Some Unpleasant Central Bank Balance Sheet Arithmetic

Saroj Bhattarai

University of Texas at Austin

Keio University
Oct 31, 2017

Motivation

- Central bank balance sheet size and composition have changed
  - Result of unconventional monetary policy by major central banks
- Composition change has generated mismatches
  - Interest-bearing short-term liabilities (reserves)
  - Long-term (or foreign currency) assets
- Such maturity (or currency) mismatches can generate non-trivial fluctuations in central bank income and remittances to the Treasury

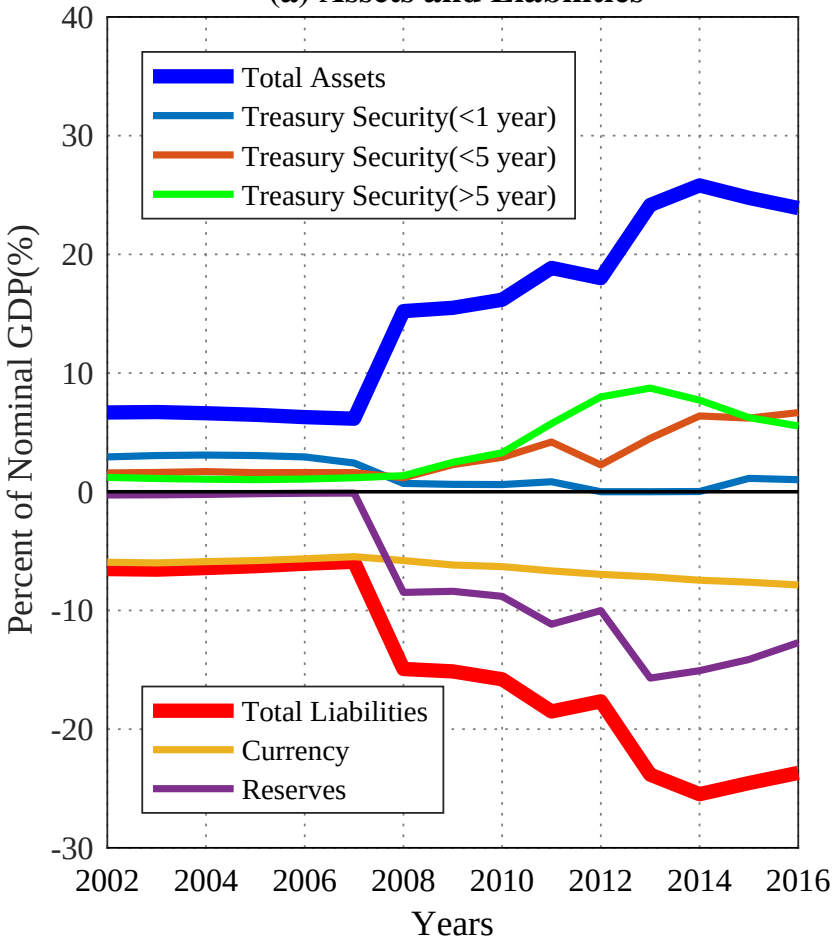
Research questions

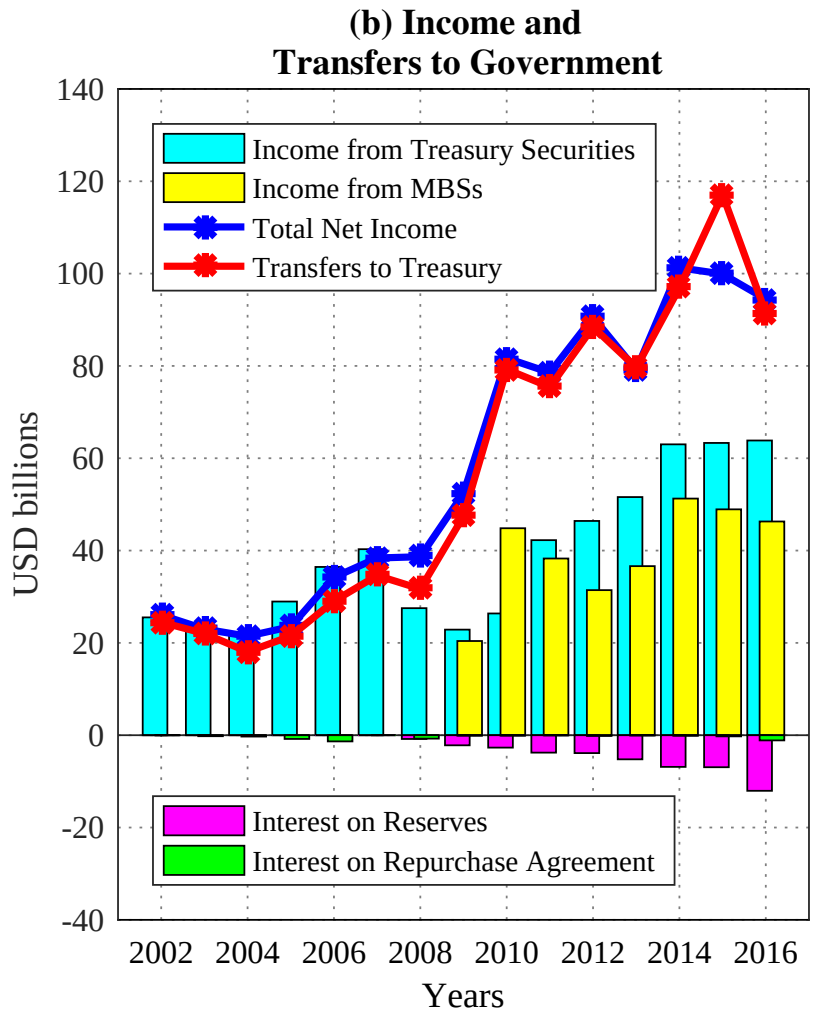
- Do these mismatches affect conventional monetary policy?
  - What monetary and fiscal policy regime can make it matter?
- If so, how exactly does it constrain conventional monetary policy?
  - How is the path of interest rate (or exchange rate) affected?
- What are the implications for monetary policy transmission?
  - Use an otherwise standard dynamic GE model
  - Transmission of a current monetary policy shock (surprise shock)
  - Transmission of a monetary policy news shock (forward guidance shock)

