Procyclical Finance: The Money View

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joining OSU Fisher College of Business (Finance)

4 April 2017
Introduction: Motivation

- In the years leading up to the Great Recession
  - Demand for money-like assets: Deposits, MMMF (repo, ABCP), Treasuries
    - Corporate liquidity management (e.g. Poszar, 2011)
    - Foreign savings (e.g. Bernanke, 2003)
    - Demand for collateral (e.g. BIS, 2001)
  - Supply of money-like assets: Short term debt issued by the financial sector
    - Leverage increases (e.g. Adrian and Shin (2010))
- Financial crisis: A collapse in the supply of money-like assets
Introduction: Questions

Today’s theme: Dynamics of demand and supply of money-like asset

1. Financial instability
   - What drives the cyclicality of financial intermediaries’ leverage?

2. Real economic fluctuations
   - Depth, frequency, and duration of financial crises?

3. Asset pricing
   - How does banks’ money creation affect asset prices?

4. Government debt
   - How does government debt affect financial instability?
Introduction: Model Preview - Structure

**Households**
- Assets: Collateral (e.g., houses), Bank, firm equities
- Liabilities: Bank Loan, Equity

“Borrowing Sector”
inc. borrowing firms: industrials, energy ...

**Banks**
- Assets: Loans
- Liabilities: Deposits, Equity

“Intermediation”
inc. depository & shadow

**Intangible Firms**
- Assets: Cash, Intangible Assets
- Liabilities: Equity

“Saving Sector”
inc. cash firms: tech, drugs ...

**Government**
- Assets: Tax
- Liabilities: Debt

Data: Money Decomposition  Data: Cash Evolution  Data: T-Bill Before and After the Crisis
Introduction: Model Preview - Literature

- Starting point: borrowing constraint on firms' investment

- What financial intermediaries can do?
  - Money: issue securities held by firms as internal liquidity – Holmström and Tirole (1998); “liquidity” is bank debt (Hart and Zingales (2015))

- What limits intermediaries' activities?

- Money view + firms’ money demand + B/S channel → new predictions
Introduction: Predictions

1 Financial instability - procyclical intermediary leverage

2 Real economic fluctuation
   - Procyclical leverage + banks’ payout/recapitalization under friction →
     Frequent crisis, slow recovery (10 years)

3 Collateral asset pricing
   - Banks chase assets to back money: low loan rate → high collateral price

4 Government debt amplifies leverage cycle and prolongs crisis
   - Stabilizing effect: Greenwood, Hanson, and Stein (2015), Krishnamurthy and Vissing-Jorgensen (2015); Woodford (2016)
Model: Households

Households

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|           | Equity       |

Intangible Firms

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Model: Households

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- Collateral depreciates stochastically
  \[ \delta dt - \sigma dZ_t \]
- One-to-one mapping between collateral and loan:
  Loan default rate = \[ \delta dt - \sigma dZ_t \]
1. Loan return is risky:
   \[ R_t - (\delta dt - \sigma dZ_t) \]

2. HH FOC: \[ R_t = \rho + \delta - \kappa_t \]

   Loan \leq Collateral Value = q_t^T k_t^T
Model: Entrepreneurs – Intangible Firms

1. \( R_t - \delta = \rho - \kappa_t^T \)  
   Loan \( \leq \) Collateral Value

2. Loan return is risky:  
   \( R_t - (\delta dt - \sigma dZ_t) \)
Model: Entrepreneurs – Intangible Firms

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### Model: Entrepreneurs – Intangible Firms

#### Intangible Firms

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<td>$q_t^I k_t^I$</td>
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\[
E \left[ \int_{t=0}^{\infty} e^{-\rho t} dc_t^I \right]
\]

Equity issuance: $dc_t^I < 0$
Model: Entrepreneurs – Intangible Firms

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\[ \mathbb{E} \left[ \int_{t=0}^{\infty} e^{-\rho t} dc_t^I \right] \]

Equity issuance: $dc_t^I < 0$

One unit of capital produces $\alpha dt$

Aggregate capital: $K_t^I = \int_{s \in [0,1]} k_t^I (s) \, ds$
Model: Entrepreneurs – Intangible Firms

Intangible Firms

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Poisson $\lambda$

Capital destroyed

Grow

Invest goods $i_t^I k_t^I$
Model: Entrepreneurs – Intangible Firms

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Poisson $\lambda$

Capital destroyed

Grow

Invest goods $i_t^t k_t^I$

Assets

Intangible Capital upgraded $q_t^I [1 + F(i_t^I)] k_t^I$

Liabilities

Equity
Model: Entrepreneurs – Intangible Firms

Intangible Firms

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Poisson $\lambda$

Capital destroyed

Grow

No external financing

Invest goods $i_t^I k_t^I$

Assets

Liabilities

Intangible Capital upgraded

$q_t^I \left[ 1 + F(i_t^I) \right] k_t^I$

Equity
Model: Entrepreneurs – Intangible Firms

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<td>Intangible capital $q_t^I k_t^I$</td>
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Capital destroyed

Poisson $\lambda$

Grow

No external financing

Invest goods $i_t^I k_t^I$

Assets

Intangible Capital upgraded

$\lambda^I$ $[1 + F(i_t^I)] k_t^I$

Liabilities

Equity
## Model: Entrepreneurs – Intangible Firms

### Intangible Firms

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<td>$m_t^{I}k_t^{I}$</td>
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<tr>
<td>$q_t^{I}k_t^{I}$</td>
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### Capital destroyed

- **Poisson $\lambda$**
- **Grow**
- **No external financing**
- **Invest goods** $i_t^{I}k_t^{I}$
- $i_t^{I} \leq m_t^{I}$

### Assets

**Intangible Capital upgraded**

$$q_t^{I} \left[ 1 + F \left( i_t^{I} \right) \right] k_t^{I}$$

**Liabilities**

**Equity**
**Model: Entrepreneurs – Intangible Firms**

### Intangible Firms

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<td>( m_t^I k_t^I )</td>
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<tr>
<td>Intangible</td>
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<tr>
<td>capital</td>
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<td>( q_t^I k_t^I )</td>
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#### Capital destroyed

