The short rate disconnect in a monetary economy

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Motivation

- Standard Euler equation for nominal short rate

  $$E_t\left[M_{t+1}\frac{1+i_t}{1+\pi_{t+1}}\right]=1$$

  - representative agent model: M_{t+1} = MRS
- Important equation for monetary economics
  - central bank policy rate i_t = short rate in pricing kernel
  - i_t changes & π_{t+1} sticky $\rightarrow$ M_{t+1} adjusts $\rightarrow$ real effects
- Empirical success of asset pricing equation mixed
  - models that fit well long maturity assets don't price short rate

    $\rightarrow$ short rate disconnect
  - surprising? Households don't hold short bonds, only via banks/MMFs

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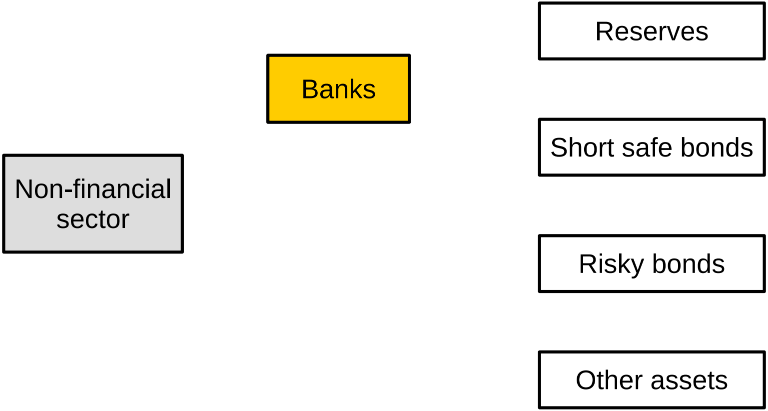
This paper: monetary asset pricing with banks

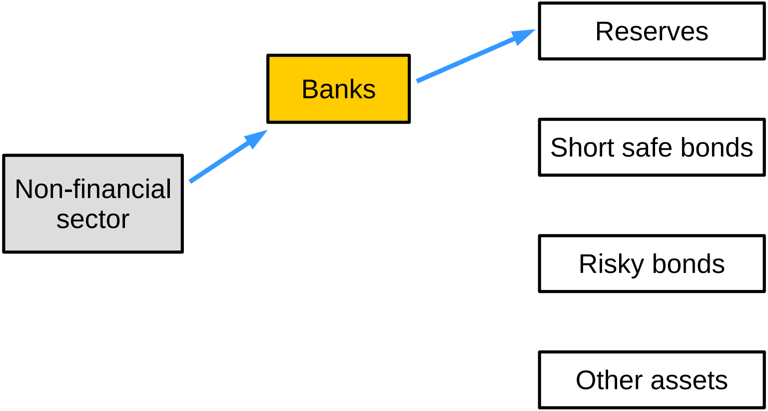
- Non-financial sector: pricing kernel M_{t+1} & deposit demand
- Banks issue deposits, choose assets & leverage
  - friction: asset management costly, more so if leverage high

  $\rightarrow$ banks value short safe bonds to back deposits
- Short safe safe bonds scarce $\rightarrow$ priced exclusively by banks
  - observed short rate < short rate in M_{t+1} := "shadow rate"
  - transmission of monetary policy through bank balance sheets
- Quantitative assessment
  - estimate shadow spread in the data: high at the end of booms
  - bank Euler eqns.: high spread $\rightarrow$ low leverage & low safe asset share
  - data: stable relationships at business cycle frequencies