Related literature

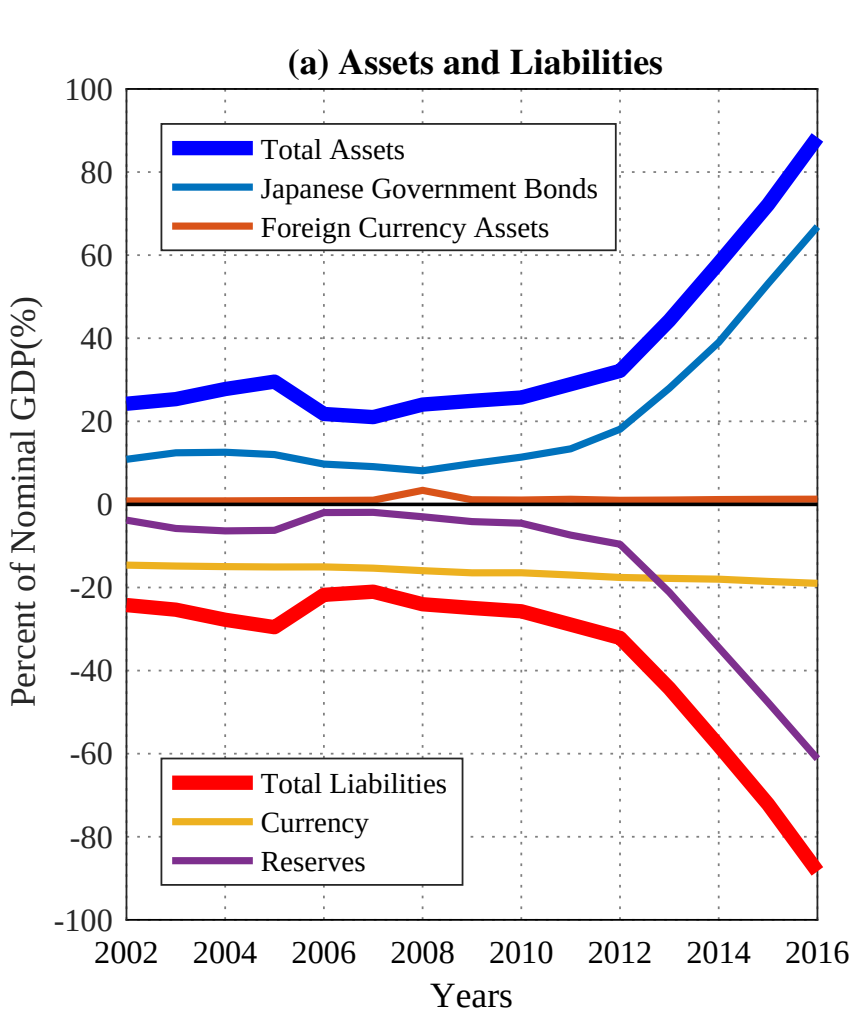
- Monetary and fiscal policy interactions
  - Unpleasant monetarist arithmetic and fiscal theory of the price level (Sargent and Wallace (1981), Sims (1994), Woodford (1995), ...)
- Central bank balance sheet and monetary policy
  - Pre-crisis (Sims (2004), Sims (2005), Jeanne and Svensson (2007), Berriel and Bhattarai (2009))
  - QE, interest on reserves, and implications (Hall and Reis (2013), Del Negro and Sims (2015), Bhattarai, Eggertsson, and Gafarov (2016))
- Forward guidance puzzle and resolutions
  - Del Negro, Giannoni, and Patterson (2015), Mckay, Nakamura, and Steinsson (2016), ...
- Correlation between nominal rate and inflation/real rate
  - Neo-Fisherism (Williamson (2015))