- Poisson \( \lambda \)
- Grow
- No external financing
- Invest goods \( i_t^I k_t^I \)
- \( i_t^I \leq m_t^I \)

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<td>( q_t^I [1 + F(i_t^I)] k_t^I )</td>
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**Proposition: Money demand function**

\[
\rho - r_t = \lambda \left[ q_t^I F(m_t^I) - 1 \right]
\]

- Deposit carry cost
- Convenience yield
Model: Entrepreneurs – Intangible Firms

Households

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Collateral premium $\kappa_t^T$

1. $R_t - \delta = \rho - \kappa_t^T$
   Loan $\leq$ Collateral Value

2. Loan return is risky:
   $R_t - (\delta t - \sigma dZ_t)$

Banks

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Money demand

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Intangible Assets

Money demand

$\rho - r_t = \lambda [q_t F'(m_t) - 1]$
### Model: Banks

#### Households

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1. \( R_t - \delta = \rho - \kappa_t T \)
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Net interest margin:
\( R_t - \delta - r_t = \rho - r_t - \kappa_t T \)

Focus: What limits deposit creation?

#### Intangible Firms

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\( \rho - r_t = \lambda [q_t F'(m_t) - 1] \)
Money demand

**Money demand**
Model: Banks

### Households

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1. $R_t - \delta = \rho - \kappa_T^T$
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- Risk-neutral banker
- Issue deposits at rate $r_t$
  - Choose debt-to-equity ratio $x_t^B$ (leverage)
- Issue equity under proportional cost $\chi$
  → Balance-sheet channel

### Intangible Firms

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$\rho - r_t = \lambda [q_t^l F'(m^l_t) - 1]$
- Money demand

Details
### Model: Banks

#### Households

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1. Value function: $q_B^t \cdot$ equity,
   with $\frac{dq^B_t}{q^B_t} = \mu^B_t dt + \sigma^B_t dZ_t$ in equilibrium

2. Pay dividends when $q^B_t = 1$;
   raise equity when $q^B_t = 1 + \chi$ (barriers)

3. Required return:
   $-\text{cov}_t \left( \frac{dq^B_t}{q^B_t}, \text{loan return} \right) = \gamma^B_t \sigma^B$, with $\gamma^B_t = -\sigma^B_t$

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$\rho - r_t = \lambda \left[ q^I_t F' (m^I_t) - 1 \right]$ Money demand

Details
Model: Banks

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1. \( R_t - \delta = \rho - \kappa_t^T \)
   Loan \( \leq \) Collateral Value

2. Loan return is risky:
   \[ R_t - (\delta dt - \sigma dZ_t) \]

**Proposition:** Intermediary money pricing

\[ \rho - r_t - \kappa_t^T = \gamma_t^B \sigma \]

\[ \rho - r_t = \lambda \left[ q_t^I F'(m_t^I) - 1 \right] \]
Money demand

Money demand
Equilibrium: State Variable Dynamics

Simulated Sample Paths of the State Variable

State variable = \( \frac{\text{Aggregate Bank Equity}}{\text{Total Capital Stock}} \)

State Variable & Solution  |  Boundary Conditions  |  Calibration
Equilibrium: Procyclical Balance-sheet Capacity

\[ \gamma_t^B \text{ and Bank Equity} \]

- Blue line: \( \gamma_t^B \)
- Red dashed line: Issuance boundary \( q_t^B = 1 + \chi \)
- Green dashed line: Payout boundary \( q_t^B = 1 \)

- Red arrow: Bad shock
- Green arrow: Good shock

\begin{align*}
\gamma_t^B & = 1 + \chi \\
q_t^B & = 1
\end{align*}
Equilibrium: Procyclical Balance-sheet Capacity

\(\gamma_t^B \) through the Cycle

- Issuance boundary: \( q_t^B = 1 + \chi \)
- Payout boundary: \( q_t^B = 1 \)

60\% - 30\% = 30\% of time

State Variable CDF
Result 1: Leverage Dynamics

### Households

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\[
\rho - r_t - \kappa_t^T = \gamma_t^B \sigma \\
\text{Intermediary money pricing}
\]

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\[
\rho - r_t = \lambda \left[ q_t^I F'(m_t^I) - 1 \right] \\
\text{Money demand}
\]

Question 1: Why is financial intermediaries’ leverage procyclical?
Result 1: Procyclical Money Creation

Money Demand: $\rho - r_t = \lambda \left[ q_t^l F'(m_t^l) - 1 \right]$
Result 1: Procyclical Money Creation

Money Demand: \( \rho - r_t = \lambda \left[ q_t^l F' \left( m_t^l \right) - 1 \right] \)
Result 1: Intertemporal Feedback and Procyclical Money Demand

*Intertemporal complementarity of money demand*

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<tr>
<th>Present</th>
<th>Future</th>
<th>Future</th>
<th>Future</th>
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<tbody>
<tr>
<td>date $t$</td>
<td>date $t + dt$</td>
<td>date $t + 2dt$</td>
<td>...</td>
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- Good shock
  - $\gamma_t^B$ & carry cost falls
  - Deposits increase
  - Capital grows faster in $dt$
  - Capital value $q_t^I$ increases

- $\gamma_{t+dt}^B$ & carry cost falls
  - Deposits increase
  - Capital grows faster in $dt$
  - Capital value $q_{t+dt}^I$ increases

- $\gamma_{t+2dt}^B$ & carry cost falls
  - Deposits increase
  - Capital grows faster in $dt$
  - Capital value $q_{t+2dt}^I$ increases

Persistent Effect of Shocks
Result 1: Procyclical Leverage

Bank Leverage $x_i^B$

Cumulative Probability

HH's collateral constraint binds

Financial Innovation – collateral velocity  
Banks Hold $K^T$  
Evidence: Adrian and Shin (2010)
Result 2: Cyclical Money Creation and Investment Inefficiencies

Households

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<th>Assets</th>
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<tbody>
<tr>
<td><strong>Tangible</strong></td>
<td><strong>Bank Loan</strong></td>
</tr>
<tr>
<td>Collateral</td>
<td><strong>Equity</strong></td>
</tr>
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<td><em>B’s and I’s</em></td>
<td></td>
</tr>
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<td>equities</td>
<td></td>
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</tbody>
</table>

