Why are Banks Exposed to Monetary Policy?

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Banks are exposed to monetary policy shocks

Assets	Liabilities
Loans (long term)	Deposits (short term)
	Net Worth

- Maturity mismatch → interest rate risk

- Transmission channel of monetary policy

- Begenau, Piazzesi & Schneider (2014): banks use derivatives (interest rate swaps) to *increase* exposure to interest rate risk

Why do banks choose this exposure?

- Focus on banks as providers of liquidity
- Banks' exposure to interest-rate risk is part of dynamic hedging strategy
  - deposit spreads co-move with interest rate (Drechsler et al. 2015)
  - capital gains offset flow returns
  - implement with maturity-mismatched balance sheet
- Fits level, time series, and cross-section of maturity mismatch

Technology and Preferences

- Fixed capital stock k produces constant output flow $y = ak$
- "Households" and "bankers" with the same preferences:

$$f(x, U) = \rho(1-\gamma) U \left(\log(x) - \frac{1}{1-\gamma} \log((1-\gamma) U) \right)$$

  Epstein-Zin with EIS=1 and RRA γ

- Currency-and-deposits in the utility function:
  - x: Cobb-Douglas aggregator of c (consumption) and m (money)

$$x(c, m) = c^{\beta} m^{1-\beta}$$

  - m: CES aggregator of h (real currency) and d (real deposits). Elasticity ϵ

$$m(h, d) = \left(\alpha^{\frac{1}{\epsilon}} h^{\frac{\epsilon-1}{\epsilon}} + (1-\alpha)^{\frac{1}{\epsilon}} d^{\frac{\epsilon-1}{\epsilon}} \right)^{\frac{\epsilon}{\epsilon-1}}$$

Monetary Policy

- Currency supplied via (stochastic) lump-sum transfers
- Flexible prices
- Reverse-engineered to produce stochastic process for interest rates:

$$di_t = \mu\left(i_t\right) dt + \sigma\left(i_t\right) dB_t$$

  - B is standard Brownian Motion
  - Friedman rule is optimal $i_t = 0$
  - In quantitative section, Cox-Ingersoll-Ross process:

$$\mu\left(i\right) = -\lambda\left(i - \bar{i}\right)$$
$$\sigma\left(i\right) = \sigma\sqrt{i}$$

Deposits

- Bankers can issue deposits up to leverage limit

$$d^S \leq \phi n$$

  - regulatory constraint/economic condition for deposits to be liquid
  - prevents infinite supply of deposits
  - makes bankers' net worth an important state variable

- In equilibrium deposits pay (endogenous) nominal rate $i_t^d < i_t$. Spread:

$$s_t = i_t - i_t^d > 0$$

Markets

- Complete markets
  - real interest rate: $r_t = i_t - \mu_{p,t}$
  - trade exposure to B at price π_t
- Capital and lump-sum transfers priced by arbitrage
- No assumptions on what assets banks hold

Household and Banker's Problems

- Household

$$\max_{w,x,c,m,h,d,\sigma_w} U(x)$$

$$s.t. \quad \frac{dw_t}{w_t} = \left(r_t + \sigma_{w,t}\pi_t - \hat{c}_t - \hat{h}_t i_t - \hat{d}_t \underbrace{\left(i_t - i_t^d\right)}_{\equiv s_t}\right) dt + \sigma_{w,t} dB_t$$

$$x_t = c_t^{\beta} m_t^{1-\beta}$$

$$m_t = \left(\alpha^{\frac{1}{\epsilon}} h_t^{\frac{\epsilon-1}{\epsilon}} + (1-\alpha)^{\frac{1}{\epsilon}} d_t^{\frac{\epsilon-1}{\epsilon}}\right)^{\frac{\epsilon}{\epsilon-1}}$$

$$w_t \geq 0$$

- Banker: same except bankers earn spread on deposits issued:

$$\frac{dn_t}{n_t} = \left(r_t + \sigma_{n,t}\pi_t - \hat{c}_t - \hat{h}_t i_t - \hat{d}_t s_t + \hat{d}_t^S s_t\right) dt + \sigma_{n,t} dB_t$$

$$\hat{d}_t^S \leq \phi$$

Equilibrium Definition

- State variables:
  - i: current level of interest rates
  - $z = \frac{n}{n+w}$: fraction of total wealth held by bankers