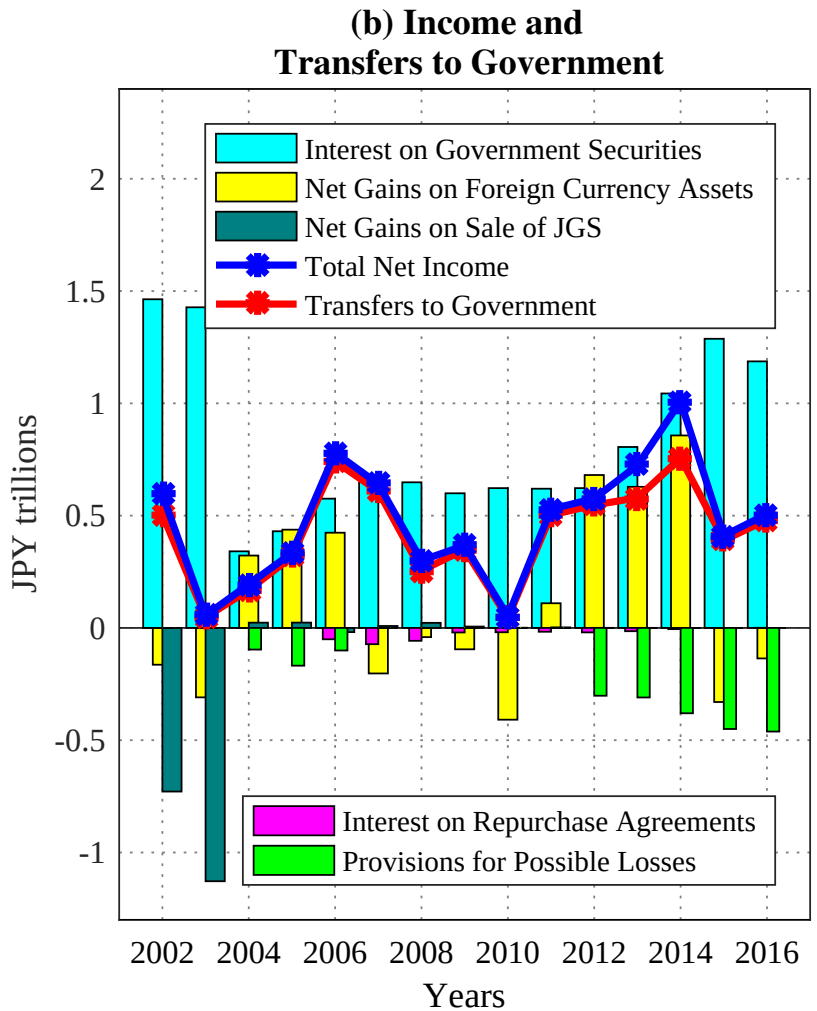
US Federal Reserve



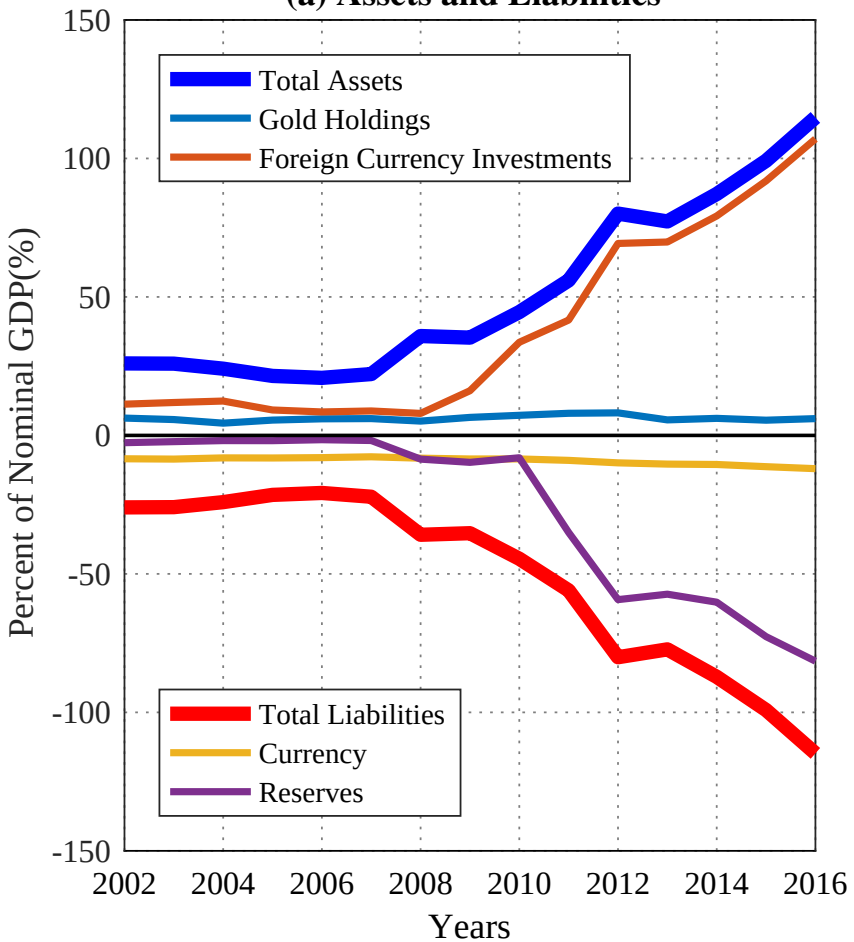


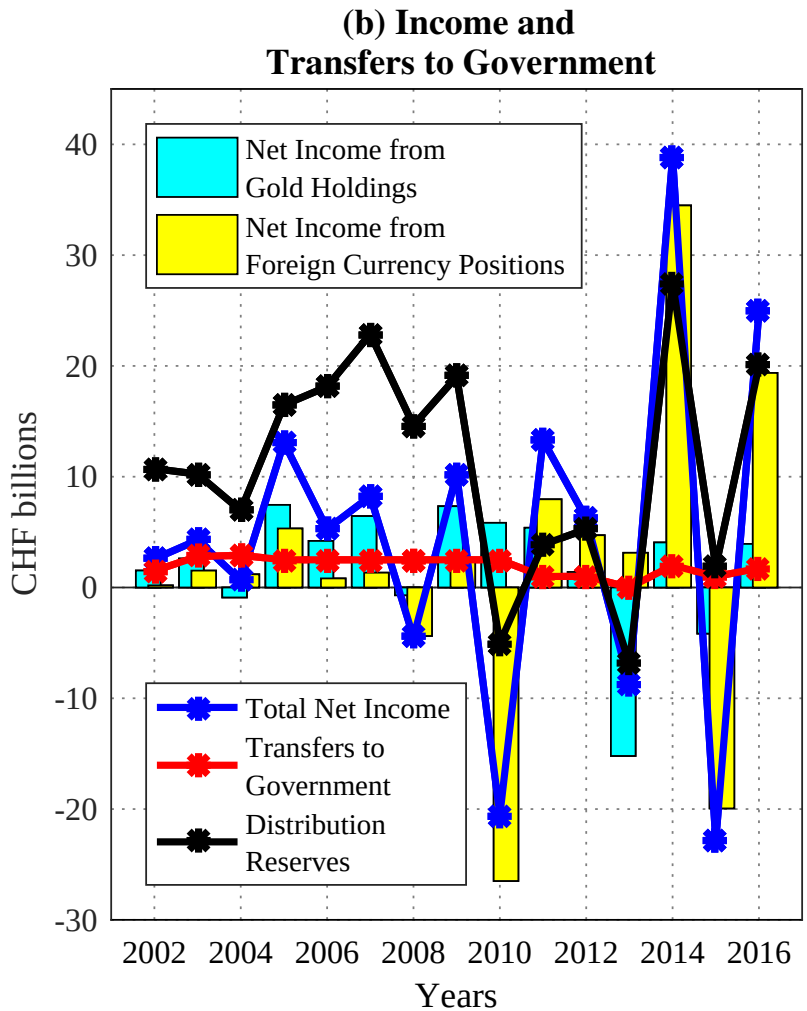
Bank of Japan





Swiss National Bank





Closed economy model

- Nominal central bank flow budget constraint

$$Q_{1t}B_{t-1} - L_{t-1} - M_{t-1} - P_t T_t = Q_{2t}B_t - Q_{1t}L_t - M_t$$

  where P_t is the price level
- Balance sheet variables (model of maturity mismatch)
  - M_t: non-interest bearing liabilities
  - L_t : one-period liabilities with Q_{1t} its price
  - B_t : two-period assets with Q_{2t} its price
- Monetary/fiscal policy interaction variable
  - T_t : central bank transfer to the Treasury
- Conventional monetary policy instrument
  - Q_{1t}: one-period bond price

Closed economy model

- Real flow budget constraint

$$Q_{1t} b_{t-1} \Pi_t^{-1} - l_{t-1} \Pi_t^{-1} - m_{t-1} \Pi_t^{-1} - T_t = Q_{2t} b_t - Q_{1t} l_t - m_t$$

  where Π_t is gross inflation

- Complete market asset-pricing

$$Q_{1t} = E_t \left[\zeta_{t,t+1} \Pi_{t+1}^{-1} \right], \; Q_{2t} = E_t \left[\zeta_{t,t+1} Q_{1t+1} \Pi_{t+1}^{-1} \right]$$

  where $\zeta_{t,t+1}$ is the stochastic discount factor

Closed economy model

- Approximate the budget constraint and asset pricing conditions and abstract from cash/seigniorage
- Expectations hypothesis: $\hat{Q}_{2t} = \hat{Q}_{1t} + E_t \hat{Q}_{1t+1}$
- Budget constraint

$$b_{N,t} = \frac{1}{\beta} b_{N,t-1} - \frac{1}{\beta} \hat{T}_t + bR_{N,t}$$

where net interest income

$$R_{N,t} \equiv \hat{Q}_{1t} - \beta E_t \hat{Q}_{1t+1}$$

- Note some features
  - Sufficient state variable: $b_{N,t} \equiv \beta \hat{b}_t - \hat{l}_t$
  - Inflation does not appear (both assets and liabilities nominal)

Closed economy model

- PV form

$$b_{N,t-1} = \sum_{t=0}^{\infty} \beta^t \hat{T}_t - \beta b \sum_{t=0}^{\infty} \beta^t R_{N,t}$$

where net interest income

$$R_{N,t} \equiv \hat{Q}_{1t} - \beta E_t \hat{Q}_{1t+1}$$

- Consider a fixed PV of $\hat{T}_t$ (As in Sargent and Wallace (1981))
  - This is a *balance sheet constrained* central bank
- When a closed economy central bank is *balance sheet constrained*
  - Increase in $R_{N,t}$ today leads to a decrease in future (similar to higher seigniorage today leading to lower seigniorage in future)
  - Interest rate path in future gets constrained (similar to inflation)
  - This is *unpleasant central bank balance sheet arithmetic*

GE model

Closed economy model

- Standard GE model to assess policy and macro implications
  - Endogenous determination of inflation and output
- Monetary policy rules
  - Standard interest rate policy rule
  - Central bank transfer rule
- Policy experiments
  - Monetary policy surprise shock
  - Monetary policy news shock (forward guidance)

Households

- Representative household maximizes

$$E_0 \sum_{t=0}^{\infty} \beta^t U(c_t, h_t)$$

where c_t is a CES aggregate of differentiated varieties $c_t(i)$

- Household flow budget constraint

$$I_{t-1}^H \Pi_t^{-1} - Q_{1t} b_{t-1}^H \Pi_t^{-1} = Q_{1t} I_t^H - Q_{2t} b_t^H + c_t - w_t h_t - \varphi_t + \tau_t$$

where w_t is real wages, φ_t is profits from firms, and τ_t is net lump-sum taxes from the Treasury

Firms

- Continuum of monopolistically competitive firms
- Firm $i \in [0,1]$ produces output $y_t(i)$ using labor
- Firm i sets prices $P_t(i)$ for its good facing demand

$$\frac{y_t(i)}{y_t} = \left(\frac{P_t(i)}{P_t}\right)^{-\nu}$$

and subject to cost of adjusting prices

$$d\left(\frac{P_t(i)}{P_{t-1}(i)}\right)$$

- Firm i maximizes expected discounted profits

$$E_0 \sum_{t=0}^{\infty} \zeta_{0,t} \varphi_t(i)$$

Monetary policy

- Central bank flow budget constraint

$$Q_{1t} b_{t-1} \Pi_t^{-1} - I_{t-1} \Pi_t^{-1} - T_t + K = Q_{2t} b_t - Q_{1t} I_t$$

where K is any other central bank revenue net of operations cost

- An interest-rate feedback rule

$$\beta Q_{1t}^{-1} = \left(\frac{\Pi_t}{\Pi} \right)^{\phi_\pi} \exp(\varepsilon_{It})$$

where $\phi_\pi \geq 0$

- Surprise and news shock

$$\varepsilon_{It} = \rho \varepsilon_{It-1} + \exp(\sigma) \varepsilon_t$$

$$\varepsilon_{It} = \rho \varepsilon_{It-1} + \exp(\sigma) \varepsilon_{t-k}$$

Monetary policy

- Transfer to the treasury rules

$$T_t^b - \frac{T}{2} = \psi_{bT}\beta\left(b_{t-1} - b\right),\ T_t^l - \frac{T}{2} = -\psi_{lT}\left(l_{t-1} - l\right)$$