1. $R_t - \delta = \rho - \kappa_t^T$
   Loan $\leq$ Collateral Value

2. Loan return is risky:
   $R_t - (\delta dt - \sigma dZ_t)$

Banks

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<td><strong>Loans</strong></td>
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$\rho - r_t - \kappa_t^T = \gamma_t^B \sigma$
Intermediary money pricing

Intangible Firms

<table>
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<tr>
<td><strong>Cash</strong></td>
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</tr>
<tr>
<td><strong>Intangible</strong></td>
<td></td>
</tr>
<tr>
<td>Assets</td>
<td></td>
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</table>

$\rho - r_t = \lambda \left[ q_t F' \left( m_t^I \right) - 1 \right]$
Money demand

Question 2: What are the macro consequences of cyclical money creation?
Result 2: Instability & Stagnation

Panel A: Cumulative Probability

Panel B: Time (Years) to Recovery

Expected time to reach from issuance boundary

Positive growth

Aggregate Bank Equity
Total Goods Produced per Year

Cumulative Probability
Issuance boundary
Payout boundary
Result 2: Static and Dynamic Investment Inefficiencies

Decompose money premium: \( \rho - r_t = \gamma_t^B \sigma + \kappa_t^T \)

Convenience yield: \( \rho - r_t = \lambda \left[ q_t^I F' (m_t^I) - 1 \right] \)
Result 2: Static and Dynamic Investment Inefficiencies

Decompose money premium: $\rho - r_t = \gamma_t B \sigma + \kappa_t T$

Convenience yield: $\rho - r_t = \lambda [q_t F'(m_t) - 1]$

- Investment inefficiencies
Result 2: Static and Dynamic Investment Inefficiencies

\[ \Delta \text{Decompose money premium: } \rho - r_t = \gamma_t^B \sigma + \kappa_t^T \]

\[ \Delta \text{Convenience yield: } \rho - r_t = \lambda \left[ q_t^F'(m_t^l) - 1 \right] \]

- Investment inefficiencies
  - Static: \( q_t^l F'(m_t^l) > 1 \), given current capital valuation \( q_t^l \)
Result 2: Static and Dynamic Investment Inefficiencies

Decompose money premium: \( \rho - r_t = \gamma_t^B \sigma + \kappa_t^T \)

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- Investment inefficiencies
  - Static: \( q_t^l F'(m_t^l) > 1 \), given current capital valuation \( q_t^l \)
  - Dynamic: \( q_t^l < q_{FB}^l \), low capital valuation due to suboptimal growth
Result 2: Static and Dynamic Investment Inefficiencies

Decompose money premium: \( \rho - r_t = \gamma^B_t \sigma + \kappa^T_t \)

Convenience yield: \( \rho - r_t = \lambda \left[ q_t' F'(m_t^l) - 1 \right] \)

- Investment inefficiencies
  - Static: \( q_t' F'(m_t^l) > 1 \), given current capital valuation \( q_t^l \)
  - Dynamic: \( q_t^l < q_{FB}^l \), low capital valuation due to suboptimal growth

- Limits on money creation
  1. Bank balance-sheet capacity, due to recapitalization friction
  2. General inside liquidity shortage (Holmström and Tirole (1998))
Result 2: Investment Cycle

Panel A: Static Inefficiency

Panel B: Dynamic Inefficiency
Result 2: Investment Cycle

Panel A: Static Inefficiency

Panel B: Dynamic Inefficiency
Result 3: Collateral Pricing & Intermediated Money Premium

Households

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Intangible Firms

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$\rho - r_t = \lambda \left[ q^I_t F' \left( m^I_t \right) - 1 \right]$
Money demand

**Question 3:** How does money creation push up collateral price?
Result 3: Collateral Pricing & Intermediated Money Premium

\[ \rho - r_t = \gamma_t^B \sigma + \kappa_t^T \]

Money demand curve
Bank indifference curve: low equity
Bank indifference curve: high equity
Max deposits created limited HH borrowing

\[ \kappa_t^T > 0 \]
Result 3: Collateral Pricing & Intermediated Money Premium

Panel A: Collateral Premium $\kappa^T_i$

Panel B: Tangible Capital Price $q^T_t$

Tangible Capital Pricing
Question 4: How does government debt affect the leverage cycle and duration of crisis?
Result 4: Equity Crowding Out & Amplified Leverage Cycle

Panel A: Bank Leverage ($x_t^B$)

Panel B: Cumulative Probability

New deposit demand curve
Evidence
Result 4: Government Debt and Stagnation

Expected Time to Recovery from Bank Recapitalization Boundary

- 1972 - 1982
- 1990 - 2007
- 2010 - present

Years

0 5 10 15 20 25 30

Government Debt / Output

0 50% 100% 150%
Conclusion

0 Intermediary balance-sheet impairment → money-like securities supply ↓
   → resources reallocation ↓
Conclusion

0 Intermediary balance-sheet impairment $\rightarrow$ money-like securities supply $\downarrow$
  $\rightarrow$ resources reallocation $\downarrow$

1 *Intermediary* B/S: procyclical money creation $\rightarrow$ procyclical leverage
Conclusion

0 Intermediary balance-sheet impairment $\rightarrow$ money-like securities supply ↓
   $\rightarrow$ resources reallocation ↓

1 *Intermediary B/S*: procyclical money creation $\rightarrow$ procyclical leverage

2 *Macro*: investment inefficiencies, frequent and stagnant crises
Conclusion

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3 *Asset pricing*: intermediated money premium in collateral price
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4 *Government debt*: crowd out banks’ profit and prolong crisis
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1 *Intermediary B/S*: procyclical money creation $\rightarrow$ procyclical leverage

2 *Macro*: investment inefficiencies, frequent and stagnant crises

3 *Asset pricing*: intermediated money premium in collateral price

4 *Government debt*: crowd out banks’ profit and prolong crisis

- General: money demand dynamics $\rightarrow$ leverage and financial instability
- Extensions: *financial markets, regulatory constraint, credit view*
Model: Households

