Money and Banking in a New Keynesian Model

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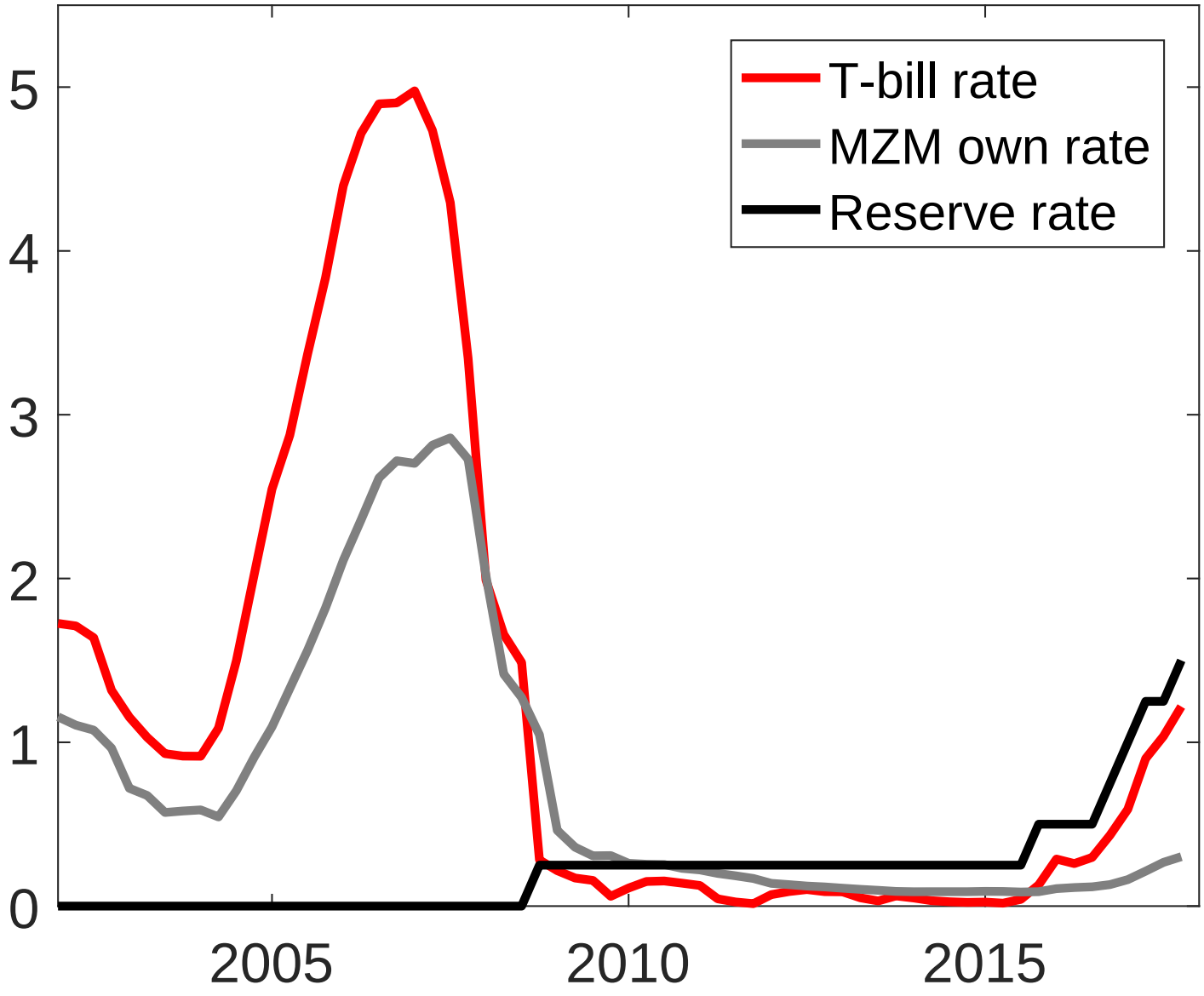
Various interest rates



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 on Fed funds or reserves
  - households do not hold these assets directly
  - banks hold these assets to back inside money

  $\rightarrow$ convenience yields on inside money, Fed funds, reserves
- Imperfect pass-through from policy rate to short rate
  - interest rate policy less powerful
  - less scope for multiple equilibria, even without Taylor principle
  - weaker pass-through if more nominal rigidities in balance sheets

Outline: three models

1. Central bank digital currency = reserve accounts for everyone
   - central bank controls interest rate on money & its supply

   $\Rightarrow$ minimal model to illustrate imperfect pass-through

2. Banking with abundant reserves ("floor system")
   - central bank controls reserve rate (= bond rate) & reserve supply