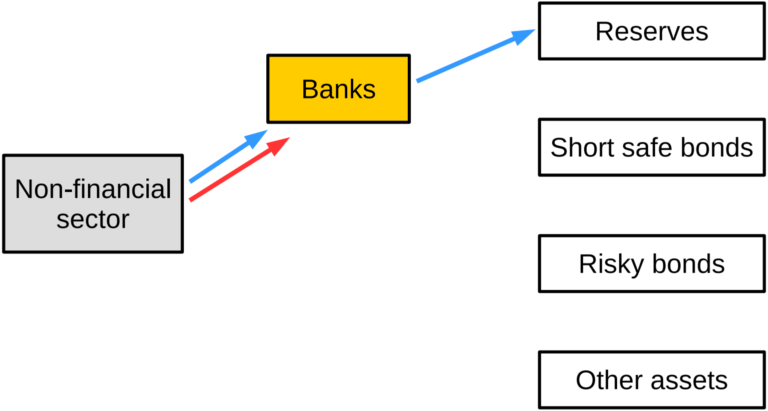
Households, banks, assets



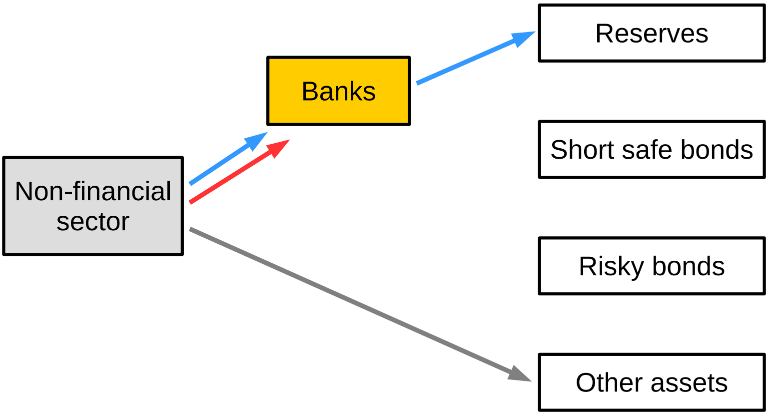
Liquidity benefits from deposits, reserves



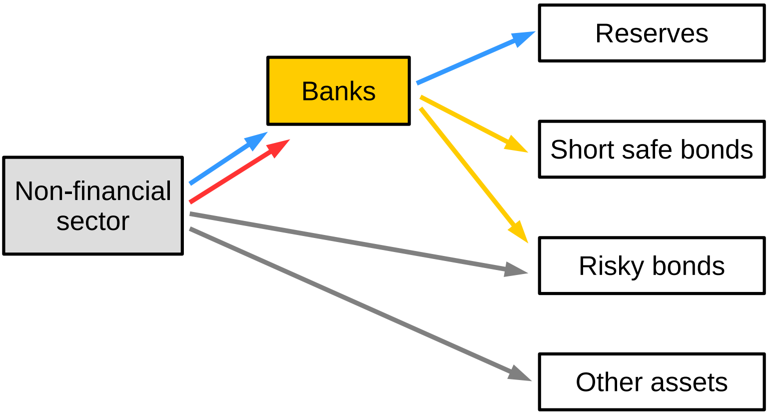
Bank capital structure: debt (deposits) vs equity



Some assets held directly by households



Who holds bonds? Banks want safe collateral



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Literature

- Quantitative monetary asset pricing consumption-based: Lucas 80...
  related: short end disconnect in arbitrage free models: Duffee 96...
- Convenience yield on bonds Patinkin 56, Tobin 63, Bansal-Coleman 96, Krishnamurthy-Vissing-Jorgensen 12, Venkateswaran-Wright 12, Andolfatto-Williamson 14, Nagel 15
- Intermediary asset pricing He-Krishnamurthy 13, Brunnermeier-Sannikov 14, Greenwood-Vayanos 14, Bocola 15, Moreira-Savov 15, Koijen-Yogo 15, He-Kelly-Manela 17, Haddad-Sraer 18, Hanson-Lucca-Wright 18
- Bank liquidity management & demand for reserves Bhattacharya-Gale 87, Whitesell 06, Curdia-Woodford 11, Reis 16, Bianchi-Bigio 17, Drechsler-Savov-Schnabl 17, DeFiore-Hoerova-Uhlig 17, Piazzesi-Schneider 17
- Monetary policy with financial frictions & banking Curdia-Woodford 10, Gertler-Karadi 11, Gertler-Kiyotaki-Queralto 11, Christiano-Motto-Rostagno 12, Del Negro-Eggertson-Ferrero-Kiyotaki 17, Brunnermeier-Sannikov 16, *Williamson 12, 14, DiTella-Kurlat 17, Piazzesi-Rogers-Schneider 18*