- A unit mass of risk-neutral households: $\mathbb{E} \left[ \int_{t=0}^{\infty} e^{-\rho t} dc_t^T \right]$
Model: Households

- A unit mass of risk-neutral households: $\mathbb{E} \left[ \int_{t=0}^{\infty} e^{-\rho t} dc_t^T \right]$

- Each own $k_t^T$ units of tangible capital
  - One unit of capital produces $\alpha dt$ goods
Model: Households

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- Each own $k^T_t$ units of tangible capital
  - One unit of capital produces $\alpha dt$ goods

- Borrow from banks: loans $\leq q^T_t k^T_t$
  - Capital price $q^T_t$
  - Lagrange multiplier: $\kappa^T_t \geq 0$

Aggregate shock $dZ_t$: $\delta dt - \sigma dZ_t$
fraction of capital destroyed per $dt$
Loan cost: $(1 + R_t dt) \left[ 1 - (\delta dt - \sigma dZ_t) \right] = 1 + R_t dt - (\delta dt - \sigma dZ_t)$
Model: Households

- A unit mass of risk-neutral households: \( \mathbb{E} \left[ \int_{t=0}^{\infty} e^{-\rho t} d\zeta_t^T \right] \)

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- Loan cost: \( (1 + R_t dt) \left[ 1 - (\delta dt - \sigma d\zeta_t) \right] = 1 + R_t dt - (\delta dt - \sigma d\zeta_t) \)
  - default probability
Model: Households

- A unit mass of risk-neutral households: \( \mathbb{E} \left[ \int_{t=0}^{\infty} e^{-\rho t} dc_t^T \right] \)

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- Proposition: \( R_t - \delta = \rho - \kappa_t^T \)
Model: Banks

- A unit mass of representative bankers maximize

\[ E \left\{ \int_{t=0}^{\tau} e^{-\rho t} \left[ I_{\{dc_t^B \geq 0\}} - (1 + \chi) I_{\{dc_t^B < 0\}} \right] dc_t^B \right\} \]

- \( dc_t^B > 0 \) means payout; \( dc_t^B < 0 \) means issuance subject to dilution cost
Model: Banks

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\[ \mathbb{E} \left\{ \int_{t=0}^{\tau} e^{-\rho t} \left[ \mathbb{I}\{dc_t^B \geq 0\} - (1 + \chi) \mathbb{I}\{dc_t^B < 0\} \right] dc_t^B \right\} \]

- \( dc_t^B > 0 \) means payout; \( dc_t^B < 0 \) means issuance subject to dilution cost

- Balance sheet management

\[ de_t^B = -dc_t^B \]

\[ \text{equity change} \quad \text{payout/issue} \]
Model: Banks

- A unit mass of representative bankers maximize

\[
\mathbb{E}\left\{ \int_{t=0}^{\tau} e^{-\rho t} \left[ \mathbb{I}\{dc_t^B \geq 0\} - (1 + \chi) \mathbb{I}\{dc_t^B < 0\} \right] dc_t^B \right\}
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- \( dc_t^B > 0 \) means payout; \( dc_t^B < 0 \) means issuance subject to dilution cost

- Balance sheet management

\[
de_t^B = - dc_t^B + e_t^B x_t^B \left[ R_t dt - (\delta dt - \sigma dZ_t) \right]
\]

\( de_t^B \) equity change \( dc_t^B \) payout/issue \( e_t^B x_t^B \) loan value \( \delta dt - \sigma dZ_t \) loan return
Model: Banks

- A unit mass of representative bankers maximize

\[ \mathbb{E} \left\{ \int_{t=0}^{\tau} e^{-\rho t} \left[ \mathbb{I}_{\{dc_t^B \geq 0\}} - (1 + \chi) \mathbb{I}_{\{dc_t^B < 0\}} \right] dc_t^B \right\} \]

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\[
de_t^B = -dc_t^B + e_t^B x_t^B \left[ R_t dt - (\delta dt - \sigma dZ_t) \right] - e_t^B \left( x_t^B - 1 \right) r_t dt
\]

- Deposits: short-term risk-free debt with interest \( r_t dt \)
Model: Banks

- A unit mass of representative bankers maximize

\[
\mathbb{E} \left\{ \int_{t=0}^{\tau} e^{-\rho t} \left[ \mathbb{I}_{\{ dc_t^B \geq 0 \}} - (1 + \chi) \mathbb{I}_{\{ dc_t^B < 0 \}} \right] dc_t^B \right\}
\]

- \( dc_t^B > 0 \) means payout; \( dc_t^B < 0 \) means issuance subject to dilution cost

- Balance sheet management

\[
\begin{align*}
\frac{de_t^B}{dt} &= - \frac{dc_t^B}{dt} + e_t^B x_t^B \left[ R_t dt - (\delta dt - \sigma dZ_t) \right] - e_t^B \left( x_t^B - 1 \right) r_t dt - e_t^B \iota dt \\
&= \text{equity change} - \text{payout/issue} + \text{loan value} \times \text{loan return} - \text{debt value} \times \text{interest}
\end{align*}
\]

- Deposits: short-term risk-free debt with interest \( r_t dt \)
- Cost of operations \( \iota \) motivates payout
Banks’ value function: $q^B_t e^B_t$, with $\frac{dq^B_t}{q^B_t} = \mu^B_t dt + \sigma^B_t dZ_t$ in equilibrium

- Pay dividends when $q^B_t = 1$; raise equity when $q^B_t = 1 + \chi$ (barriers)
Model: Banks

- Banks’ value function: $q_t^B e_t^B$, with $\frac{dq_t^B}{q_t^B} = \mu_t^B dt + \sigma_t^B dZ_t$ in equilibrium
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- Banks are effectively risk-averse
  - Issuance cost: $dZ_t < 0$ decreases $e_t^B$, but increases marginal value $q_t^B$
Model: Banks

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- Expected return from loans financed by risk-free debt: $\rho - r_t - \kappa_t^T$
  - Reminder: HH’s indifference condition is $R_t - \delta = \rho - \kappa_t^T$
Model: Banks

