Money and Banking in a New Keynesian Model

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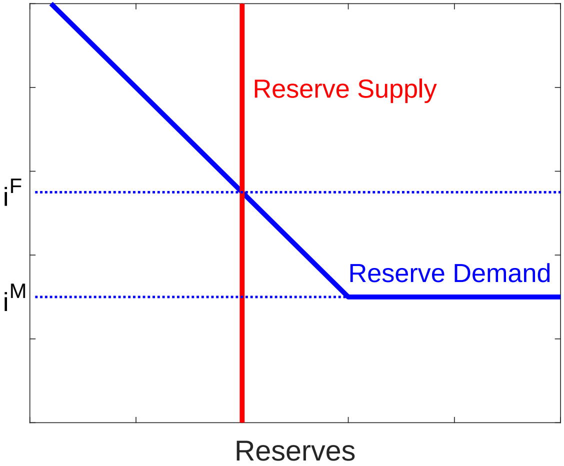
Motivation

- Standard New Keynesian model
  - central bank controls short rate in household stochastic discount factor
  - short rate = return on savings & investment
- This paper: New Keynesian model with banking sector
  - central bank controls interest rate on fed funds or reserves
  - households do not hold these assets directly
  - banks hold these assets to back inside money

  → disconnect between policy rate & short rate
- Central bank chooses reserve supply
  - scarce reserves ('corridor system'): policy targets fed funds rate, fixes reserve rate, adjusts reserves to implement target
  - abundant reserves ('floor system'): policy targets reserve rate

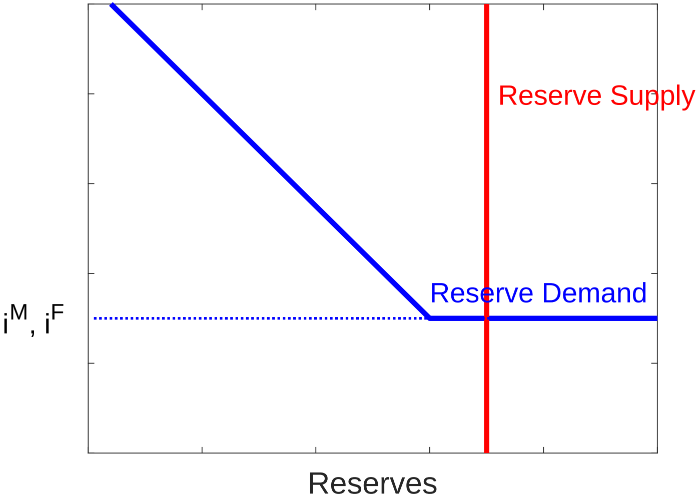
Banking with scarce reserves ("corridor system")

- higher policy rate i^F is tax on banks' liquidity



Banking with abundant reserves ("floor system")

- higher policy rate i^M does not change banks' cost of liquidity



Implications

- Standard NK model
  - interest rate is all that matters, plumbing & quantities not important
- NK model with banks
  - disconnect between policy rate & short rate
    - affects transmission of policy
    - plumbing and quantities matter
  - stronger pass-through from policy rate to short rate in corridor system
    - corridor system: tighter policy is tax on liquidity
  - nominal assets held by banks important for output & inflation
  - less scope for multiple equilibria, even without Taylor principle
- Plan for talk:
  - Transmission in minimal model with disconnect (no banks)
  - Introduce banks

Minimal model with short rate disconnect (no banks)

- Representative household
  - utility separable in labor + CES bundle of consumption & money
  - σ = IES for bundles, η = interest elasticity of money demand
  - for now, separable in consumption & money: $\eta = \sigma$
  - later consider complementarity: $\eta < \sigma$
- Firms
  - consumption goods = CES aggregate of intermediates
  - intermediate goods made 1-1 from labor, Calvo price setting
- Government: central bank digital currency
  - path or feedback rule for money supply D_t
  - path or feedback rule for *policy rate* i_t^D = interest rate on money
  - lump sum taxes adjust to satisfy budget constraint
- Market clearing: goods, money, labor
  - i_t^S = short rate in household SDF adjusts endogenously
  - familiar special case: NK model with money growth rule & peg $i_t^D = 0$

