
Balance Sheet ---

Reserves	Deposits
Loans	Equity

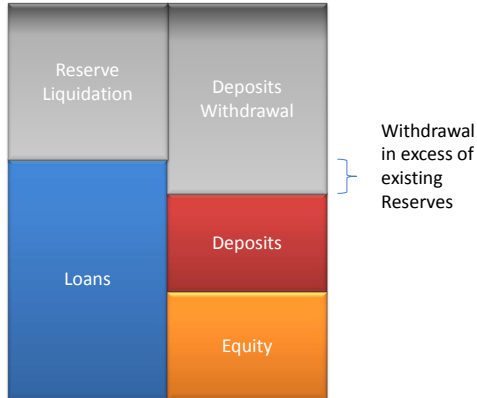
Expansion of Lending



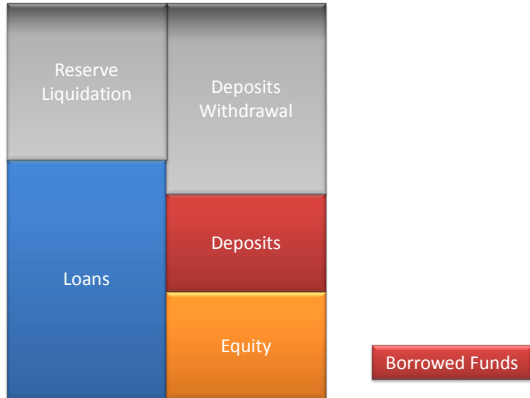
Withdrawal Risk



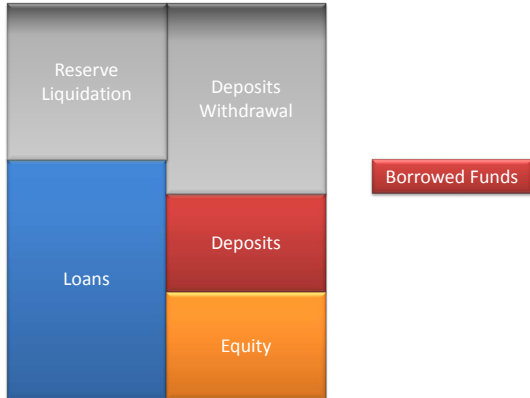
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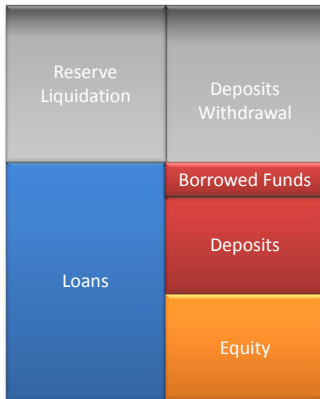
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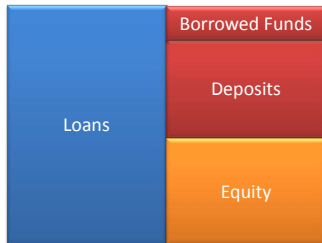
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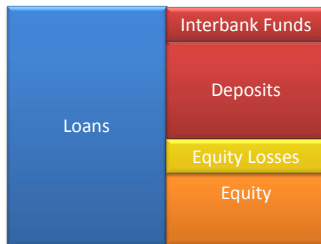
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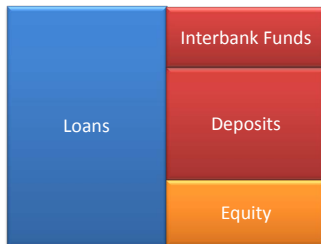
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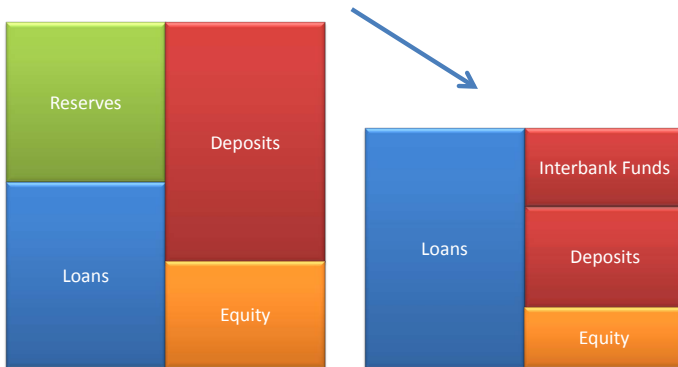
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Value Function - Lending Stage ---