   $\Rightarrow$ works like CBDC model, but coefficients depend on bank balance sheets

3. Banking with scarce reserves ("corridor system")
   - central bank sets reserve rate, targets interbank rate
   - supply of reserves adjusts to achieve target rate

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

Central bank digital currency model: setup

- Representative household
  - 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 for money supply D_t
  - path or 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

Linear dynamics

- Linearize around steady state with zero inflation, policy rate r^P
- Standard NK Phillips curve & Euler equation

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

- Interest rate pass-through: equalize expected returns

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

$i_t^S - \delta$: discount rate

$i_t^D - r^D$: interest rate policy

$\frac{\delta - r^D}{\eta}\left(\hat{p}_t + \hat{y}_t - \hat{d}_t\right)$: convenience yield, increasing in velocity = spending / money

- Monetary policy
  - path for money supply + path or rule for policy rate i_t^D

Comparison to three equation NK model

- Same NK Phillips curve & Euler equation
- Interest rate pass-through

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

discount rate | interest rate policy | convenience yield, increasing in velocity = spending / money

- Policy does not control short rate in SDF i_t^S
  - convenience yield on money = endogenous wedge
  - imperfect pass through: higher policy rate lowers convenience yield
  - approach standard model if demand very elastic
  - Taylor rule for $i_t^D \to$ price level targeting rule for i_t^S
- Price level a (nontrivial) state variable
- Money supply is separate policy tool

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discount rate | interest rate policy | convenience yield, increasing in velocity = spending / money

- Money demand & supply in standard model

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

  - zero interest rate on money
  - money elastically supplied to achieve i_t^S
  - system block recursive, "money doesn't matter"

Interest rate policy

- Standard model: short rate = policy rate

$$i_t^S - \delta = i_t^S - \delta$$

- Transmission in standard model

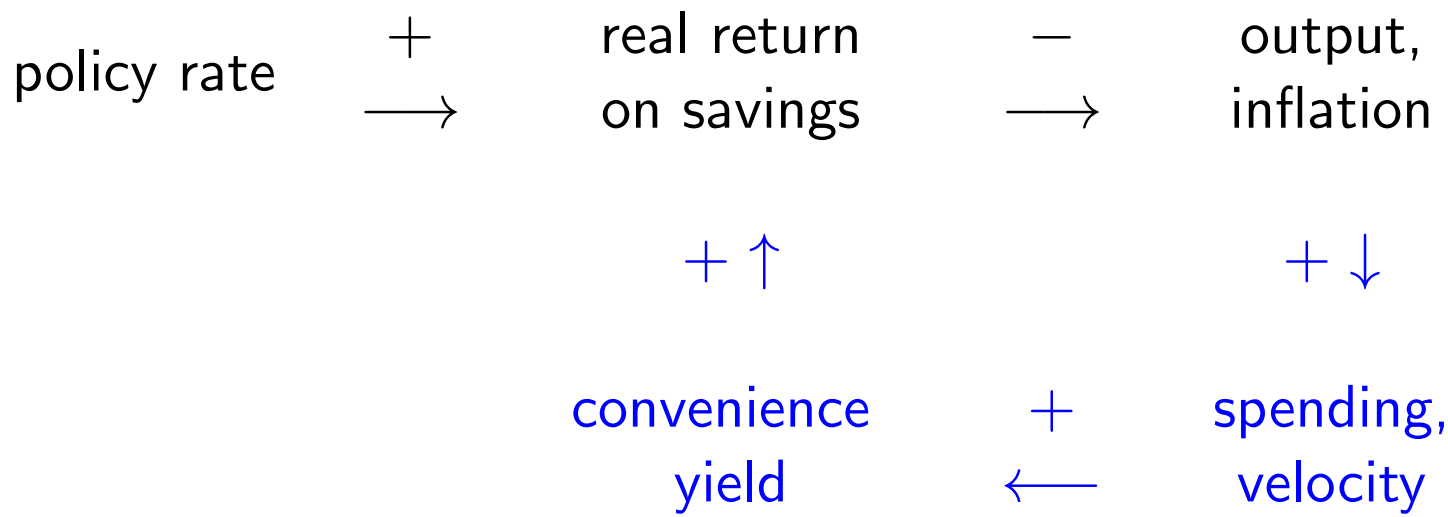
$$\text{policy rate} \quad \overset{+}{\longrightarrow} \quad \text{real return on savings} \quad \overset{-}{\longrightarrow} \quad \text{output, inflation}$$