Linear dynamics

- Steady state with zero inflation
- Standard NK Phillips curve & Euler equation

$$\begin{aligned} \Delta\hat{p}_t &= \beta\Delta\hat{p}_{t+1} + \lambda\left(\varphi + \frac{1}{\sigma}\right)\hat{y}_t \\ \hat{y}_t &= \hat{y}_{t+1} - \sigma\left(i_t^S - \Delta\hat{p}_{t+1} - \delta\right) \end{aligned}$$

- Households' choose money holdings to equalize expected returns

$$i_t^S - \delta = \quad i_t^D - r^D \quad + \quad \frac{\delta - r^D}{\eta}\left(\hat{p}_t + \hat{y}_t - \hat{d}_t\right)$$

policy rate

convenience yield, increasing in velocity = spending / money

- Structure of difference equation
  - Standard model: block recursive, solve for $(\hat{p}_t, \hat{y}_t)$ given policy rate i_t^S
  - CBDC model: solve for $(\hat{p}_t, \hat{y}_t, i_t^S)$ given policy tools i_t^D and $\hat{d}_t$
  - state variable $\hat{p}_t$ with initial condition $\hat{p}_0$

Monetary policy

- Standard model: short rate i_t^S = policy rate

- Transmission of interest rate policy

$$\text{policy rate} \quad \overset{+}{\longrightarrow} \quad \begin{matrix}\text{real return}\\ \text{on savings}\end{matrix} \quad \overset{-}{\longrightarrow} \quad \begin{matrix}\text{output,}\\ \text{inflation}\end{matrix}$$

- Money supplied elastically to implement i_t^S, fix $i_t^D = 0$

Monetary policy

- CBDC model: convenience yield is endogenous wedge

$$i_t^S - \delta = i_t^D - r^D + \frac{\delta - r^D}{\eta}\left(\hat{p}_t + \hat{y}_t - \hat{d}_t\right)$$

- Transmission of interest rate policy

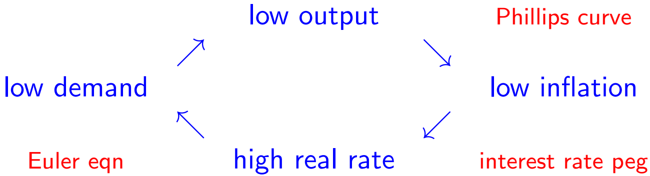
policy rate	$\overset{+}{\longrightarrow}$	real return on savings	$\overset{-}{\longrightarrow}$	output, inflation
		$+\uparrow$		$+\downarrow$
		convenience yield	$\overset{+}{\longleftarrow}$	spending, velocity

$\Rightarrow$ convenience yield dampens effect

- Money supply = independent policy instrument

Local determinacy with interest rate peg

- Standard model: many bounded solutions to difference equation
- When do we get multiple bounded equilibrium paths?



- Taylor principle: policy reacts aggressively to low inflation

Local determinacy with interest rate peg

- Standard model: many bounded solutions to difference equation
- When do we get multiple bounded equilibrium paths?

		low output		Phillips curve
	↗	↓	↘	
low demand		low convenience yield	←	low inflation
	↖	↓	↙	
Euler eqn		low real rate		interest rate peg

- CBDC model: endogenous convenience yield as a stabilizing force
  - works like Taylor principle: lower rate if lower inflation, output
  - strength depends on preferences, technology, policy

Conditions for local determinacy

- Policy: interest rate & money supply
  - exogenous path for i_t^D or Taylor rule $i_t^D = r^D + \phi_\pi \Delta \hat{p}_t + v_t$
  - compare three scenarios for money supply rule

1. Exogenous path for money supply
   - always local determinacy: convenience yield responds strongly to π

2. Exogenous path for real balances: $D_t = P_t G_t$
   - local determinacy iff $\frac{\delta - r^D}{\eta} > \frac{\lambda(\varphi + 1/\sigma)}{1-\beta}(1 - \phi_\pi)$
   - less scope for multiple equilibria if
     - ★ money demand less elastic (low η) $\rightarrow$ conv. yield responds more to y
     - ★ flatter NK Phillips curve, e.g. prices more sticky, lower λ
     - ★ more aggressive inflation response: higher ϕ_π

3. Nominal rigidities in money supply: $D_t = \mu D_{t-1} + P_t G, \quad \mu < 1$
   - local determinacy if μ sufficiently large
   - predetermined nominal money $\rightarrow$ convenience yield responds more