Non-financial sector: pricing kernel & deposit demand

- Discrete time, infinite horizon economy
- Non-financial sector, we introduce only
  - real pricing kernel M_{t+1} prices all risky assets

    $\rightarrow$ nominal pricing kernel $M^{\$}_{t+1} = M_{t+1} P_t / P_{t+1}$

    $\rightarrow$ nominal safe bond rate $E_t[M^{\$}_{t+1}](1 + i^B_t) \leq 1$

    $\rightarrow$ nominal "shadow rate" $E_t[M^{\$}_{t+1}](1 + i^S_t) = 1$
  - "money demand " function: $v_t(D_t/P_t) = i^S_t - i^D_t$

    $\rightarrow$ needs deposits to make transactions

    $\rightarrow$ accepts deposit rate below shadow rate: $i^S_t - i^D_t > 0$

Banks & deposit supply

- Banks are competitive firms, maximize shareholder value
  - equity held by non-financial sector, payoff discounted by M_{t+1}
- Balance sheet
  - total assets A_t dollars

    $\rightarrow$ reserves, short nominal bonds, risky claims
  - portfolio weights: reserves α_t^M, short bonds α_t^B

    $\rightarrow$ weighted nominal return on assets $r_{t+1}^{\alpha,\$}$
  - leverage ℓ_t = deposits / assets
- No equity or asset adjustment costs
  - frictionless equity & bond markets
  - consider sequence of two period bank problems

Frictions

- Delegated asset management cost, per unit of assets
  - can be derived from bankruptcy cost
  - increasing and convex in ex-post leverage: $k\left(\ell_t/(1+r_{t+1}^{\alpha,\$})\right)$

    $\ell_t/(1+r_{t+1}^{\alpha,\$})$ = deposits / (nom. return on assets)

    $\rightarrow$ large if return on assets is low

    $\rightarrow$ convexity makes bank effectively more risk averse

    $\rightarrow$ $k(0) > 0$: asset management costly even at zero leverage

- Liquidity management cost, per unit of deposits
  - can be derived from frictional interbank credit market
  - decreasing and convex in liquidity ratio: $f(m_t)$ with

    m_t = (reserves $\alpha_t^M A_t$) / (depositors' transactions $\zeta_t D_t$)

Banks' optimization problem

- Choose leverage ℓ & asset weights α to maximize levered return

asset payoffs net leverage cost	$\left(E_t \left[M_{t+1}^{\$} \left(1 - k \left(\frac{\ell_t}{1 + r_{t+1}^{\alpha,\$}} \right) \right) (1 + r_{t+1}^{\alpha,\$}) \right] - 1 \right) A_t$
deposit financing less liquidity cost	$+ \left(\frac{i_t^S - i_t^D}{1 + i_t^S} - \zeta f(m_t) \right) D_t$

- Tradeoffs
  - capital structure: cheap financing vs leverage & liquidity cost
  - reserves: liquidity benefit vs opportunity cost
  - other assets: expected collateral benefit vs risk

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asset payoffs
net leverage cost

$$\left(E_t\left[M^{\$}_{t+1}\left(1-k\left(\frac{\ell_t}{1+r^{\alpha,\$}_{t+1}}\right)\right)(1+r^{\alpha,\$}_{t+1})\right]-1\right)A_t$$

deposit financing
less liquidity cost

$$+\left(\frac{i^S_t-i^D_t}{1+i^S_t}-\zeta f(m_t)\right)D_t$$

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Payment intermediary asset pricing

- FOC for short safe bond:

$$E_t\left[M_{t+1}^{\$}\left(1-k\left(\frac{\ell_t}{1+r_{t+1}^{\alpha,\$}}\right)+k'\left(\frac{\ell_t}{1+r_{t+1}^{\alpha,\$}}\right)\frac{\ell_t}{1+r_{t+1}^{\alpha,\$}}\right)\right](1+i_t^B)=1$$

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- Intermediary pricing kernel
  - asset management cost enters in two ways

    $\rightarrow$ proportionally lowers the return on assets (even when $\ell_t = 0$)

    $\rightarrow$ additional dollar of realized return lowers ex-post leverage
  - bad state for bank? low nominal return on assets!