$$V_t^l(b, m, d, f, w) = \max_{\{c, \tilde{b}, \tilde{d}, \tilde{m}\} \geq 0} u(c) + \mathbb{E} \left[V_t^b(\tilde{b}, \tilde{m}, \tilde{d}, \omega) \right]$$

$$\begin{aligned} & P_t c + \tilde{b} + \tilde{m} - \tilde{d} \\ &= b(1 + i_t^b) - d(1 + i_t^d) + m(1 + i_t^{IOR}) - (1 + \bar{i}_t^f) f - (1 + i_t^{dw}) w - P_t T_t \end{aligned}$$

(Budget Constraint)

$$\tilde{d} \leq \kappa \left(\tilde{b} + \tilde{m} - \tilde{d} \right).$$

(Capital Requirement)

Value Function - Balancing Stage _____

$$V_t^b(\tilde{b}, \tilde{m}, \tilde{d}, \omega) = \beta V_t^l(b', \tilde{m}', d', f, w)$$

$$b' = \tilde{b} \quad (\text{Evolution of Loans})$$

$$d' = \tilde{d} + \omega \tilde{d} \quad (\text{Evolution of Deposits})$$

$$m' = \tilde{m} - \omega \tilde{d} \left(\frac{1 + i_{t+1}^d}{1 + i_{t+1}^{ior}} \right) + f + w \quad (\text{Evolution of Reserves})$$

$$s = \tilde{m} + \frac{\omega \tilde{d}_{t+1} (1 + i_{t+1}^d)}{1 + i_{t+1}^{IOR}} - \rho \tilde{d}_{t+1} (1 + \omega) \quad (\text{Reserve Balance})$$

$$m' \geq \rho d' \quad (\text{Reserve Requirement})$$

$$f = \psi_t^- s \text{ and } w_{t+1} = (1 - \psi_t^-) s \text{ for } s < 0 \quad (2)$$

$$f = \psi_t^+ s \text{ and } w_{t+1} = 0 \text{ for } s > 0.$$

One Value Function ---

Define

$$e_t \equiv \frac{b_t(1 + i_t^b) + m_t(1 + i_t^{ior}) - d_t (1 + i_t^d) - \left(1 + i_t^f\right) f_t - \left(1 + i_t^f\right) w_t - T_t}{P_t}.$$

$$V_t(e) = \max_{\{c, \tilde{m}, \tilde{b}, \tilde{d}\} \geq 0} u(c) + \beta \mathbb{E}_t [V_{t+1}(e')],$$

$$e = \frac{\tilde{b} + \tilde{m} - \tilde{d}}{P_t} + c, \quad (\text{Budget Constraint})$$

$$e' = \left((1 + i_{t+1}^{ior}) \tilde{m} + (1 + i_{t+1}^b) \tilde{b} - (1 + i_{t+1}^d) \tilde{d} + \chi_{t+1}(s) \right) \frac{(1 - \tau_{t+1})}{P_{t+1}},$$

(Evolution of Equity)

$$s = \tilde{m} + \frac{\omega_t \tilde{d}' (1 + i_{t+1}^d)}{1 + i_{t+1}^{IOR}} - \rho \tilde{d}' (1 + \omega) \quad (\text{Reserve Balance})$$

$$\tilde{d} \leq \kappa \left(\tilde{b} + \tilde{m} - \tilde{d} \right). \quad (\text{Capital Requirement})$$