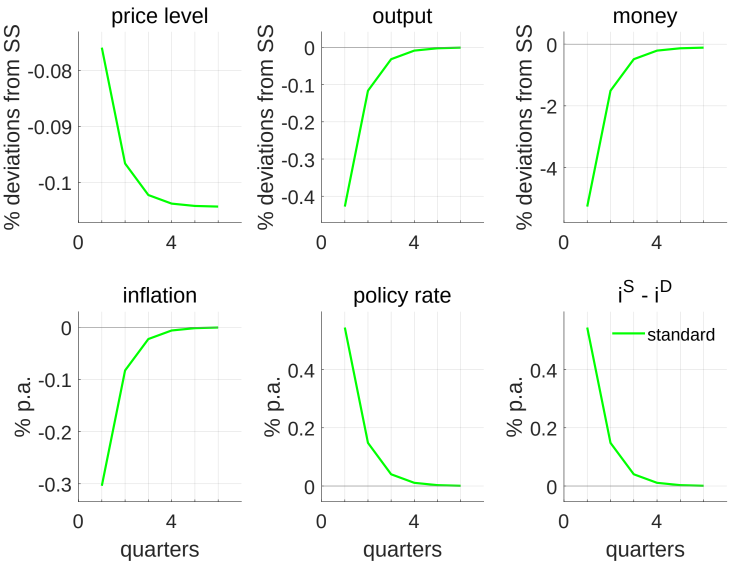
Cost channel

- Consumption & money complements in utility
  - nonseparable utility with $\eta < \sigma$
  - higher cost of liquidity $i_t^S - i_t^D$ makes shopping less attractive
    $\rightarrow$ reduce consumption, increase leisure/decrease labor
    $\rightarrow$ lower output, higher inflation

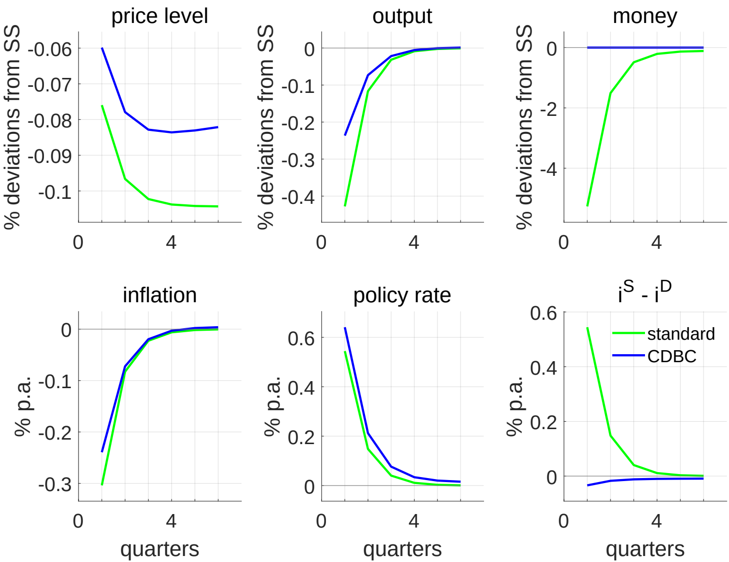
- Effect of higher policy rate on cost of liquidity $i_t^S - i_t^D$
  - standard model: higher i_t^S with fixed i_t^D $\rightarrow$ higher cost
  - CBDC model: higher i_t^D + imperfect pass-through $\rightarrow$ lower cost

- Numerical example
  - $\delta = 4\%, r^D = 1.6\%, \sigma = 1, \eta = .2$, standard cost & Calvo pars
  - constant money supply
  - Taylor rule with coefficient 1.5 on inflation, .5 on past short rate
  - compare impulse responses to $25bp$ monetary policy shock

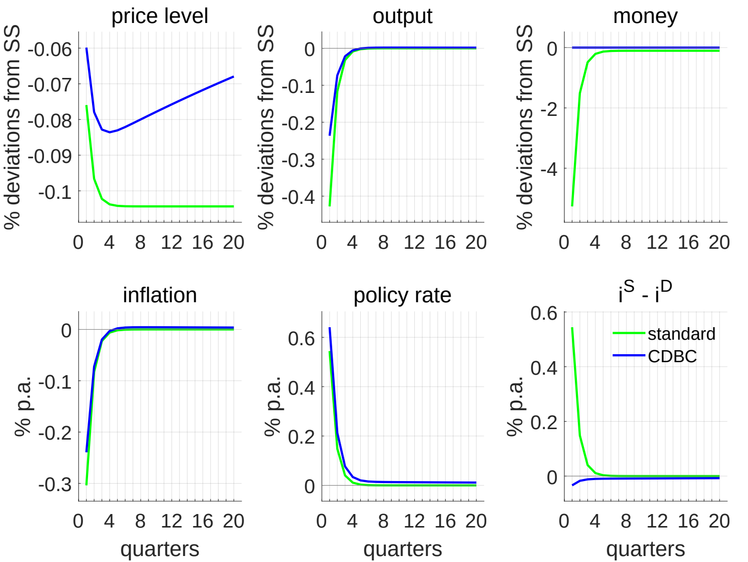
IRFs to 25 bp monetary policy shock: standard model