Interest rate policy

- Central bank digital currency: interest rate pass-through

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

- Transmission with central bank digital currency



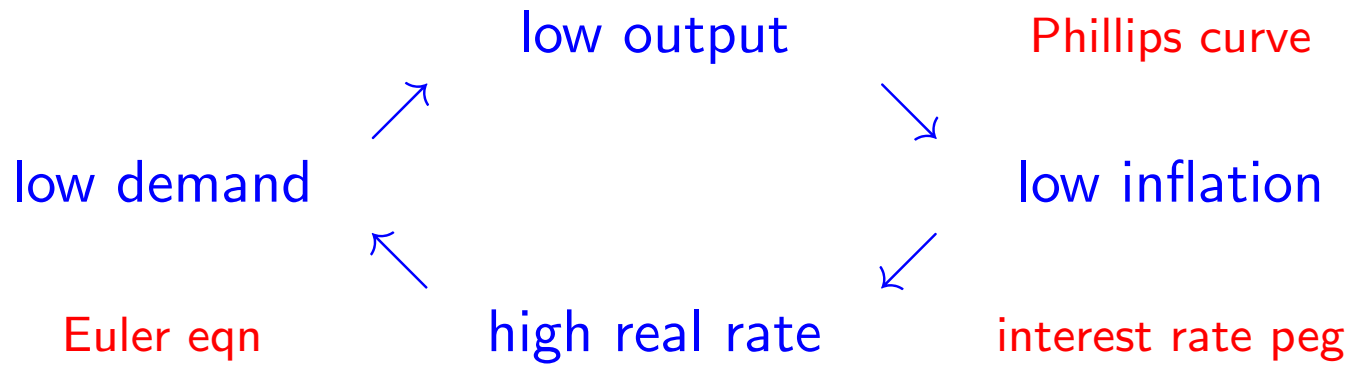
- More dampening of interest policy if
  - money demand less interest elastic, money supply less income elastic

Local determinacy

- Interest rate pass-through

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

- Multiple bounded equilibrium paths with interest rate peg?



- Central bank digital currency
  - lower spending $\rightarrow$ lower convenience yield, lower return on savings!
  - works like Taylor principle: lower rate if low inflation, output

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

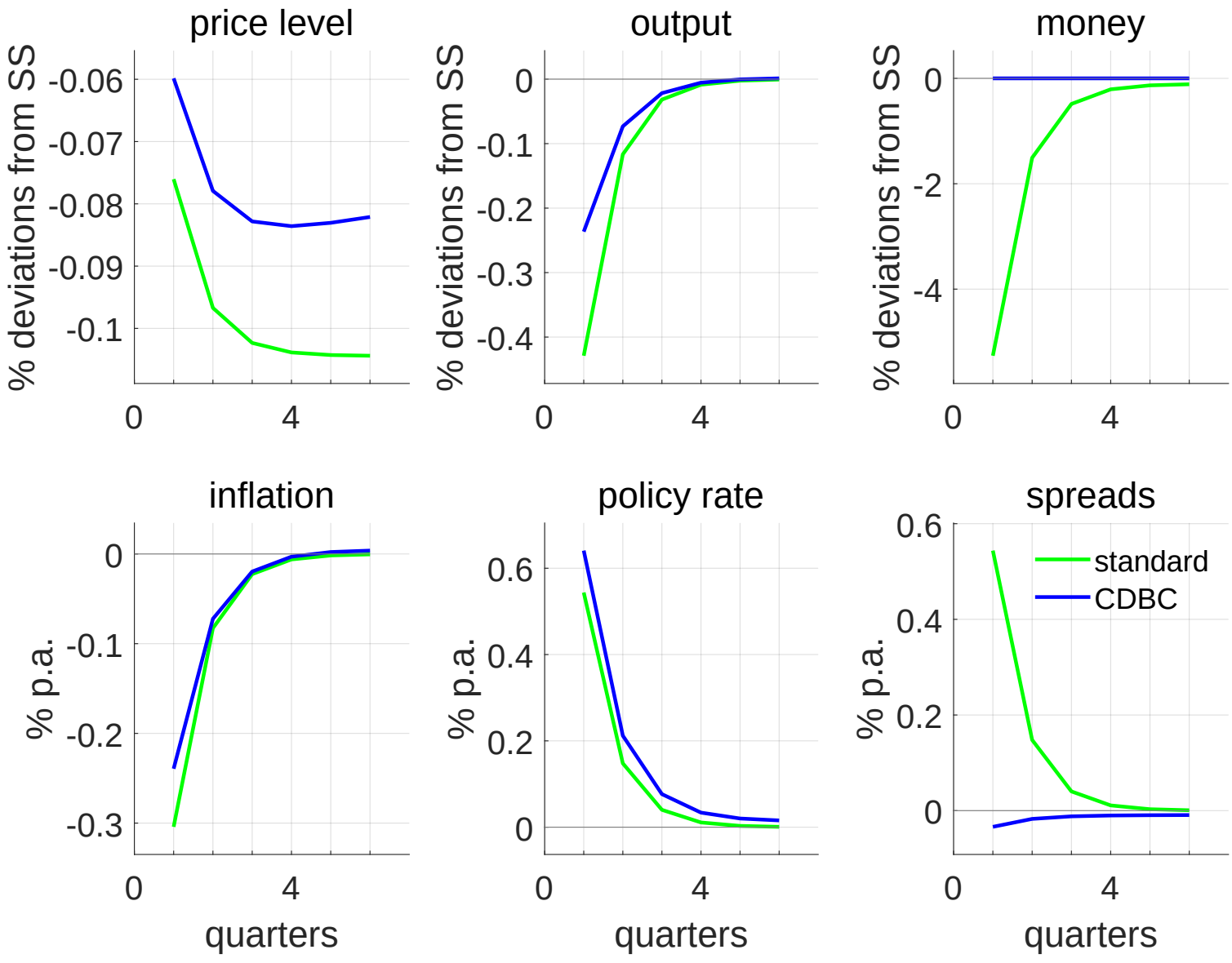
    $\rightarrow$ reduce consumption, increase leisure/lower labor