Closing the Model

- Loan Market Clears

$$\frac{B_{t+1}^d}{P_t} = \Theta_t^b \left(\frac{1}{(1 + i_{t+1}^b)} \frac{P_{t+1}}{P_t} \right)^\epsilon, \epsilon > 0, \Theta_t > 0,$$

- Deposit Market Clears (today perfectly elastic supply)

$$\frac{D_{t+1}^S}{P_t} = \Theta_t^d \left(\frac{1}{(1 + i_{t+1}^d)} \frac{P_t}{P_{t+1}} \right)^\zeta, \zeta > 0, \Theta_t^d > 0,$$

Central Bank Policies: The Fed ---

- Sets quantity of reserves M_t^{Fed}
- Buys loans B_{t+1}^{FED} , place deposits D_{t+1}^{FED}
- Discount window and interest on reserve rates i^{dw}, i^{ior}
- Fed budget constraint:

$$\begin{aligned} & M_t^{Fed}(1 + i_t^{ior}) + D_{t+1}^{Fed} + B_{t+1}^{Fed} + W_{t+1}^{Fed} \dots \\ = & M_{t+1}^{Fed} + D_t^{Fed}(1 + i_t^d) + B_t^{Fed}(1 + i_t^b) + W_t^{Fed}(1 + i_t^{dw}) + P_t T_t. \end{aligned}$$

- Stationary equilibrium: constant nominal growth of balance sheet
- Impulse responses: focus on fixed nominal balance sheet or keep constant inflation (today)

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Market Clearing

$$\int_j b_{t+1}^j + B_{t+1}^{Fed} = B_{t+1}^d \quad (\text{Loans markets clearing})$$

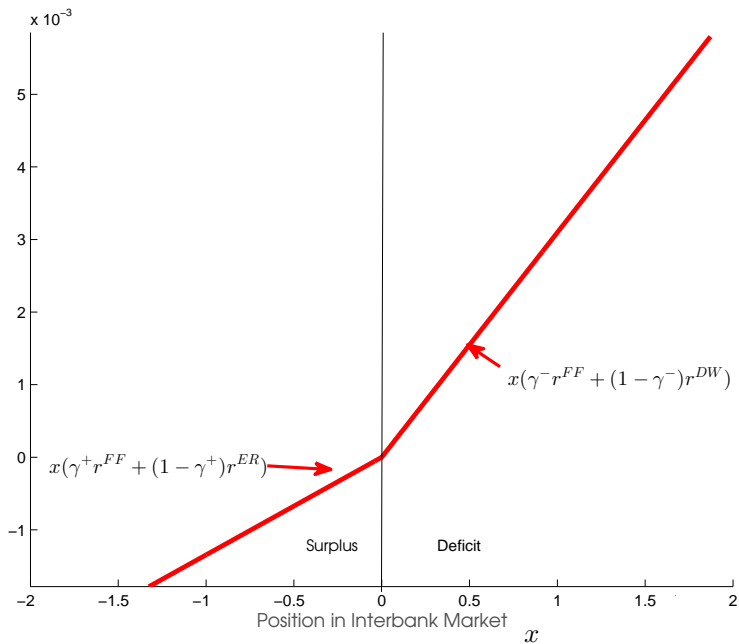
$$\int_j d_t^j - D_{t+1}^{Fed} = D_{t+1}^S \quad (\text{Deposits market clearing})$$