- Total transfer to the Treasury $(T_t = T_t^b + T_t^l)$

$$T_t - T = \psi_{bT}\beta\left(b_{t-1} - b\right) - \psi_{lT}\left(l_{t-1} - l\right)$$

- Baseline/specific case

$$T_t - T = \psi_T\left[\beta\left(b_{t-1} - b\right) - \left(l_{t-1} - l\right)\right]$$

- Gross position constant over time $(T_t^b = T_t^l)$

Fiscal policy

- No govt spending for simplicity
- Treasury turns over all central bank remittances to the household
- Treasury has zero holdings of reserves and long-term bonds
- So, very simple fiscal policy

$$T_t = \tau_t$$

$$L_t^T = 0,\ B_t^T = 0$$

Market clearing and definitions

- Market clearing

$$y_t(i) = c_t(i) + d\left(\frac{P_t(i)}{P_{t-1}(i)}\right)$$

$$b_t - b_t^H = b_t^T = 0,\ I_t^H - I_t = I_t^T = 0$$

- Definitions (similar to the simple model)

$$R_{N,t} \equiv \frac{Q_{1t}}{Q_{2t}} - \frac{1}{Q_{1t}}$$

$$b_{N,t-1} \equiv [\beta (b_{t-1} - b) - (I_{t-1} - I)]$$

Policy regimes and functional forms

- Policy rules

$$\beta Q_{1t}^{-1} = \left(\frac{\Pi_t}{\Pi}\right)^{\phi_\pi} \exp(\varepsilon_{lt})$$

$$T_t - T = \psi_T \left[\beta \left(b_{t-1} - b\right) - \left(l_{t-1} - l\right)\right]$$

- Policy regimes
  - Balance sheet unconstrained regime: $\phi_\pi > 1$; sufficiently large ψ_T
  - Balance sheet constrained regime: $\phi_\pi < 1$; small ψ_T
- Functional forms

$$U(c_t, h_t) = \log C_t - A h_t,\ y_t = h_t$$

$$d(\Pi_t) = \frac{\kappa}{2}(\Pi_t - 1)^2$$

Calibration and simulation

- Baseline parameterization

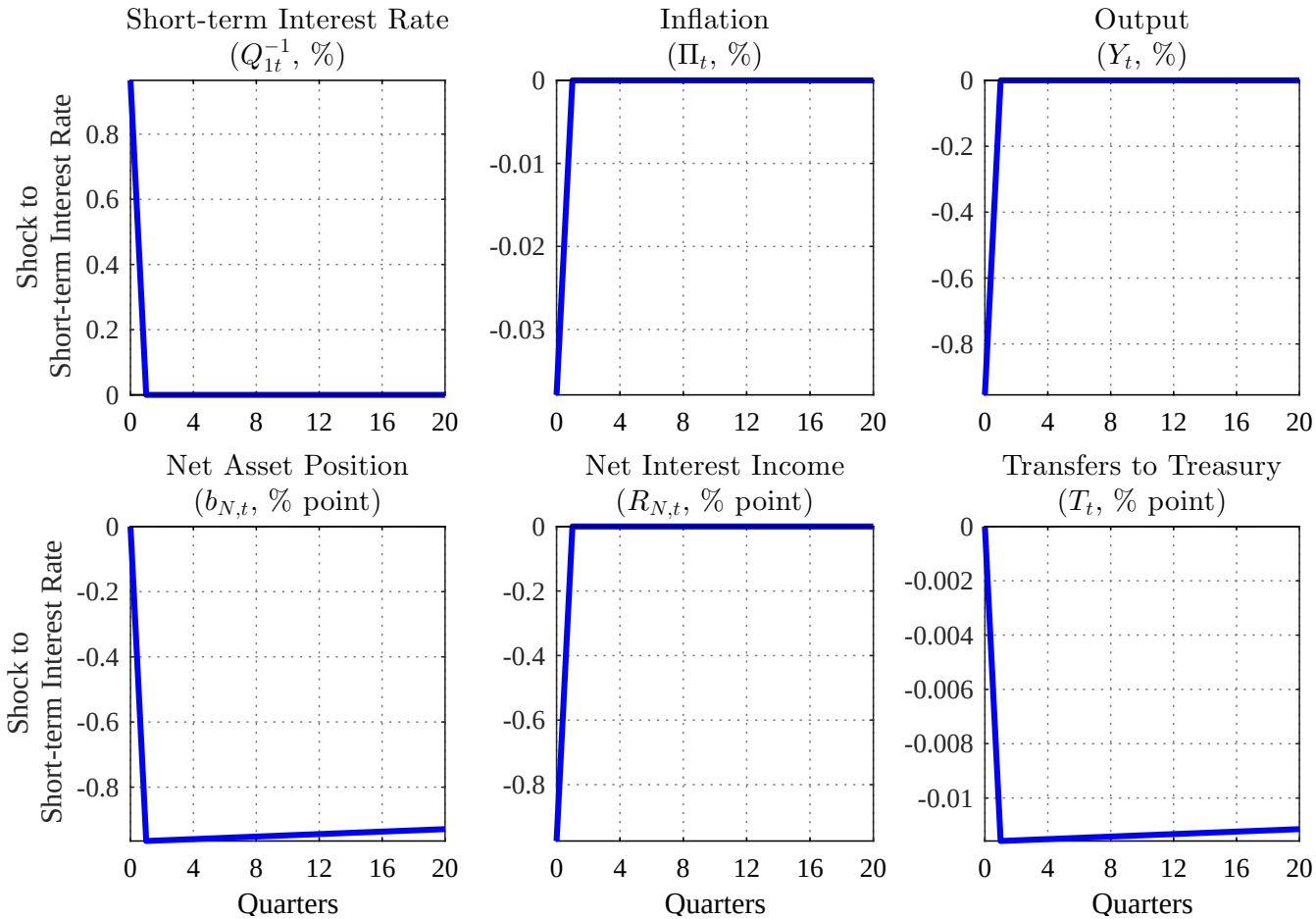
Table: Parameterization of the model

Parameter	Value	Parameter	Value
b	1	ϕ_π	1.05; 0.95
κ	150	ψ_T	0.012; 0.009
T	0.1	ν	7
β	0.99	ρ	0

- Fully non-linear deterministic simulation
  - Economy starts in the non-stochastic steady-state and then transitions back to it in the long-run