    $\rightarrow$ lower output, higher inflation

- Effect of higher policy rate:
  - 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
  - $\delta = 4.9\%, r^D = 2.5\%, \sigma = 1, \eta = .2$, 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 monetary policy shock



CBDC model: summary

- Policy rate = rate on money, which has convenience yield
  - imperfect pass through from policy rate to short rate in SDF
  - weaker policy impact, especially with cost channel
  - determinacy even when central bank does not respond to inflation
  - money is a separate policy tool
- Role of money supply as "nominal anchor"
  - government fixes nominal money: stronger convenience yield effect
  - not essential for above results
- Propositions on determinacy for more general money supply rules
  - need conditions for coefficients, easy to satisfy with separability
  - with cost channel: multiple equilibria with strong output response
- Key properties shared by banking models...

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Banking with abundant reserves

- Many monopolistically competitive banks
  - households care about CES bundle of deposit varieties; elasticity η^b
  - households own banks, maximize shareholder value

Assets		Liabilities	
M	Reserves	Money	D
A	Other assets	Equity	

  - leverage constraint: $D_t \leq \ell \left(M_t + \rho A_t \right)$ with $\rho < 1$
  - costless adjustment of equity

- Government: floor system with abundant reserves
  - path for supply of reserves M_t
  - path or rule for interest rate on reserve i_t^M

- Market clearing for reserves & other bank assets
  - exogenous supply of nominal assets A_t

Dynamics with abundant reserves

- NK Phillips curve & Euler equation unchanged
- Interest rate pass-through: reserve rate to short rate

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

  - banks equate returns on assets & liabilities to cost of capital i_t^S
  - reserves back inside money, inherit convenience yield of deposits

- Cost of liquidity

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

  - markup over banks' marginal cost; determines strength of cost channel

- 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

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Banking with scarce reserves

- Liquidity shocks
  - deposit in- or outflows after choice of reserves, loans, deposits
  - competitive Fed funds market: borrow, lend reserves at rate i^F
  - leverage constraint must hold *after* liquidity shocks
  - Fed funds worse collateral than reserves, weight $\phi < 1$
- Optimal liquidity management
  - borrow if too few reserves to meet outflows, lend reserves otherwise
  - liquidity benefit of reserves: hold reserves even if $i^M < i^F$
  - elastic deposit supply: falls with policy rate to avoid costly leverage
- Government: corridor system with scarce reserves
  - path or rule for fed funds rate i^F_t, reserve rate i^M; here $i^M = 0$
  - reserve supply adjusts to meet interest rate targets
  - reserves scarce in equilibrium if Funds rate sufficiently high
- Reserveless limit: share of reserves in bank assets $\to 0$