    $\rightarrow$ high $\ell_t/(\text{nominal return})$

Payment intermediary asset pricing

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- Intermediary pricing kernel
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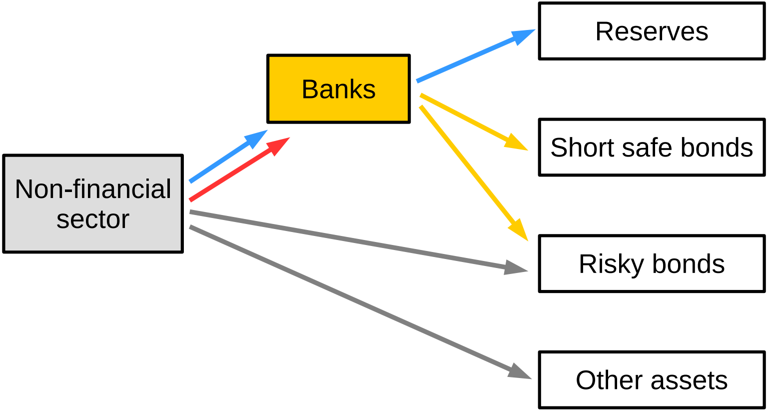
    $\rightarrow$ proportionally lowers the return on assets (even when $\ell_t=0$)

    $\rightarrow$ additional dollar of realized return lowers ex-post leverage
- Rearrange: $i^S_t - i^B_t \approx E_t\left[M^{\$}_{t+1}\left(k'\left(\tilde{\ell}_{t+1}\right)\tilde{\ell}_{t+1}-k\left(\tilde{\ell}_{t+1}\right)\right)\right]$
  - spread $i^S_t - i^B_t$: collateral benefits less delegation cost
  - can show: zero spread when banks safe $(\alpha^B+\alpha^M=1)$
  - in general: risky bank values safe bonds more than non-fin sector

    $\rightarrow$ short rate disconnect

Who holds bonds? Banks want safe collateral



Short rate disconnect in the data

- Model: M_{t+1} prices risky claims, but not short safe bonds. Data?
  - measure shadow rate: 3-month rate from estimated yield curve model
    $\rightarrow$ exclude T-bills from estimation (Gurkaynak, Sack, Wright (2007))
  - shadow spread: estimated shadow rate minus 3-month T-bill rate

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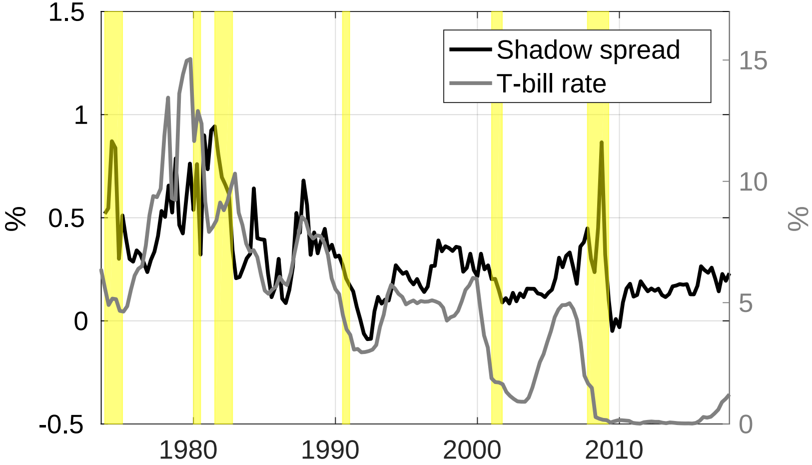