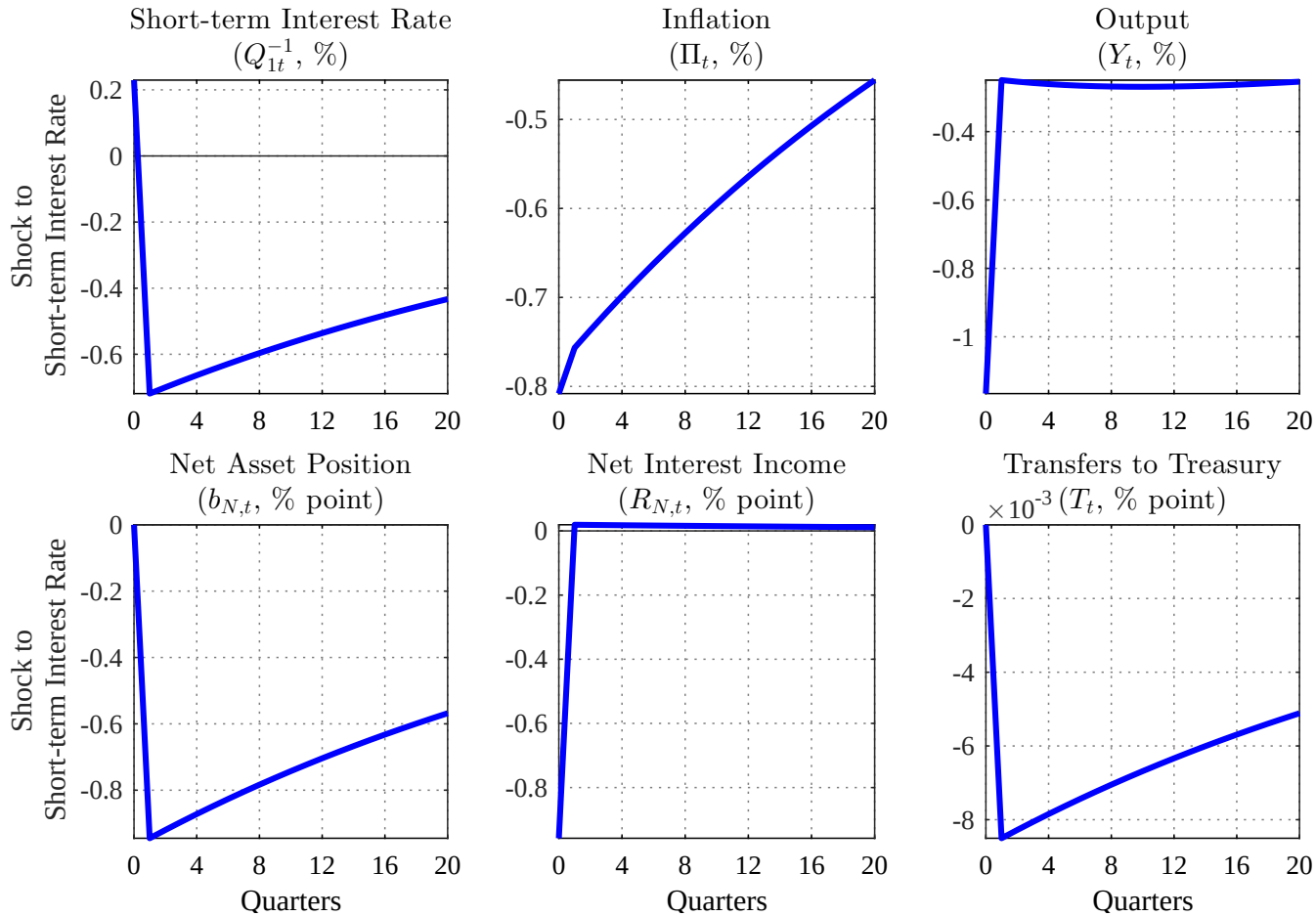
Balance sheet unconstrained central bank

Impulse responses to a surprise monetary policy shock



Balance sheet constrained central bank

Impulse responses to a surprise monetary policy shock



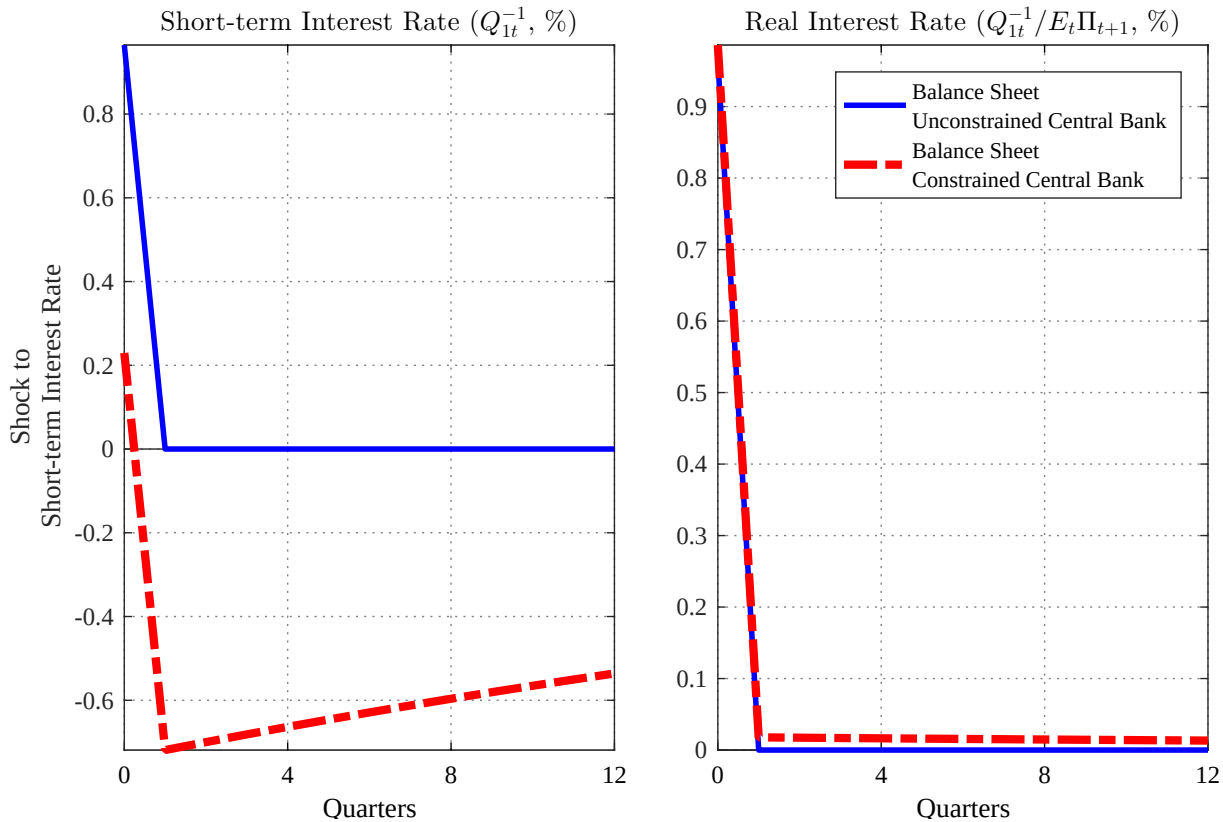
Balance sheet constrained central bank

- Positive interest rate shock leads to a decline in net interest income
- Balance sheet considerations mean net interest income rises in future
- Net interest income increase requires a fall in future of the short-term interest rate and a slow transition back
- The short-term interest rate is below steady-state, but this leads to a fall in inflation in this regime (positively correlated!)
- Output falls on impact and throughout the transition (sticky prices)
  - Real effects stronger and more persistent (paradoxical?)