- Equilibrium
  1. Value functions and policy functions
  2. Prices
  3. Law of motion for z

  such that

  1. Value and policy functions solve household & banker's problem
  2. Markets clear
     - 2.1 goods
     - 2.2 currency
     - 2.3 deposits
     - 2.4 capital
  3. Law of motion for z is consistent with policy functions

Deposit Spread

- From the FOCs and market clearing for deposits we get a static equation for the deposit spread:

$$\underbrace{(1-\alpha)\left(\frac{\iota\left(i,s\right)}{s}\right)^{\epsilon}}_{\frac{d}{m}}\underbrace{(1-\beta)\,\frac{\chi(i,s)}{\iota\left(i,s\right)}}_{\frac{m}{x}}\underbrace{\frac{\rho}{\chi(i,s)}}_{\frac{x}{\omega}} = \underbrace{\phi}_{\frac{d}{n}}\underbrace{z}_{z\equiv\frac{n}{\omega}}$$

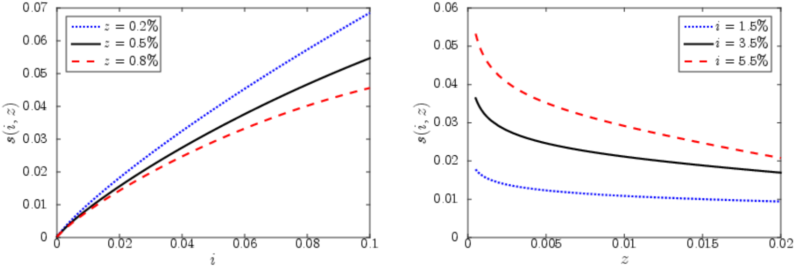
where ι and χ are CES and Cobb-Douglas price indices

$$\iota(i,s) = \left(\alpha i^{1-\epsilon} + (1-\alpha)\, s^{1-\epsilon}\right)^{\frac{1}{1-\epsilon}}$$

$$\chi\left(i,s\right) = \left(\beta\right)^{-\beta}\left(\frac{\iota\left(i,s\right)}{1-\beta}\right)^{1-\beta}$$

- Solve for spread $s\left(i,z\right)$
  - decreasing in z
  - increasing in i if $\epsilon > 1$

Deposit Spread $s(i, z)$



- OLS regression of spread (Drechsler et al. [2014]) on i (Libor 6m) and z (Flow of Funds):

$$
\begin{array}{cccccccccc}
s & = & 0.3\% & + & 0.66 & i & - & 0.99 & z & \\
 & & (0.22\%) & & (0.028) & & & (0.25) & & \\
 & & & & & & & & & \\
s & = & 0.3\% & + & 0.98 & i & - & 4.07 & i^2 & - \; 0.71 \; z \\
 & & (0.44\%) & & (0.17) & & & (2.02) & & \quad (0.32)
\end{array}
$$

Exposure of z to monetary shocks B

- Value function has form

$$V_t^h(w) = \frac{(\zeta_t w)^{1-\gamma}}{1-\gamma} \qquad \text{for household}$$

$$V_t^b(n) = \frac{(\xi_t n)^{1-\gamma}}{1-\gamma} \qquad \text{for banker}$$

  the endogenous ζ_t and ξ_t capture forward-looking investment opportunities

- FOCs for risk exposure:

$$\underbrace{\sigma_w = \frac{\pi}{\gamma} + \frac{1-\gamma}{\gamma}\sigma_\zeta}_{\text{household}} \qquad \underbrace{\sigma_n = \frac{\pi}{\gamma} + \frac{1-\gamma}{\gamma}\sigma_\xi}_{\text{banker}}$$