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- Do households hold T-bills directly?
  $\rightarrow$ they could, but don't: TreasuryDirect data
- US Financial Accounts Details
  $\rightarrow$ measured T-bills are predominantly held by intermediaries
  $\rightarrow$ unaccounted bills fit dynamics & magnitude of bank Treasuries

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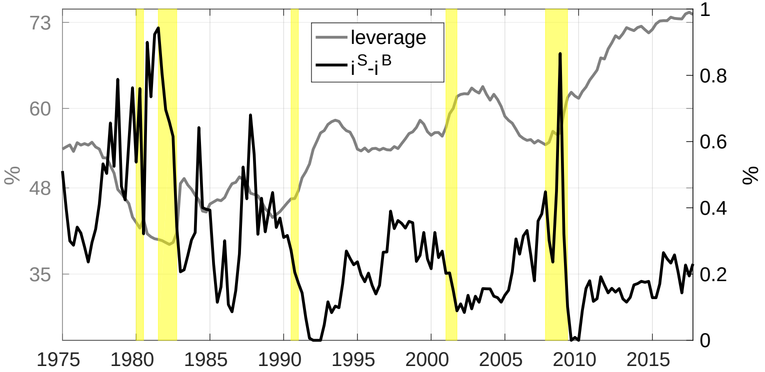
- Key model prediction
  - higher shadow spread $\rightarrow$ lower safe asset share & leverage

Data on balance sheet ratios

- Model with representative payment intermediary sector
  - leverage l_t = deposits/ assets & safe portfolio share α_t
- Measure deposits: money of zero maturity (MZM)
  - stable money demand for MZM, includes money market funds
- Measure assets: depository institutions and MMFs in Flow of Funds
  - consolidate sectors, subtract liabilities with higher seniority than D_t
- Measure safe portfolio share: fraction of short safe bonds in above
  - e.g. reserves, vault cash, Treasuries, net-repo loans

Stylized fact: shadow spread vs. leverage



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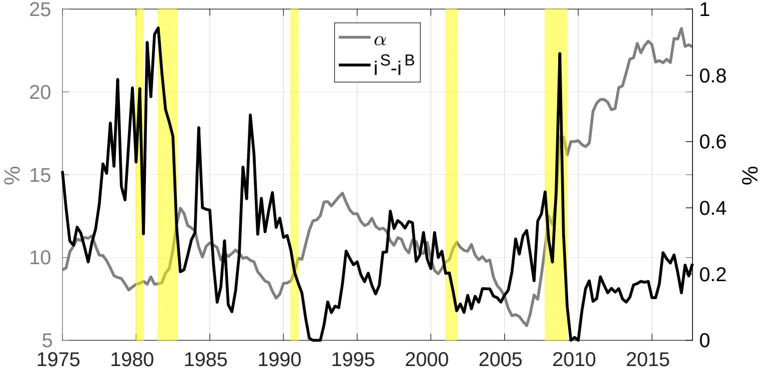

Optimal leverage & portfolio share

- Use bank Euler equations to solve for leverage and portfolio shares
  - summarize portfolio choice by $\alpha_t = \alpha_t^M + \alpha_t^B$
    $\rightarrow$ good approximation when α_t^M small or liquidity benefits small
  - cost function: $k\left(\frac{\ell_t}{1+r_{t+1}^{\alpha,\$}}\right) = b\left(\bar{k} + \left(\frac{\ell_t}{1+r_{t+1}^{\alpha,\$}}\right)^{\gamma}\right)$
  - risky return distribution log-normal under $M_{t+1}^{\$}$-risk-neutral measure
- Safe portfolio share

  $$\alpha_t \approx 1 - \frac{1}{\gamma\sigma_t^2}\log\left(1 + \frac{i_t^S - i_t^B}{b\bar{k}}\right)$$

  - decreasing in spread (expensive collateral), increasing in risk
- Leverage

  $$\ell_t \approx \exp(i_t^S - \alpha_t(i_t^S - i_t^B))\exp\left(-\frac{1}{2\sigma_t^2}\frac{1}{\gamma}\left(\log\left(1 + \frac{i_t^S - r_t^B}{b\bar{k}}\right)\right)^2\right)\left(\frac{\bar{k}}{\gamma - 1}\right)^{1/\gamma}$$