IRFs to 25 bp monetary policy shock: standard vs CBDC

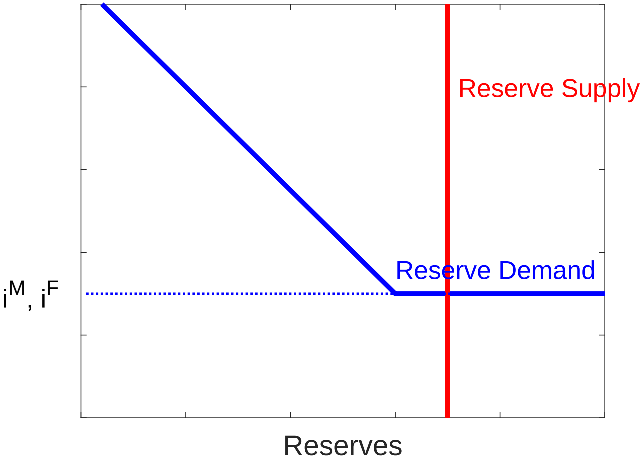


IRFs to 25 bp monetary policy shock: standard vs CBDC



NK Model with Banks

- central bank provides abundant reserves ("floor system")
  - reserves are special as collateral, not needed for liquidity
  - monetary policy targets reserve rate



Banking sector

- Balance sheet

Assets		Liabilities	
M	Reserves	Money	D
A	Other assets	Equity	

- Shareholders maximize present value of cash flows

$$M_{t-1}\left(1+i_{t-1}^{M}\right)-M_t-D_{t-1}\left(1+i_{t-1}^{D}\right)+D_t$$
$$+A_{t-1}\left(1+i_{t-1}^{A}\right)-A_t$$

- Costless adjustment of equity

- Leverage constraint: $D_t \leq \ell\left(M_t+\rho A_t\right)$
  - $\rho < 1$ other assets are lower quality collateral to back (inside) money

Bank optimization: perfect competition

- Nominal rate of return on equity $= i_t^S$
  - banks equate returns on assets & liabilities to cost of capital i_t^S
  - $\gamma_t =$ multiplier on leverage constraint
- Optimal portfolio choice: assets valued as collateral

$$\begin{aligned} i_t^S &= i_t^M + \ell\gamma_t\left(1 + i_t^S\right) \\ i_t^S &= i_t^A + \rho\ell\gamma_t\left(1 + i_t^S\right) \end{aligned}$$

- Optimal money creation: money requires leverage cost

$$i_t^S = i_t^D + \gamma_t\left(1 + i_t^S\right)$$

$\Rightarrow$ Marginal cost pricing of liquidity

$$i_t^S - i_t^D = \frac{1}{\ell}\left(i_t^S - i_t^M\right)$$

Bank market power

- Many monopolistically competitive banks
- Households care about CES bundle of deposit varieties

$$D_t = \left(\int \left(D_t^i \right)^{1-\frac{1}{\eta_b}} \right)^{\frac{1}{1-\frac{1}{\eta_b}}}$$

  - $\eta_b =$ elasticity of substitution between bank accounts

$\Rightarrow$ Constant markup over marginal cost

$$i_t^S - i_t^D = \frac{\eta_b}{\eta_b - 1} \frac{1}{\ell} \left(i_t^S - i_t^M \right)$$

Equilibrium with abundant reserves

- Government: floor system with abundant reserves
  - path or rule for supply of reserves M_t
  - path or rule for interest rate on reserves i_t^M
- Market clearing for reserves & other bank assets
  - path or rule for exogenous supply of nominal assets A_t
  - stands in for borrowing by firms or against housing
  - nominal rigidity in A_t could be due to long term debt
- Characterizing equilibrium
  - NK Phillips curve & Euler equation unchanged