  - Premium + dynamic hedging
  - Income vs. substitution. If $\gamma > 1$, income effect dominates

Exposure of z to monetary shocks B

- Therefore, exposure of $z \equiv \frac{n}{n+w}$:

$$\sigma_z = (1-z)(\sigma_n - \sigma_w)$$

$$\implies \sigma_z = (1-z)\frac{1-\gamma}{\gamma}(\sigma_\xi - \sigma_\zeta)$$

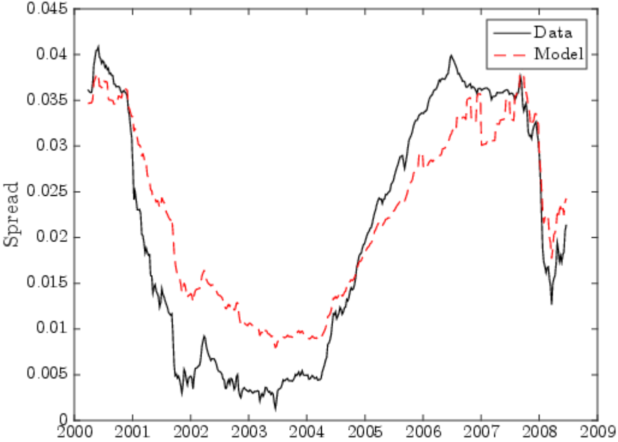
- How banks share of wealth z reacts to an increase in interest rates depends on:
  - how relative investment opportunities ξ/ζ react: $\sigma_\xi - \sigma_\zeta > 0$
  - income vs substitution effects: $\frac{1-\gamma}{\gamma} < 0$

- Dynamic hedge: banks are willing to take a loss when interest rates rise because they expect large spreads looking forward

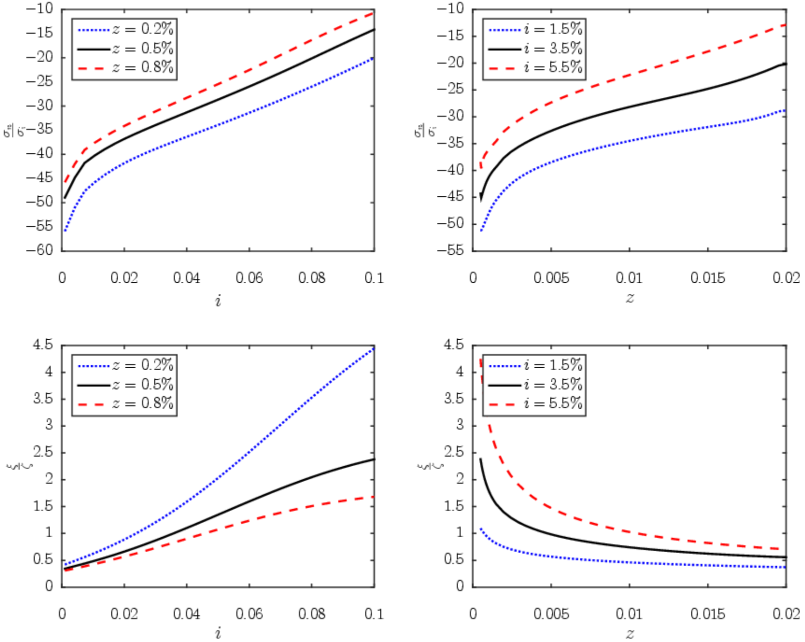
Parameter Values

	Meaning	Value	Remarks
γ	Risk aversion	10	$\sim$ Bansal & Yaron (2004)
$\bar{i}$	Mean interest rate	3.5%	6m LIBOR
σ	Volatility of i	0.044	
λ	Mean reversion of i	0.056	Volatility of 10-year rates
ρ	Discount rate	0.055	$\frac{\text{consumption}}{\text{wealth}}$
ϕ	Leverage	8.77	$\frac{\text{Checking + Savings}}{\text{Net Worth}}$
α	CES weight on currency	0.95	Time series of $s(i,z)$ (Drechsler et. al. 2014)
β	CD consumption share	0.93	
ϵ	Elasticity currency / deposits	6.6	
$\tilde{\sigma}_a$	Volatility of TFP	0.073	Risk free rate
τ	Tax on bank equity	0.195	Average z