Comparison

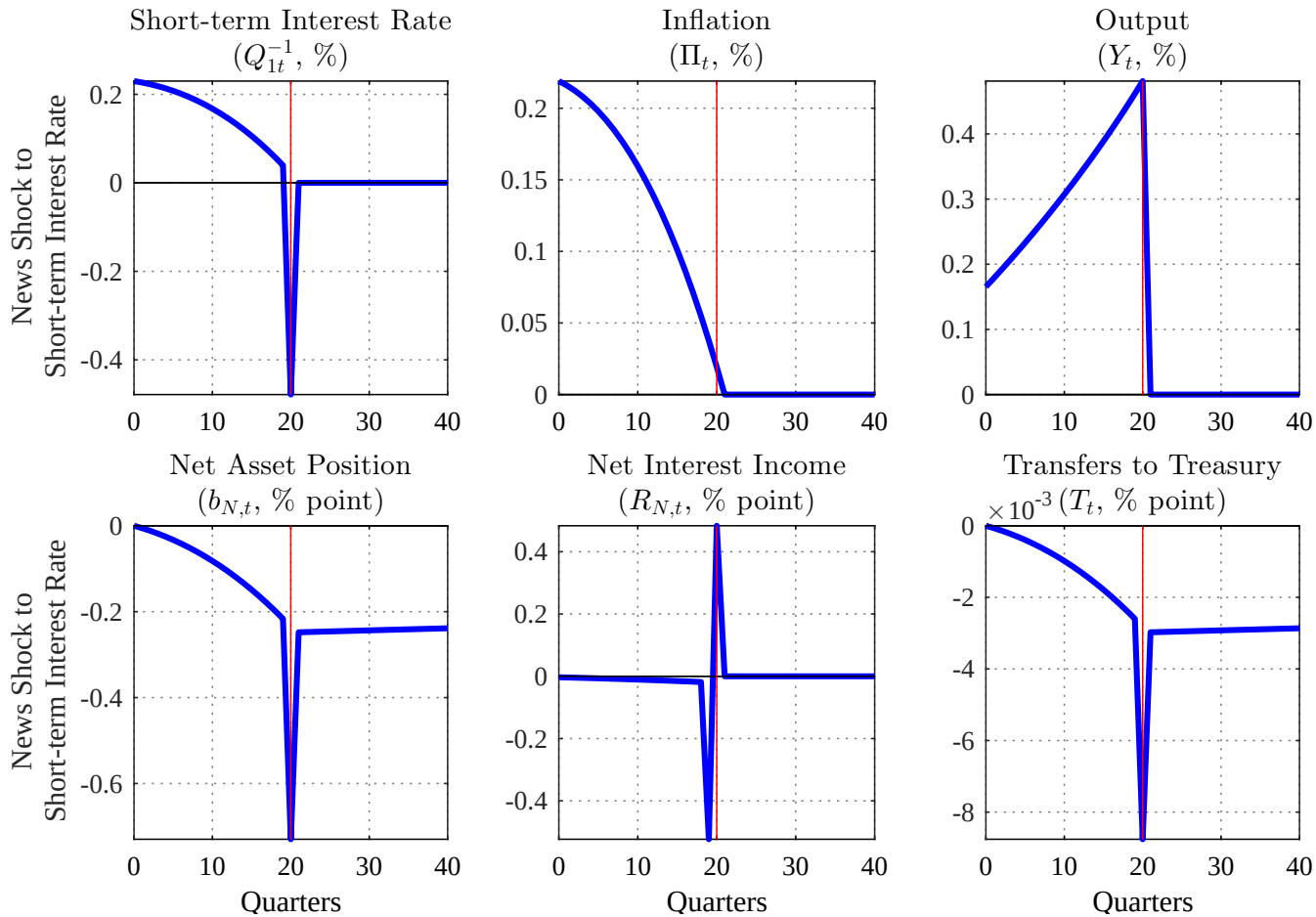
Real interest rate across the two regimes

- Correlation between nominal and real interest rate different
- Nominal rate below while real rate above steady-state when the central bank is balance sheet constrained



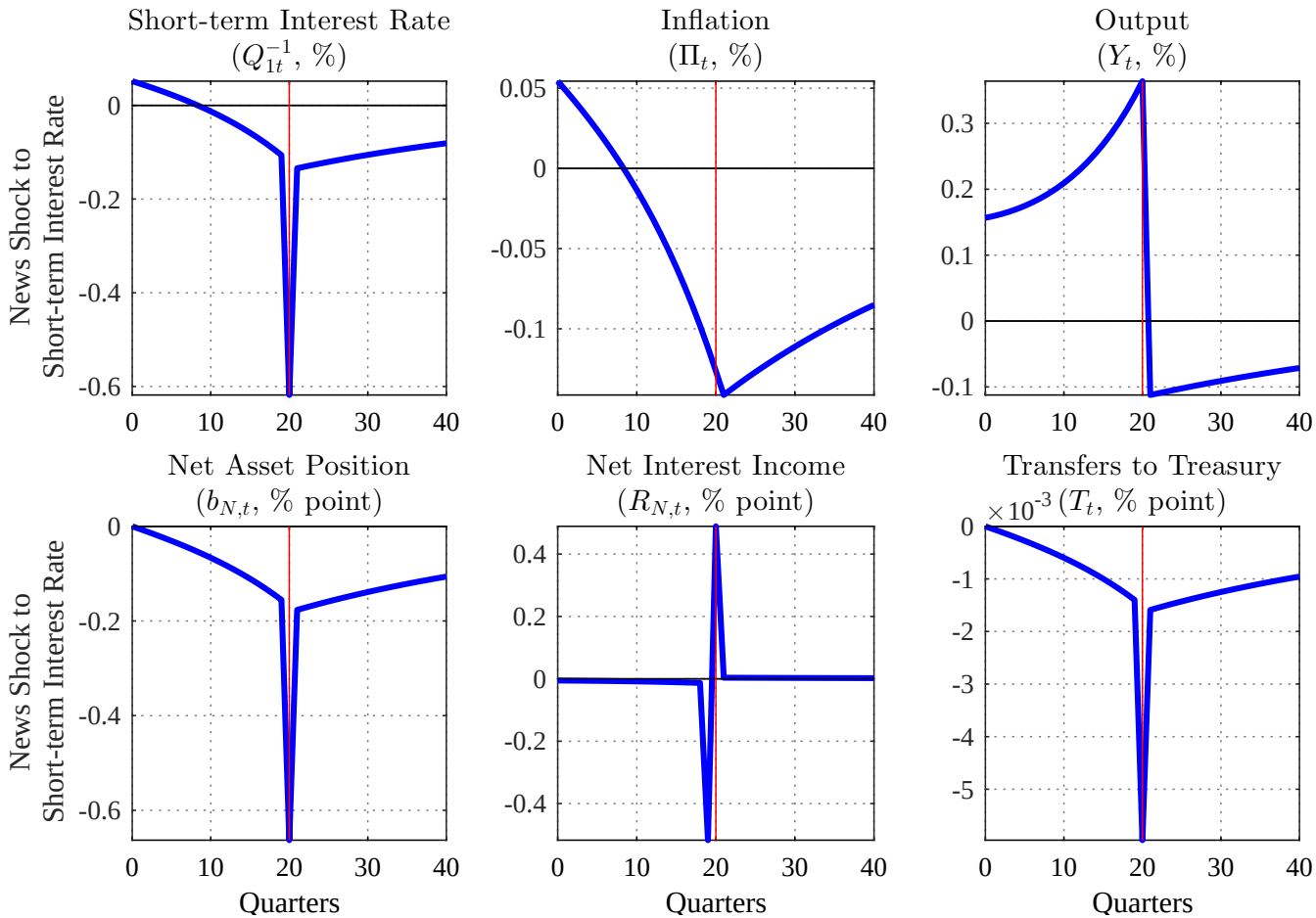
Balance sheet unconstrained central bank