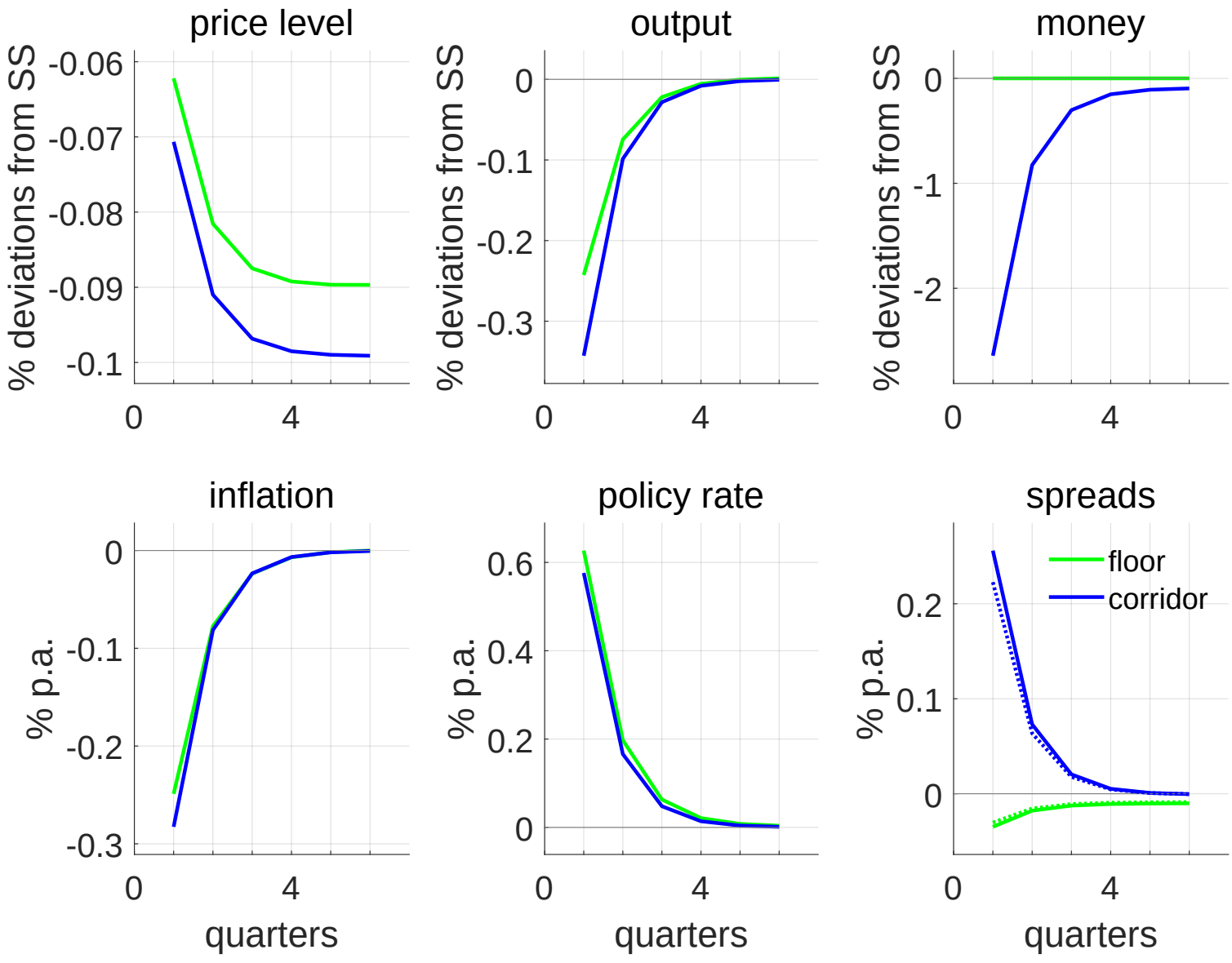
Dynamics with scarce reserves

- Same transmission mechanism as before
  - interest rate pass-through: Fed funds rate i_t^F to short rate i_t^S
  - cost of liquidity: $i_t^S - i_t^D =$ markup $\left(i_t^S - i_t^F\right)$
- New element: elastic money supply, parameter ε

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

  - elastic supply of reserves: money supply income- and interest elastic
  - higher ε: closer to standard model
- Numerical example: compare IRFs under floor & corridor systems
  - $\delta =$ short rate from term structure model estimated w/o Tbills
  - policy rates $r^F, r^M =$ average Tbill rate
  - deposit rate = MZM own rate, markup chosen to match spread
  - ε chosen to match impact effect on deposit rate in corridor system

IRFs to monetary policy shock



Conclusion

- Imperfect pass-through from policy rate to short rate
  - interest rate policy less powerful
  - less scope for multiple equilibria, even without Taylor principle
  - weaker pass-through 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, large difference in IRFs
  - corridor system closer to standard model than floor system