Deposit Spread $s(i, z)$



Banks' exposure to movements in interest rates: σ_n/σ_i



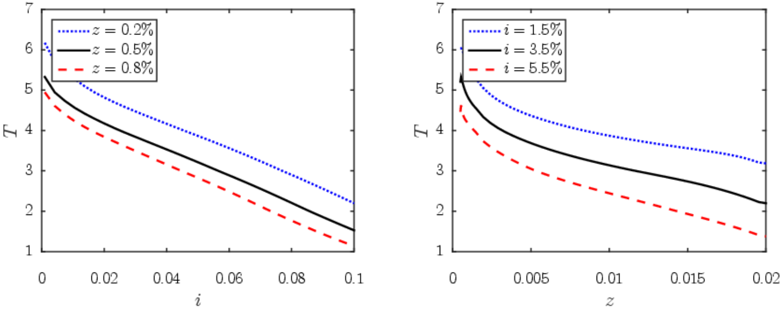
Maturity Mismatch T

- Implement σ_n with "traditional" balance sheet:
  - assets: zero coupon nominal bond of maturity T
  - liabilities: short-term nominal liabilities (e.g. deposits)

- Compute maturity mismatch:
  - Price bonds of every maturity $p^B(i, z; T)$
  - Compute exposure of each bond to interest rates $\sigma_{p^B(i,z;T)}$
  - Find maturity T such that

$$\sigma_n = (1 + \phi)\, \sigma_{p^B(i,z;T)}$$

Maturity Mismatch



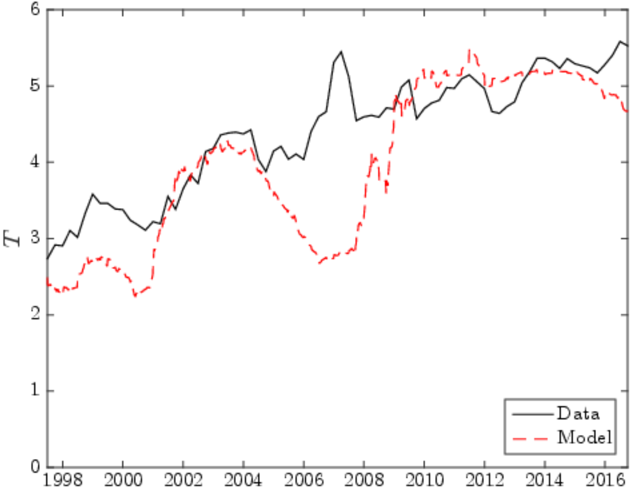
- Higher maturity mismatch when i and z are low: reflects larger sensitivity of $s(i, z)$ to changes in i in that region. OLS:

$$T = \underset{(0.1)}{4.4} - \underset{(6.8)}{11.7}\, i - \underset{(0.4)}{1.9}\, z$$

Quantitative evaluation: time series

- Construct banks' maturity mismatch using Call Reports (English et al. (2012))
- record contractual or repricing maturity of assets and liabilities, and substract
- asset-weighted median across banks
- compare with model predictions based on time series for i and z

Maturity mismatch time series



- Levels: avg. maturity mismatch data: 4.4 yrs; model: 3.9 yrs
- Time pattern: maturity mismatch high when i low; correlation: 0.77

Cross sectional evidence

- Model: banks with more deposits should have a larger maturity mismatch
- Re-solve banker's problem with different $\phi = d/n$; for each ϕ compute the whole time series of maturity mismatch, and take average
- Regress maturity mismatch on ϕ: $\beta = 0.42$
- Same regression in the data

	Median	OLS
Constant	2.6	3.6
	(0.0023)	(0.063)
ϕ	0.43	0.26
	(0.0004)	(0.013)
N	$10,351$	$10,351$