$$\int_j m_{t+1}^j = M_{t+1}^{Fed} \quad (\text{Reserves market clearing})$$

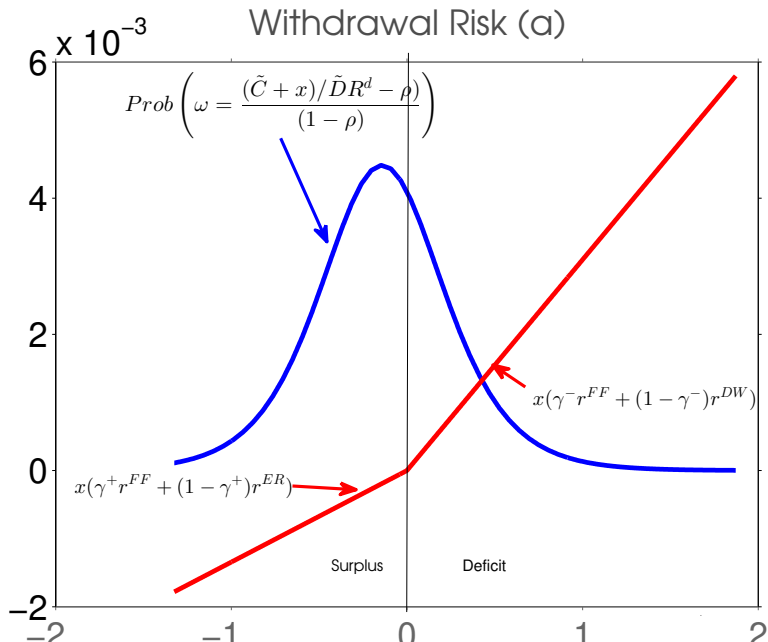
$$\int_j f_t^j = 0 \quad (\text{Interbank markets clearing})$$