Dynamics with abundant reserves

- Interest rate pass-through: reserve rate to short rate

$$i_t^S - \delta = i_t^M - r^M + \frac{\delta - r^M}{\eta} \left(\hat{p}_t + \hat{y}_t - \hat{d}_t \right)$$

  - reserves back inside money, inherit convenience yield of deposits

- Money supply

$$\hat{d}_t = \frac{M}{M + \rho A} \hat{m}_t + \frac{\rho A}{M + \rho A} \hat{a}_t$$

  - reserves a separate policy instrument: QE stimulates economy!
  - other bank assets also matter: bad loan shocks contractionary

$\Rightarrow$ Works like CBDC model, but coefficients depend on banking system

Banking with scarce reserves

- Banks manage liquidity
  - deposit outflow/inflow $\tilde{\lambda} D_t$ to/from other banks
  - iid liquidity shock $\tilde{\lambda}$ has mean zero, cdf G with bounded support
  - satisfy leverage constraint after deposit inflow/outflow
  - borrow/lend in competitive fed funds market at rate i^F
- Assets valued as collateral, reserves also for liquidity
- Government:
  - path or rule for fed funds rate i_t^F, reserve rate i^M; here $i^M = 0$
  - reserve supply adjusts to meet interest rate targets
- Market clearing for reserves, Fed funds
  - reserves scarce: quantity small relative to support of liquidity shocks
  - otherwise $i^F = i^M$ & no active Fed funds market, back to abundance
  - government selects type of equilibrium

Dynamics with scarce reserves

- Interest rate pass-through: fed funds rate to short rate

$$i_t^S - \delta = i_t^F - r^M + \frac{\delta - r^M}{\eta}\left(\hat{p}_t + \hat{y}_t - \hat{d}_t\right)$$

- Inside money in reserveless limit: share of reserves in bank assets $\rightarrow 0$

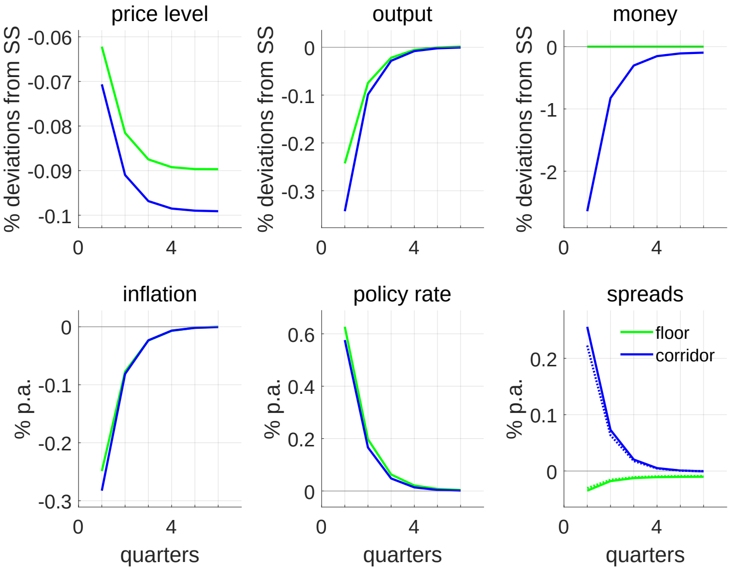
$$\hat{d}_t = \frac{\eta}{\eta+\varepsilon}\hat{a}_t + \frac{\varepsilon}{\eta+\varepsilon}\left(\hat{p}_t + \hat{y}_t - \frac{\eta}{r^F}\left(i_t^F - r^F\right)\right)$$

  - $\varepsilon =$ function of bank technology parameters

$\Rightarrow$ Works like CBDC model with more elastic money supply

- Numerical example to compare floor & corridor system

IRFs to monetary policy shock



Conclusion

- Disconnect between policy rate and short rate
  - convenience yield is endogenous wedge, changes transmission
  - less scope for multiple equilibria, even without Taylor principle
  - policy weaker if more nominal rigidities in balance sheets
- Bank models vs CBDC model
  - same basic transmission mechanism
  - difference to standard model depends on details of banking system:
    - nominal rigidities in bank balance sheets, bank market power
    - liquidity management & elasticity of deposit supply
- Corridor vs floor system
  - with cost channel, significant differences in IRFs
  - corridor system closer to standard model than floor system