Impulse responses to an anticipated monetary policy shock



Balance sheet constrained central bank

Impulse responses to an anticipated monetary policy shock

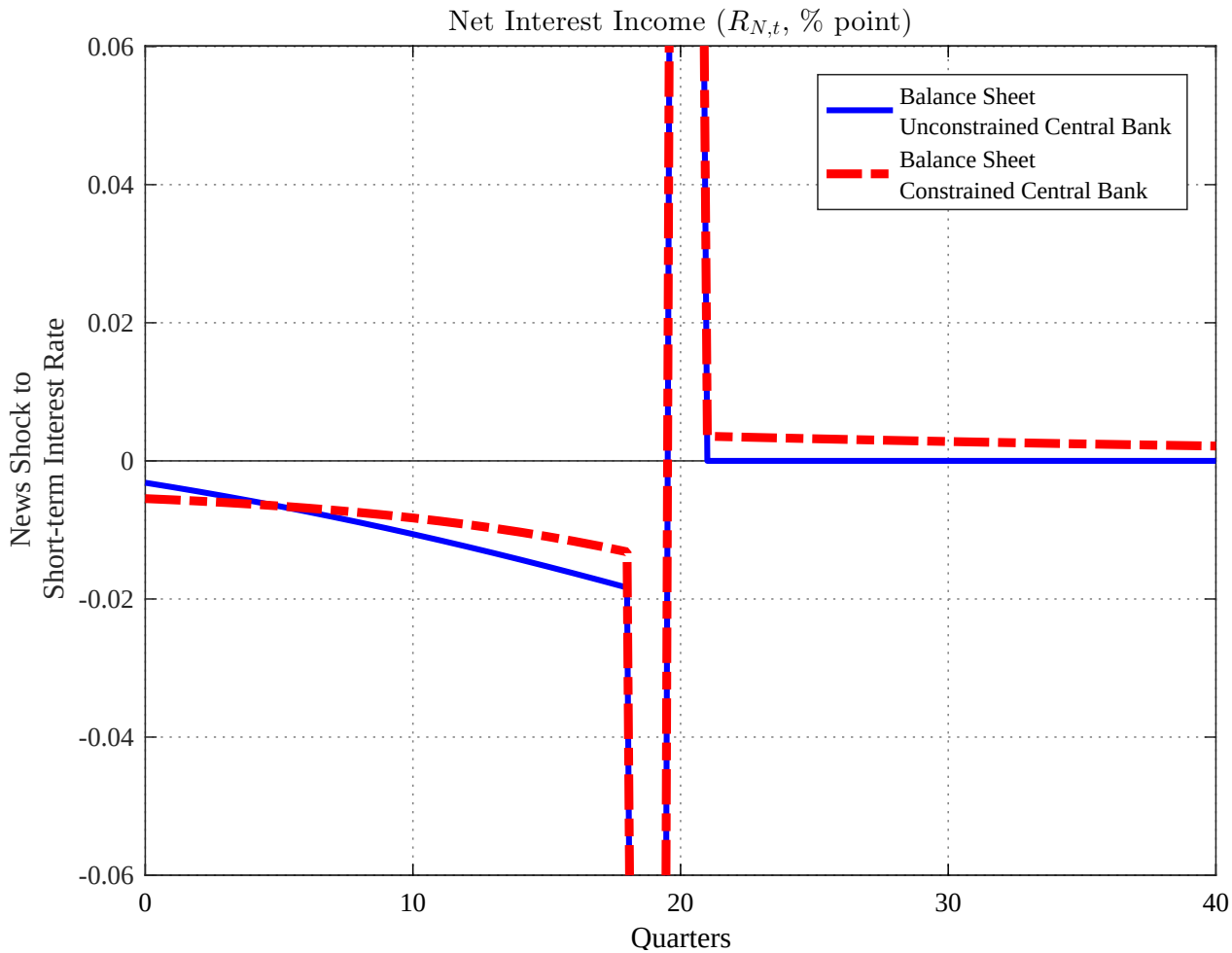


Balance sheet constrained central bank

- There is an increase in inflation and output today
- But inflation falls in future and after the shock is realized
- Net interest income cannot go back immediately to steady-state after the shock is realized
- Short-term interest rate stays below steady-state after the shock
- Positive correlation between short-term interest rate and inflation
  - Inflation falls after the shock is realized
  - Output falls because of sticky prices
- Incentive to keep short-term interest rate low with maturity mismatch is the mechanism for QE in Bhattarai, Eggertsson, and Gafarov (2016), but equilibrium here is different