$$\int_j w_t^j = W_{t+1}^{Fed} \quad (\text{Discount window market clearing})$$

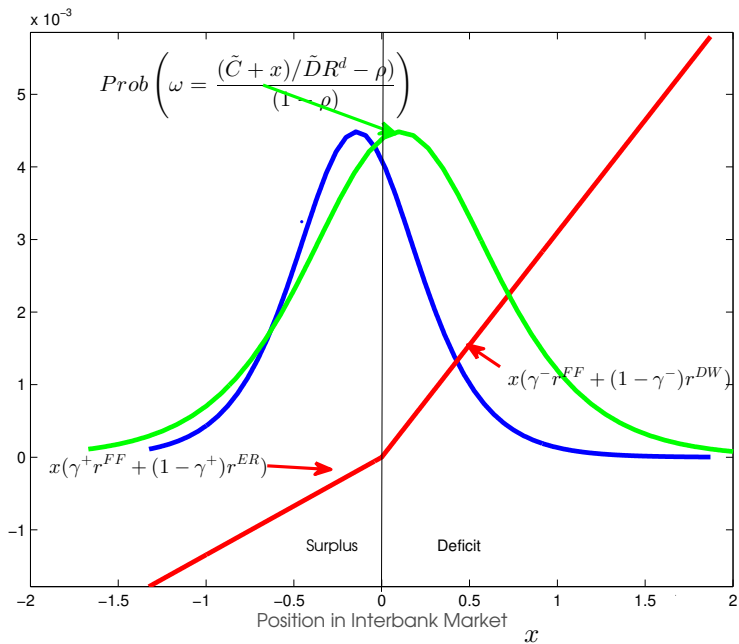
Liquidity Cost



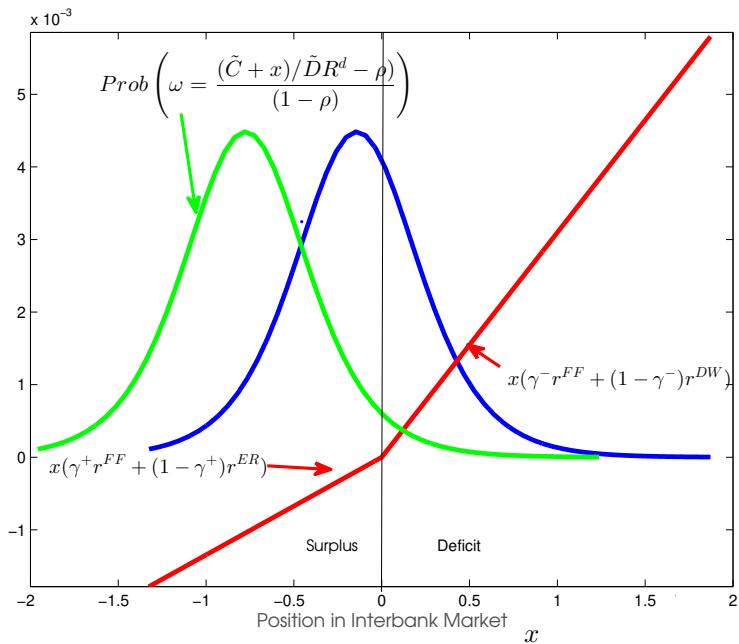
Liquidity Management



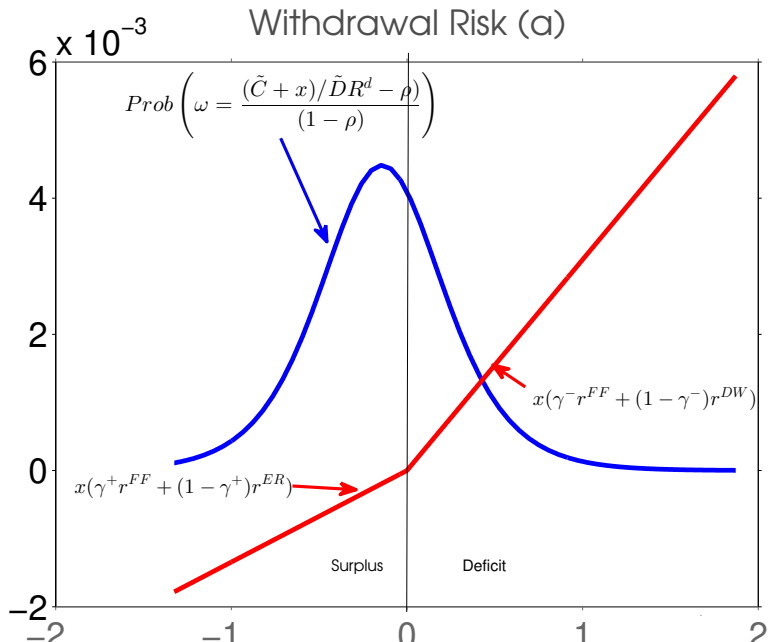
↑ Deposits



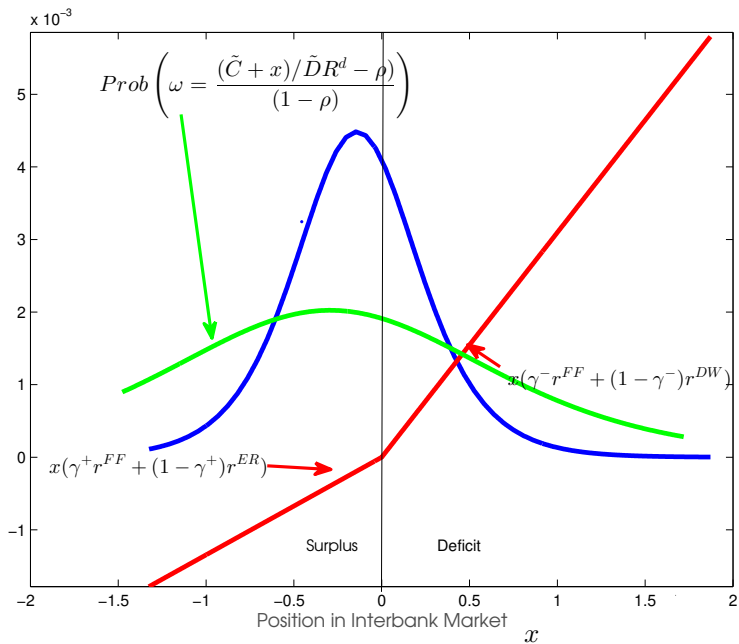
↑ Reserves ---



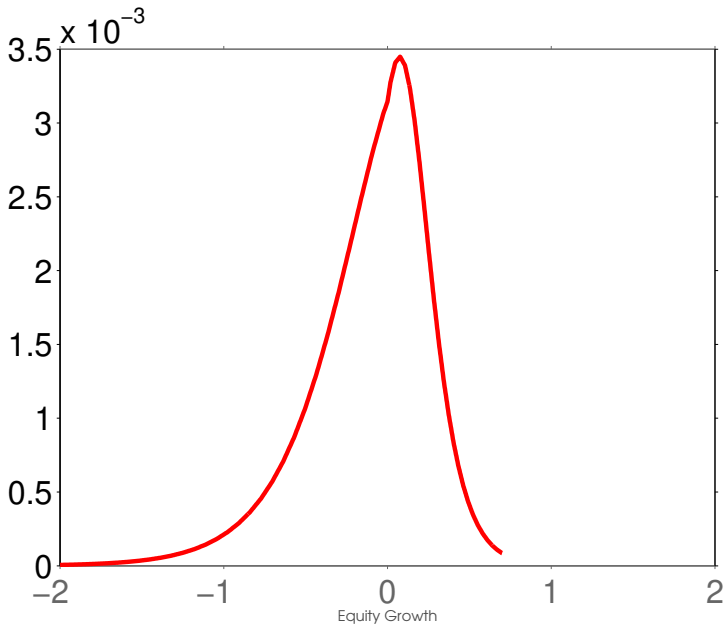
Liquidity Management



↑ Withdrawal Risk



Equity Growth



Proposition (Homogeneity and Portfolio Separation)

(i) The value function $V_t(b, m, d)$ satisfies

$$V_t(e) = v_t(e)^{1-\gamma},$$

(ii) where $v(\cdot)$ satisfies

$$\Omega_t \equiv \max_{\{\bar{b}, \bar{m}, \bar{d}\} \geq 0} \left\{ \mathbb{E}_\omega \left[R_t^b \bar{b} + R_t^m \bar{m} - R_t^d \bar{d} + \chi(\bar{m}, \bar{d}, \omega) \right]^{1-\gamma} \right\}^{\frac{1}{1-\gamma}},$$

$$\bar{b} + \bar{m} - \bar{d} = 1,$$

$$\bar{d} \leq \kappa (\bar{b} + \bar{m} - \bar{d}).$$

(iii)

$$\begin{aligned} \tilde{b}'_{t+1}(e_t) &= P_t \bar{b}_t (1 - \bar{c}) e_t, \\ \tilde{m}'_{t+1}(e_t) &= P_t \bar{m}_t (1 - \bar{c}) e_t, \\ \tilde{d}'_{t+1}(e_t) &= P_t \bar{d}_t (1 - \bar{c}) e_t. \end{aligned}$$

(iv) \bar{c}_t, v_t are given by

$$v_t = \frac{1}{1-\gamma} \left[1 + \left(\beta(1-\gamma) \Omega_t^{1-\gamma} v_{t+1} \right)^{\frac{1}{\gamma}} \right]^\gamma.$$

$$\bar{c}_t = \frac{1}{1 + [\beta(1-\gamma) v_{t+1} \Omega_t^{1-\gamma}]^{1/\gamma}}.$$