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  - Reminder: HH’s indifference condition is $R_t - \delta = \rho - \kappa_t^T$

- Required return: $-\text{cov}_t \left( \frac{dq_t^B}{q_t^B}, \text{loan return} \right) = \gamma_t^B \sigma$, with $\gamma_t^B = -\sigma_t^B$
  - Reminder: loan return is $R_t dt - (\delta dt - \sigma dZ_t)$
Model: Banks

- Banks’ value function: $q_t^B e_t^B$, with $\frac{dq_t^B}{q_t^B} = \mu_t^B dt + \sigma_t^B dZ_t$ in equilibrium
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  - Reminder: loan return is $R_t dt - (\delta dt - \sigma dZ_t)$

- Proposition $\rho - r_t - \kappa_t^T = \gamma_t^B \sigma$
Evidence: The Collapse of Money-like Security Supply

Financial Intermediary Net Supply of Money-like Securities / GDP

Financial Intermediary Money-like Liabilities - Assets / GDP

Financial Intermediary Money-like Liabilities / GDP
Evidence: R&D and Cash

Mean Cash to Assets Ratio

Year
2001 2003 2005 2007 2009 2011 2013
Non-R&D Intensive
R&D Intensive
Mean Cash to Assets Ratio
Evidence: Treasury Bill Supply
Model: Behind the Friction

- Two financing markets: (1) acquisition; (2) investment
  - Frictionless acquisition financing: to acquire existing capital (or cash)
  - Purpose disclosed on prospectus

- Asymmetric information in the investment-financing market
  - $\lambda \, dt$ fraction of firms endowed real investment technology
  - Pooled with a positive measure $\pi \, dt$ of failed firms (who can steal)
  - If $\Pr(\text{real}) = \frac{\lambda}{\lambda + \pi} \approx 0$, so financing cost $\gg$ marginal value of investment
  - No investment financing in equilibrium
Model: Behind the Friction

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  - If $\Pr(\text{real}) = \frac{\lambda}{\lambda + \pi} \approx 0$, so financing cost $\gg$ marginal value of investment
  - No investment financing in equilibrium

- Modified cash/investment policy

$$\rho - r_t + \pi = \lambda \left[ q_t F'(m_t) - 1 \right]$$
Solution: Bank Optimization

\[ HJB : \rho = \max_{\text{dy}_t^B} \left\{ \frac{(1-q_t^B)}{q_t^B} \text{I}_{\{dy_t^B > 0\}} \text{dy}_t^B + \frac{(q_t^B - 1 - \gamma_t)}{q_t^B} \text{I}_{\{dy_t^B < 0\}} (-\text{dy}_t^B) \right\} + \mu_t^B + \max_{x_t^B \geq 0} \left\{ r_t + x_t^B (R_t - \delta - r_t) - x_t^B \gamma_{t}^B \sigma \right\} - \iota \]

- Loan return's covariance with \( \frac{dq_t^B}{q_t^B} \) is \( \sigma_t^B \sigma = -\gamma_t^B \sigma \)

- Indifference condition: \( \rho - \kappa_t^T - r_t = \gamma_t^B \sigma \)
  - Reminder: HH's indifference condition is \( R_t - \delta = \rho - \kappa_t^T \)

- Payout/issuance rate \( \text{dy}_t^B = \frac{dc_t^B}{e_t} \)
  - Payout, \( \text{dy}_t^B > 0 \), if \( q_t^B \leq 1 \)
  - Issue, \( \text{dy}_t^B < 0 \), if \( q_t^B \geq 1 \)
Solution: Aggregate State Variable

- Markov equilibrium: economy indexed by

\[
\eta_t = \frac{\int_{s \in [0,1]} e^B_t(s) ds}{K^l_t + K^T_t} = \frac{E^B_t}{K^l_t + K^T_t}
\]
Solution: Aggregate State Variable

- Markov equilibrium: economy indexed by
  \[
  \eta_t = \frac{\int_{s \in [0,1]} e_t^B(s) \, ds}{K_t^I + K_t^T} = \frac{E_t^B}{K_t^I + K_t^T}
  \]

- Technical assumptions
  
  1. Production and investment are homogeneous of degree 1 in capital
  2. \(K_t^I\)'s growth spills over to \(K_t^T\); \(K_t^I\) faces destruction shock as \(K_t^T\)
Solution: Aggregate State Variable

- Markov equilibrium: economy indexed by

\[ \eta_t = \int_{s \in [0,1]} e_t^B(s) ds = \frac{E_t^B}{K_{t'} + K_t} \]

- Technical assumptions
  1. Production and investment are homogeneous of degree 1 in capital
  2. \( K_t'^{l} \)'s growth spills over to \( K_t^T; K_t'^{l} \) faces destruction shock as \( K_t^T \)

- Equilibrium dynamics

\[ \frac{d\eta_t}{\eta_t} = \mu_t dt + \sigma_t \eta_t dZ_t - dy^B_t \]

  - Bank dividend-to-equity \( dy^B_t \) is an impulse variable
  - \( \eta_t \in [\underline{\eta}, \bar{\eta}] \), reflected at payout \( q^B(\underline{\eta}) = 1 \) and issuance \( q^B(\eta) = 1 + \chi \)
Solution: Aggregation & Money Market

- Decompose bank risk aversion: \( \gamma_t^B = \epsilon_t^B \sigma_t^\eta \)

- Endogenous measure of slow moving capital: \( \epsilon_t^B = - \frac{d q_t^B / q_t^B}{d \eta_t / \eta_t} > 0 \)
Solution: Aggregation & Money Market

- Decompose bank risk aversion: $\gamma_t^B = \epsilon_t^B \sigma_t^\eta$
  - Endogenous measure of slow moving capital: $\epsilon_t^B = -\frac{dq_t^B}{q_t^B} \frac{d\eta_t}{\eta_t} > 0$

- Supply $M_t^S = \frac{Deposits}{K_t^I + K_t^T} = (x_t^B - 1) \eta_t$; demand $M_t^D = \frac{m_t^I K_t^I}{K_t^I + K_t^T} = m_t^I \phi$
  - State variable $\eta_t = \frac{E_t^B}{K_t^I + K_t^T}$
  - Interior dynamics: $\frac{d\eta_t}{\eta_t} = \mu_t^\eta dt + \sigma_t^\eta dZ_t$, and $\sigma_t^\eta = (x_t^B - 1) \sigma > 0$
Solution: Aggregation & Money Market