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  - decreasing in spread, increasing in risk, decreasing in α_t

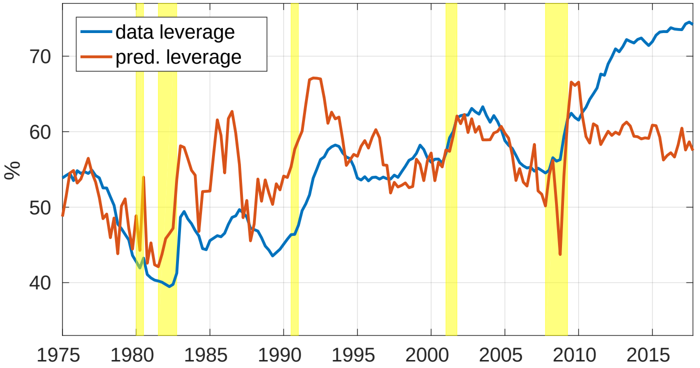
- Quantitative assessment
  - $\alpha_t, \ell_t, i_t^S - i_t^B$ observable, σ_t unobservable

    1. substitute out σ_t to relate leverage to shadow spread, safe share; use resulting equation to estimate cost function parameters
    2. back out $\gamma\sigma_t$ from safe portfolio share equation
  - "Success" = good fit of 1. + reasonable series from 2.

Model vs data

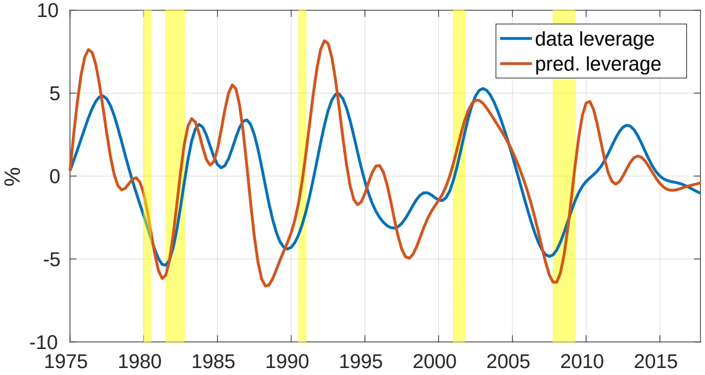
- substitute out σ_t to relate leverage to shadow spread, safe share:

$$\rightarrow \quad \ell_t = \exp(i_t^S - \alpha_t(i_t^S - i_t^B))\exp\left(-\frac{1}{2}(1-\alpha_t)\log\left(1+\frac{i_t^S - i_t^B}{b\bar{k}}\right)\right)\left(\frac{\bar{k}}{\gamma-1}\right)^{1/\gamma}$$



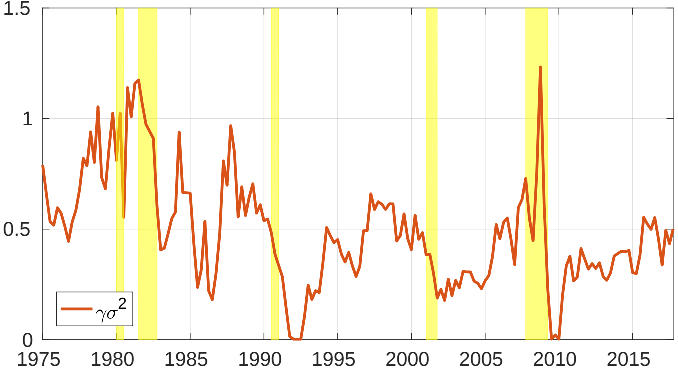
Model vs data

- Use bandpass filter (1.5y-8y) to isolate cyclical component



Model vs data

- Rearrange portfolio share equation: $\gamma\sigma_t^2 = \frac{1}{1-\alpha_t} \log\left(1 + \frac{i_t^S - i_t^B}{b\bar{k}}\right)$
  - backed out series spikes in times of financial market distress
  - implied cost in single digit basis point range