Liquidity Premium

$$\underbrace{R^b - R^m}_{\text{Liquidity Premium}} = \underbrace{\mathbb{E}_\omega \left[\frac{\partial \chi(\bar{d}, \bar{m}, \omega)}{\partial \bar{m}} \right]}_{\text{First-order liquidity premium}} + \underbrace{\mathbb{E}_\omega \frac{\text{COV}_\omega \left[(R^e)^{-\gamma}, \frac{\partial \chi(\bar{d}, \bar{m}, \omega)}{\partial \bar{m}} \right]}{\mathbb{E}_\omega \left[(R^e)^{-\gamma} \right]}}_{\text{Liquidity risk premium}}$$

$$\underbrace{R^b - R^d}_{\text{External finance premium}} = \underbrace{\frac{\mathbb{E}_\omega \left[(R_\omega^e)^{-\gamma} \cdot \frac{\partial \chi(\bar{d}, \bar{m}, \omega)}{\partial \bar{d}} \right]}{\mathbb{E}_\omega \left[(R^e)^{-\gamma} \right]}}_{\text{Deposit Liquidity Cost}} + \underbrace{\frac{\mu}{\mathbb{E}_\omega \left[(R_\omega^e)^{-\gamma} \right]}}_{\text{Collateral term}}$$

Liquidity Premium

$$\underbrace{R^b - R^m}_{\text{Liquidity Premium}} = \underbrace{\mathbb{E}_\omega \left[\frac{\partial \chi(\bar{d}, \bar{m}, \omega)}{\partial \bar{m}} \right]}_{\text{First-order liquidity premium}} + \underbrace{\mathbb{E}_\omega \frac{\text{COV}_\omega \left[(R^e)^{-\gamma}, \frac{\partial \chi(\bar{d}, \bar{m}, \omega)}{\partial \bar{m}} \right]}{\mathbb{E}_\omega \left[(R^e)^{-\gamma} \right]}}_{\text{Liquidity risk premium}}$$

$$\underbrace{R^b - R^d}_{\text{External finance premium}} = \underbrace{\frac{\mathbb{E}_\omega \left[(R_\omega^e)^{-\gamma} \cdot \frac{\partial \chi(\bar{d}, \bar{m}, \omega)}{\partial \bar{d}} \right]}{\mathbb{E}_\omega \left[(R^e)^{-\gamma} \right]}}_{\text{Deposit Liquidity Cost}} + \underbrace{\frac{\mu}{\mathbb{E}_\omega \left[(R_\omega^e)^{-\gamma} \right]}}_{\text{Collateral term}}$$

Banks are satiated with reserves if

- (i) The Fed pays interest on reserves such that $i_t^{ior} = i_t^b$
- (ii) The Fed pays interest on reserves such that $i_t^{ior} = i_t^D$, and $\kappa = \infty$
- (iii) The Fed sets the discount window rate to $i_t^{dw} = 0$

Quantitative Exercise

Calibration Strategy

- F_t approximated with a logistic distribution
 - Cross-sectional distribution of deposits growth rates (Call Reports)
 - ▶ distribution
- Loan-demand elasticity = 1.8
 - Bassett, Chosak, Driscoll, and Zakrajsek (2013)

Calibration

	Value	Source/Target
Capital requirement	$\kappa = 10$	Regulatory parameter
Discount factor	$\beta = 0.993$	Dividend ratio = 8 %
Risk aversion	$\gamma = 1$	Constant dividend-equity ratio
Reserve requirement	$\rho = 0.1$	Regulatory parameter
Deposit supply intercept	$\Theta^d = 9.6$	Annual deposit rate = 1%
Loan demand intercept	$\Theta^b = 10.4$	Unit steady state equity
Discount window rate (annual)	$i^{dw} = 6\%$	2006 value
Interest on reserves (annual)	$i^{ior} = 0\%$	2006 value
Bargaining parameter	$\eta = 0.5$	Baseline value
Inflation	$g = 2\%$	Long-run inflation target
Matching friction	$\lambda = 2.1$	DW loans to reserves $W/M = 2$
Volatility	$\sigma = 0.04$	Reserve-balance distribution
Loan demand deposit supply elasticities	$\zeta = -\epsilon = 25$	Bank credit response to policy

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- *Approach*
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 - Second: Fit calibrated sequences of shocks