- Decompose bank risk aversion: \( \gamma_t^B = \epsilon_t^B \sigma_t^\eta \)
  - Endogenous measure of slow moving capital: \( \epsilon_t^B = -\frac{dq_t^B}{q_t^B} / \frac{d\eta_t}{\eta_t} > 0 \)

- Supply \( M_t^S = \frac{Deposits}{K_t^L + K_t^T} = (x_t^B - 1) \eta_t \); demand \( M_t^D = \frac{m_t^L K_t^L}{K_t^L + K_t^T} = m_t^L \phi \)
  - State variable \( \eta_t = \frac{E_t^B}{K_t^L + K_t^T} \)
  - Interior dynamics: \( \frac{d\eta_t}{\eta_t} = \mu_t^\eta dt + \sigma_t^\eta dZ_t \), and \( \sigma_t^\eta = (x_t^B - 1) \sigma > 0 \)

- Supply curve: \( \rho - r_t = \frac{\epsilon_t^B \sigma_t^2}{\eta_t} M_t^S + \kappa_T \)
Solution: Aggregation & Money Market

- Decompose bank risk aversion: $\gamma^B_t = \epsilon^B_t \sigma^\eta_t$
  
  - Endogenous measure of slow moving capital: $\epsilon^B_t = -\frac{dq^B_t}{d\eta^t_t/\eta^t_t} > 0$

- Supply $M^S_t = \frac{Deposits}{K^l_t+K^T_t} = (x^B_t - 1) \eta^t_t$; demand $M^D_t = \frac{m^l_t K^l_t}{K^l_t+K^T_t} = m^l_t \phi$
  
  - State variable $\eta^t_t = \frac{E^B_t}{K^l_t+K^T_t}$
  
  - Interior dynamics: $\frac{d\eta^t_t}{\eta^t_t} = \mu^\eta_t dt + \sigma^\eta_t dZ_t$, and $\sigma^\eta_t = (x^B_t - 1) \sigma > 0$

- Supply curve: $\rho - r_t = \frac{\epsilon^B_t \sigma^2}{\eta^t_t} M^S_t + \kappa^T_t$

\[
\frac{\epsilon^B_t \sigma^2}{\eta^t_t} M^S_t = \epsilon^B_t (x^B_t - 1) \sigma \sigma = \epsilon^B_t \sigma^\eta_t \sigma = \gamma^B_t \sigma
\]

- Demand curve: $\rho - r_t = \lambda \left[ q^l_t F' \left( \frac{1}{\phi} M^D_t \right) - 1 \right]$
Solution: Aggregation & Money Market (con’t)

Money premium

Money demand curve:
\[ \rho - r_t = \lambda \left[ q_t^I F'(\frac{1}{\phi} M_t^D) - 1 \right] \]

Money supply curve:
\[ \rho - r_t = \frac{e^f \sigma^2}{\eta_t} M_t^S + \kappa_t^T \]

Money demand curve:
- \( \rho - r_t = \lambda \left[ q_t^I F'(\frac{1}{\phi} M_t^D) - 1 \right] \)
- \( \kappa_t^T = 0 \)

Money supply curve:
- \( \rho - r_t = \frac{e^f \sigma^2}{\eta_t} M_t^S + \kappa_t^T \)

Diagram:
- Deposits: \( K_t + K_t^I \)
- Money demand: \( q_t^I (1 - \phi) - \eta_t \)
- Money supply: \( FB = \phi i^* \)
- \( (q_t^I F''(i^*) = 1) \)
Solution: Aggregation & Money Market (con’t)

Money premium

Money demand curve:
\[ \rho - r_t = \lambda \left[ q_t^I F' \left( \frac{1}{\phi} M_t^D \right) - 1 \right] \]

Money supply curve:
\[ \rho - r_t = \frac{e_t^P \sigma^2}{\eta_t} M_t^S + \kappa_t^T \]

Panel A: \( e_t^P \)
Solution: Aggregation & Money Market (con’t)

Money premium

Money demand curve:
\[ \rho - r_t = \lambda \left[ q_t^l F'(\frac{1}{\phi} M_t^D) - 1 \right] \]

Money supply curve:
\[ \rho - r_t = \frac{c_t^B \sigma^2_t}{\eta_t} M_t^S + \kappa_t^T \]

Intangible Capital Pricing
Money premium

Money demand curve:
\[ \rho - r_t = \lambda \left[ q_t^I F' \left( \frac{1}{\phi} M_t^D \right) - 1 \right] \]

Money supply curve:
\[ \rho - r_t = \frac{\epsilon B \sigma^2}{\eta_t} M_t^S + \kappa_t^T \]

Money demand curve:
\[ \rho - r_t = \lambda \left[ q_t^I F' \left( \frac{1}{\phi} M_t^D \right) - 1 \right] \]

Money supply curve:
\[ \rho - r_t = \frac{\epsilon B \sigma^2}{\eta_t} M_t^S + \kappa_t^T \]
Money premium

Money demand curve:
\[ \rho - r_t = \lambda \left[ q_t^I F' \left( \frac{1}{\phi} M_t^D \right) - 1 \right] \]

Money supply curve:
\[ \rho - r_t = \frac{\epsilon_t^B \sigma^2}{\eta_t} M_t^S + \kappa_t^T \]

Deposits:
\[ M_t = q_t^T (1 - \phi) - \eta_t \]

Maximum credit demand:
\[ \text{FB} = \phi i^* \quad (q_t^I F'(i^*) = 1) \]
Equilibrium conditions define 3 ODEs for \((q^B(\eta), q^I(\eta), q^T(\eta))\):

- (1) Banks’ HJB; (2) firms’ F.O.C. on \(k_t^I\); (3) HHs’ F.O.C. on \(k_t^T\)

Boundary conditions:

\(\bar{\eta}:\ \frac{dq^I}{d\bar{\eta}} = 0, \quad \frac{dq^T}{d\bar{\eta}} = 0, \quad q^B = 1, \quad \text{and} \quad \frac{d(q^B\eta)}{d\bar{\eta}} = 1\)

\(\underline{\eta}:\ \frac{dq^I}{d\underline{\eta}} = 0, \quad \frac{dq^T}{d\underline{\eta}} = 0, \quad q^B = 1 + \chi, \quad \text{and} \quad \frac{d(q^B\eta)}{d\underline{\eta}} = 0\)
Solution: Calibration

- Investment technology: \( F(i) = \omega_0 i^{\omega_1} \)
- Data moments: intangible growth (Corrado and Hulten, 2010), Liquidity spread moments (CD/T-bill), Compustat cash holdings, interest rate on money (FRED MZM), Call report bankers’ wage, S&P P/E
- Plug in: Compustat intangible intensity (Peters and Taylor, 2016), mean and standard deviation loan delinquency (FRED)
Equilibrium: Intertemporal Complementarity

\[ dq_t = \mu_t q_t dt + \sigma_t q_t dZ_t. \]

\[ q_t = \frac{\alpha + \lambda \left[ q_t F (m_t^l) - m_t^l \right] - (\rho - r_t) m_t^l}{\rho - (\mu_t^l - \delta + \sigma_t^l \sigma)} \]

- \( m_{t+dt}^l \uparrow \rightarrow q_{t+dt}^l \uparrow \rightarrow \mu_t^l \uparrow \rightarrow q_t^l \uparrow \)

- Money suppliers' recapitalization friction \( \rightarrow \) Intertemporal complementarity of money holdings

- Procylical money demand feeds procyclical intermediary leverage
Equilibrium: Intermediated Collateral Premium

\[ dq_t^T = \mu_t^T q_t^T dt + \sigma_t^T q_t^T dZ_t. \]

\[ q_t^T = \frac{\alpha}{(\rho - \kappa_t^T) - (\mu_t^T - \delta + \sigma_t^T \sigma)} \]

- DR: positive collateral premium only when banks are rich
- Another channel from finance boom to asset price increase
Government Debt as Reserves

**Households**

<table>
<thead>
<tr>
<th>Assets</th>
<th>Liabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tangible Collateral</strong></td>
<td><strong>Bank Loan</strong></td>
</tr>
<tr>
<td>B’s and I’s equities</td>
<td>Equity</td>
</tr>
</tbody>
</table>

1. $R_t - \delta = \rho - \kappa_T^T$
   Loan $\leq$ Collateral Value

2. Loan return is risky:
   $R_t - (\delta dt - \sigma dZ_t)$

**Banks**

<table>
<thead>
<tr>
<th>Assets</th>
<th>Liabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loans</td>
<td>Deposits</td>
</tr>
<tr>
<td><strong>Gov. Debt</strong></td>
<td><strong>Deposits</strong></td>
</tr>
</tbody>
</table>

$\rho - r_t - \kappa_T^T = \gamma_B^B \sigma$
Intermediary money pricing

**Intangible Firms**

<table>
<thead>
<tr>
<th>Assets</th>
<th>Liabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cash</td>
<td>Equity</td>
</tr>
<tr>
<td>Intangible Assets</td>
<td>Equity</td>
</tr>
</tbody>
</table>

$\rho - r_t = \lambda \left[ q_t^I F''(m_t^I) - 1 \right]$
Money demand

---

Collateral premium $\kappa_T^T$
$\rho - r_t = \lambda \left[ q_t^l F' \left( m_t^l - \text{Gov. Debt} \right) - 1 \right]$
Equilibrium: Persistent Effect of Shocks

Impulse Response of the State Variable

$\Delta E_t [\eta_{t+T}]$

$T =$ Year 2 Year 4 Year 6 Year 8 Year 10

0 2% 4% 6% 8% 10% 12%

Procyclical Money Creation
Equilibrium: C.D.F. of State Variable

Procyclical Balance-sheet Capacity
Extension: Long-term Bank Asset

Panel A: Stationary C.D.F.

Panel B: Tangible Capital Price

Panel C: Money Premium

Panel D: Bank Asset / Equity
Extension: Financial Innovation – Collateral Velocity

Panel A: Stationary C.D.F.

\[ \text{Loans} \leq \theta q_t^T K_t^T, \ \theta > 1 \]
Extension: Regulatory Constraint

Money demand curve:
\[ \rho - r_t = \lambda \left[ q_t^K F'(m_t^D) - 1 \right] \]

Money supply curve:
\[ \rho - r_t = \frac{\epsilon_i^B \sigma^2}{\eta_t} m_t^B + \kappa_t^R \]

Regulatory Constraint
\[ M_t = (\bar{x}_t - 1) \eta_t \]
\[ FB = \phi i_t^* \]
\[ q_t^K F'(i_t^*) = 1 \]
Extension: Regulatory Constraint

Panel A: Stationary C.D.F.

Panel B: Money Premium

Panel C: Bank Asset / Equity

Panel D: Bank Asset / Equity
Extension: Credit View

Money demand curve:
\[ \rho - r_t = \lambda \left[ q_t^K F'(m_t^K) - 1 \right] \]

Money supply curve:
\[ \rho - r_t = \frac{\epsilon_t B \sigma^2}{\eta_t} m_t^B - (\bar{\rho} - \rho) \]