Real shocks under inflation targeting

- Shocks to expected growth rate $\mu_{a,t}$:

$$\frac{d\mu_{a,t}}{\mu_{a,t}} = -\lambda\left(\mu_{a,t} - \bar{\mu}_a\right)dt + \sigma\sqrt{\mu_{a,t} - \mu_{a,t}^{\min}}dB_t$$

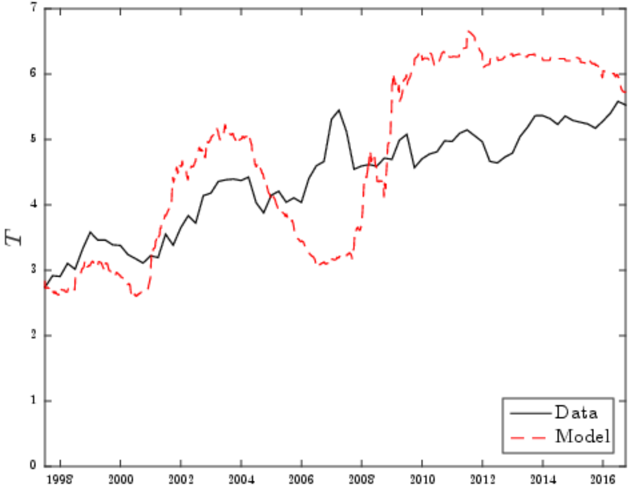
- Central bank adjusts currency supply to keep inflation constant (e.g. 2%):

$$i_t = r_t + \bar{\mu}_p$$

- Negative growth shock $\rightarrow$ low eq. real interest rate $\rightarrow$ low nominal interest rate

- Set parameters to match volatility of interest rates
  - Requires large and persistent growth shocks

Maturity Mismatch with Real Shocks



- Levels: avg. maturity mismatch data: 4.4 yrs; model: 4.7 yrs
- Time pattern: maturity mismatch high when i low; correlation: 0.51

Conclusions

- Dynamic hedging of deposit spreads explains banks interest-rate exposure
  - average, time pattern, cross-sectional pattern
- Does not depend on why interest rates move: monetary and real shocks under inflation targeting
- Banks' maturity mismatch amplifies the effects of monetary policy shock on the cost of liquidity
- Implications for other types of risk exposure (e.g. credit spreads)

Extra: Static Decisions

- Currency-deposit choice (from CES):

$$\frac{d}{m} = (1-\alpha)\left(\frac{\iota}{s}\right)^{\epsilon} \qquad \frac{h}{m} = \alpha\left(\frac{\iota}{i}\right)^{\epsilon}$$

unit cost of m is

$$\iota(i,s) = \left(\alpha i^{1-\epsilon} + (1-\alpha)\, s^{1-\epsilon}\right)^{\frac{1}{1-\epsilon}}$$

- Consumption-money choice (from Cobb-Douglas):

$$c = \beta(\chi x) \qquad \iota m = (1-\beta)\,(\chi x)$$

unit cost of x is

$$\chi\,(i,s) = (\beta)^{-\beta}\left(\frac{\iota\,(i,s)}{1-\beta}\right)^{1-\beta}$$

Extra: Dynamic Decisions

- FOC for $\hat{x}$ is the same for household and banker:

$$\underbrace{\hat{x}_t}_{\frac{x}{\text{wealth}}} \quad \underbrace{\chi_t}_{\text{unit cost of } x} = \rho$$

  - $IES = 1 \Rightarrow \frac{\text{spending}}{\text{wealth}} = \rho$

- Goods market clearing:

$$\underbrace{ak}_{\text{output}} = \underbrace{\beta}_{\frac{\text{consumption}}{\text{spending}}} \underbrace{\rho}_{\frac{\text{spending}}{\text{wealth}}} \underbrace{\omega_t}_{\text{total wealth}} \quad \Rightarrow \omega_t \equiv n_t + w_t = \frac{ak}{\beta\rho}$$

  - Cobb-Douglas + $IES = 1 \Rightarrow$ Constant wealth