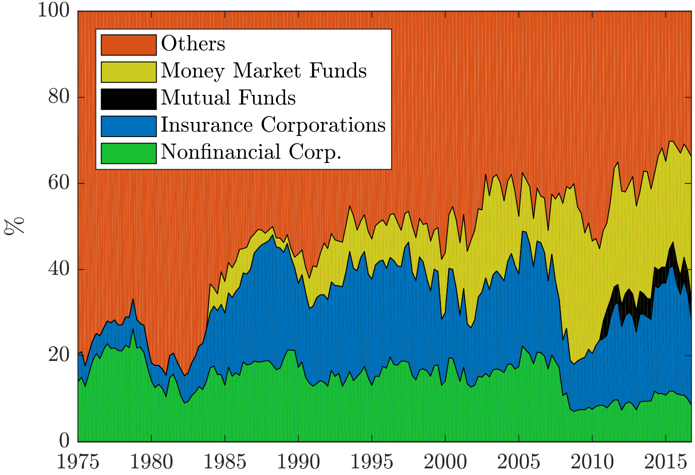


Conclusion

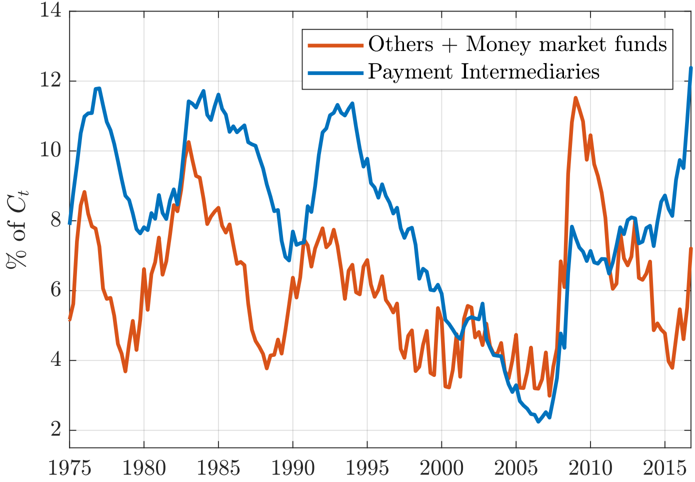
- Model of monetary economy with payment intermediaries
  - banks value short safe bonds as collateral

    $\rightarrow$ disconnect of short rate from "shadow rate"
  - shadow spread and return risk $\rightarrow$ leverage & portfolio choice
- Estimated Euler equations capture cyclical co-movement
  - structural change in asset management cost may improve overall fit
- Transmission of monetary policy through intermediary balance sheets

T-Bill holdings in FoF



Intermediary Treasury holdings



Back

Euler equations & deposit FOC

- Define $M^{\$,B}_{t+1} = M^{\$}_{t+1}\left(1 - k\left(\frac{\ell_t}{1+r^{\alpha,\$}_{t+1}}\right) + k'\left(\frac{\ell_t}{1+r^{\alpha,\$}_{t+1}}\right)\frac{\ell_t}{1+r^{\alpha,\$}_{t+1}}\right)$
- Risky bond
$$E_t\left[M^{\$,B}_{t+1}\right](1+i^M_t) \;=\; 1+f'(m_t)$$
- Short safe bond
$$E_t\left[M^{\$,B}_{t+1}\right](1+i^B_t) = 1$$
- Reserves
$$E_t\left[M^{\$,B}_{t+1}\right](1+i^M_t) \;=\; 1+f'(m_t)$$
- Deposit FOC
$$\frac{i^S_t - i^D_t}{1+i^S_t} = E_t\left[M^{\$}_{t+1}\,k'\left(\tilde{\ell}_{t+1}\right)(1+i^D_t)\right] + \zeta_t\, f(m_t) - \zeta_t\, f'(m_t)\, m_t$$