FB = \phi i_t^*
\[ q_t^K F'(i_t^*) = 1 \]
Extension: Credit View

Panel A: Bank Debt / Equity

- Without Credit Channel
- Credit Channel

Panel B: Money Premium

- Without Credit Channel
- Credit Channel

Back
### Calibration Details

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Model Moments</th>
<th>Data Moments</th>
<th>Measurement</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) $\rho$</td>
<td>0.04</td>
<td>Interest rate $\mathbb{E} [r_t]$</td>
<td>3.78%</td>
<td>3.74%</td>
</tr>
<tr>
<td>(2) $\lambda$</td>
<td>1/7</td>
<td>Intangible growth $\mathbb{E} [\mu^K_t]$</td>
<td>0.79%</td>
<td>0.74%</td>
</tr>
<tr>
<td>(3) Inv. tech.</td>
<td>$F(i) = \omega_0 i^{\omega_1}$</td>
<td>Cash to net assets $\mathbb{E} [m^I_t]$</td>
<td>41.4%</td>
<td>41.0%</td>
</tr>
<tr>
<td>$\omega_1$</td>
<td>0.99</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\omega_0$</td>
<td>0.8035</td>
<td>Expected liquidity premium $\mathbb{E} [\lambda(q^I_t F'(m^I_t) - 1)]$</td>
<td>23.81bp</td>
<td>23.65bp</td>
</tr>
<tr>
<td>(5) $\chi$</td>
<td>1</td>
<td>Liquidity premium s.d. $\text{std} [\lambda(q^I_t F'(m^I_t) - 1)]$</td>
<td>9.80bp</td>
<td>18.19bp</td>
</tr>
<tr>
<td>(6) $\alpha$</td>
<td>0.1</td>
<td>Firms’ equity P/E ratio</td>
<td>25.3</td>
<td>24.9</td>
</tr>
<tr>
<td>(7) $\iota$</td>
<td>0.02</td>
<td>Operation cost / bank income</td>
<td>52.9%</td>
<td>61.2%</td>
</tr>
<tr>
<td>(8) $\delta$</td>
<td>0.04</td>
<td></td>
<td>3.66%</td>
<td></td>
</tr>
<tr>
<td>(9) $\sigma$</td>
<td>0.02</td>
<td></td>
<td>1.62%</td>
<td></td>
</tr>
<tr>
<td>(10) $\phi$</td>
<td>0.45</td>
<td></td>
<td>45%</td>
<td></td>
</tr>
</tbody>
</table>

All moments are based on stationary distribution.
Evidence: Government Debt & Procyclicality

Panel A: Rest of the Year

Panel B: 2nd Quarter

Panel C: Treasury Bill Supply
Evidence: Government Debt & Procyclicality

<table>
<thead>
<tr>
<th>IV</th>
<th>MP-FFR</th>
<th>MP-NS</th>
<th>MP-FFR</th>
<th>MP-NS</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \Delta \ln (Leverage) )</td>
<td>0.910***</td>
<td>3.873***</td>
<td>2.527***</td>
<td>0.203</td>
</tr>
<tr>
<td></td>
<td>(0.113)</td>
<td>(1.451)</td>
<td>(0.855)</td>
<td>(1.294)</td>
</tr>
<tr>
<td>IV</td>
<td>Q2</td>
<td>Q2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \Delta \ln (\frac{T-Bill}{GDP}) ) \cdot \Delta \ln (Assets)</td>
<td>24.40</td>
<td>10.28***</td>
<td>8.999***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(38.57)</td>
<td>(2.174)</td>
<td>(2.220)</td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>189</td>
<td>77</td>
<td>77</td>
<td>188</td>
</tr>
</tbody>
</table>

1. * \( p < 0.1 \), ** \( p < 0.05 \), *** \( p < 0.01 \)
2. Newey-West HAC standard errors in parentheses, with the optimal number of lags chosen by Newey and West (1994)
3. Coefficients are estimated by GMM. Sample is from 1968Q3 to 2015Q3, and for IV estimation, starts from 1995Q1 when instruments were available. Q2 stands for Q2 dummy. MP-FFR and MP-NS are the monetary policy shocks calculated as the quarterly average of unexpected Fed fund rate change and composite interest rate changes (Nakamura and Steinsson (2015)) around FOMC announcements respectively.
Evidence: Inside Money Demand and Supply

Cash Holdings Decomposition

- Foreign Deposits
- Treasury Securities
- Commercial Papers
- Repurchase Agreements
- Checkable & Currency
- Time Deposits

As of December 2015, Financial Accounts of the United States

Inside Money Ownership

- Commercial Papers
- Repurchase Agreements
- Checkable Deposits
- Large Time Deposits

As of December 2015, Financial Accounts of the United States
Evidence: Money Premium and Cash Holdings

Panel A: Full Sample

Panel B: Subsamples by Collateral / R&D

- <1
- [1, 5]
- >5
- R&D = 0

- Cash/assets (annual average)
- Fitted
### Evidence: Money Premium and Cash Holdings

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
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<tbody>
<tr>
<td>Money premium</td>
<td>-0.0979***</td>
<td></td>
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<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>(0.0128)</td>
<td></td>
<td></td>
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<tr>
<td>C.C. * M.P.</td>
<td>0.0970***</td>
<td>0.0944***</td>
<td>0.0204***</td>
<td>0.0829***</td>
<td>0.0413***</td>
<td>0.0104***</td>
</tr>
<tr>
<td></td>
<td>(0.0121)</td>
<td>(0.0120)</td>
<td>(0.00294)</td>
<td>(0.0106)</td>
<td>(0.00532)</td>
<td>(0.00295)</td>
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<tr>
<td>Collateral Coverage</td>
<td>-0.152***</td>
<td>-0.147***</td>
<td>-0.0286***</td>
<td>-0.128***</td>
<td>-0.0689***</td>
<td>-0.0157***</td>
</tr>
<tr>
<td>(PPE / R&amp;D)</td>
<td>(0.0112)</td>
<td>(0.0113)</td>
<td>(0.00208)</td>
<td>(0.0102)</td>
<td>(0.00469)</td>
<td>(0.00452)</td>
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<tr>
<td>Market to book</td>
<td>0.0400***</td>
<td>0.0390***</td>
<td>0.00602***</td>
<td>0.0335***</td>
<td>0.0203***</td>
<td>0.0155***</td>
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<td></td>
<td>(0.00145)</td>
<td>(0.00142)</td>
<td>(0.000835)</td>
<td>(0.00138)</td>
<td>(0.00123)</td>
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<td>Time FE</td>
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<td>147920</td>
<td>163738</td>
<td>122145</td>
<td>163738</td>
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<tr>
<td>Adjusted $R^2$</td>
<td>0.234</td>
<td>0.249</td>
<td>0.747</td>
<td>0.300</td>
<td>0.481</td>
<td>0.696</td>
</tr>
</tbody>
</table>

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$