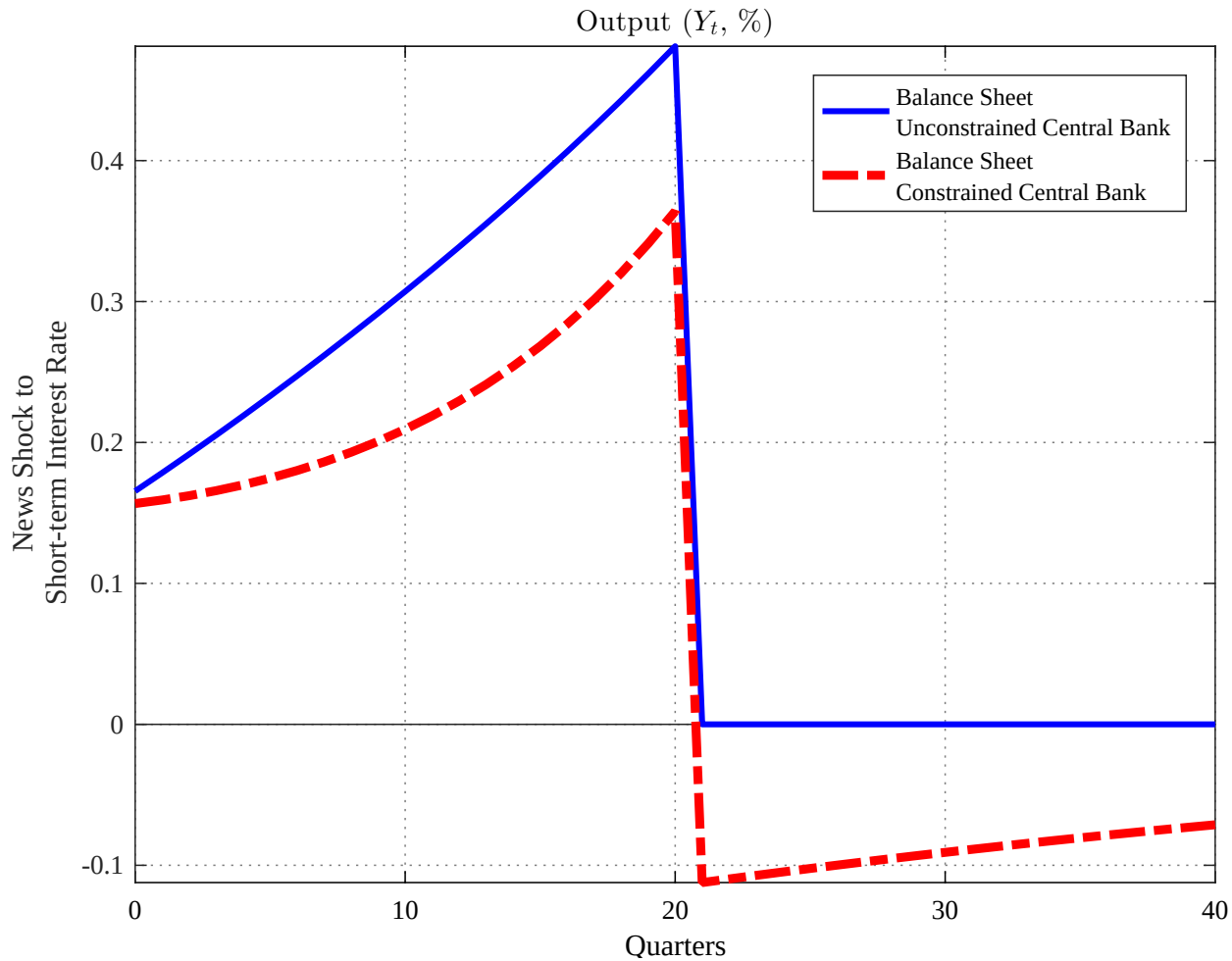
Comparison

Net interest income across the two regimes



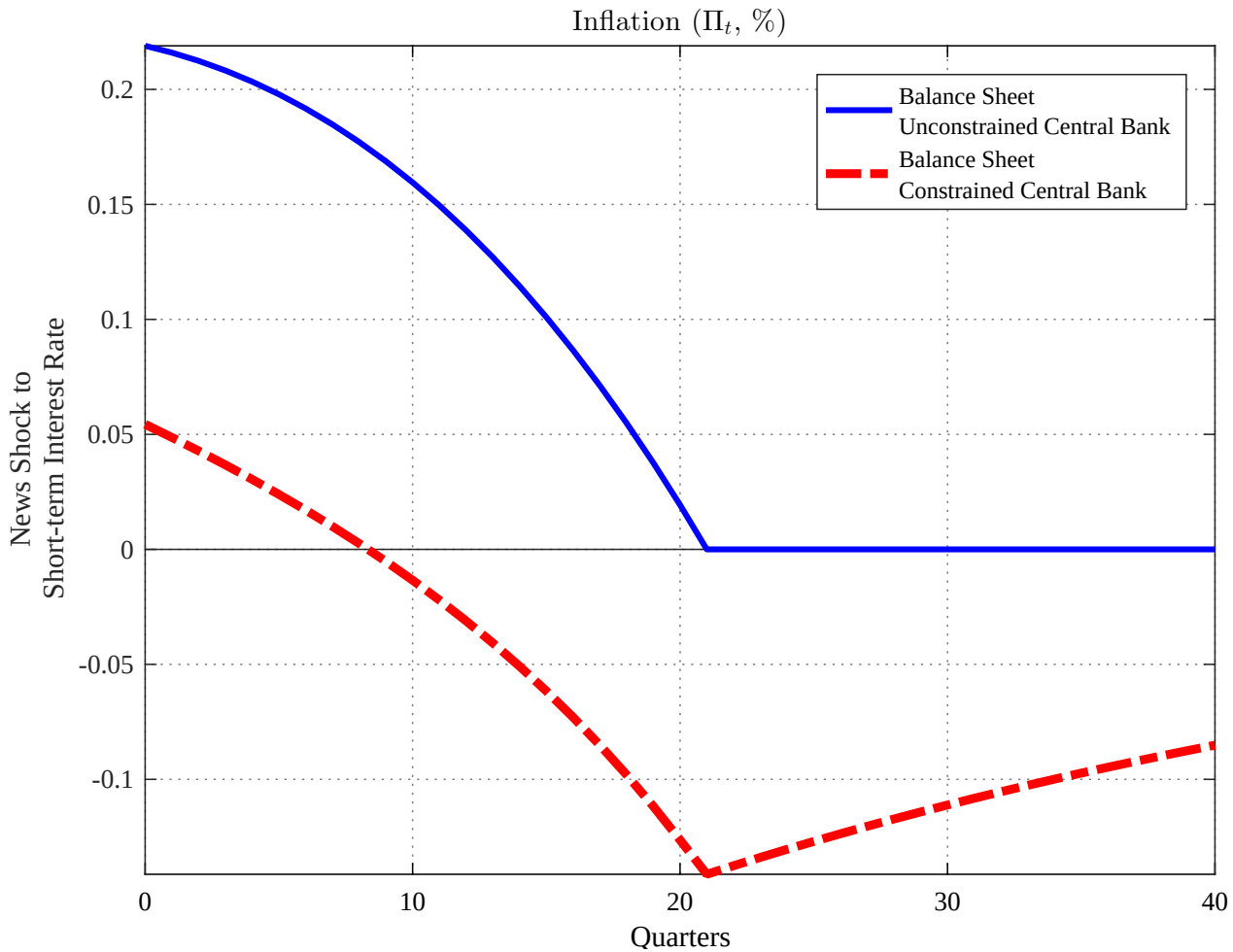
Comparison

Output across the two regimes



Comparison

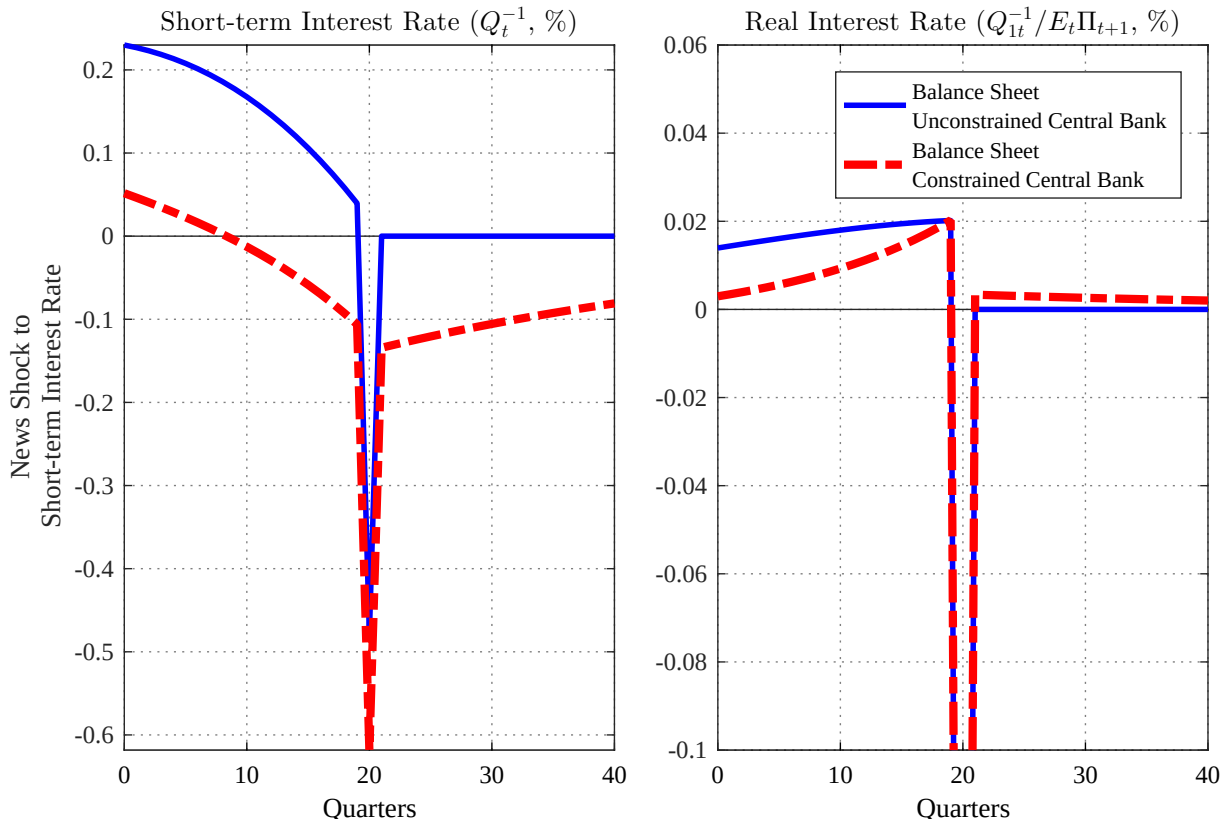
Inflation across the two regimes



Comparison

Real interest rate across the two regimes

- Correlation between nominal and real interest rate different
- Nominal rate below while real rate above steady-state when the central bank is balance sheet constrained

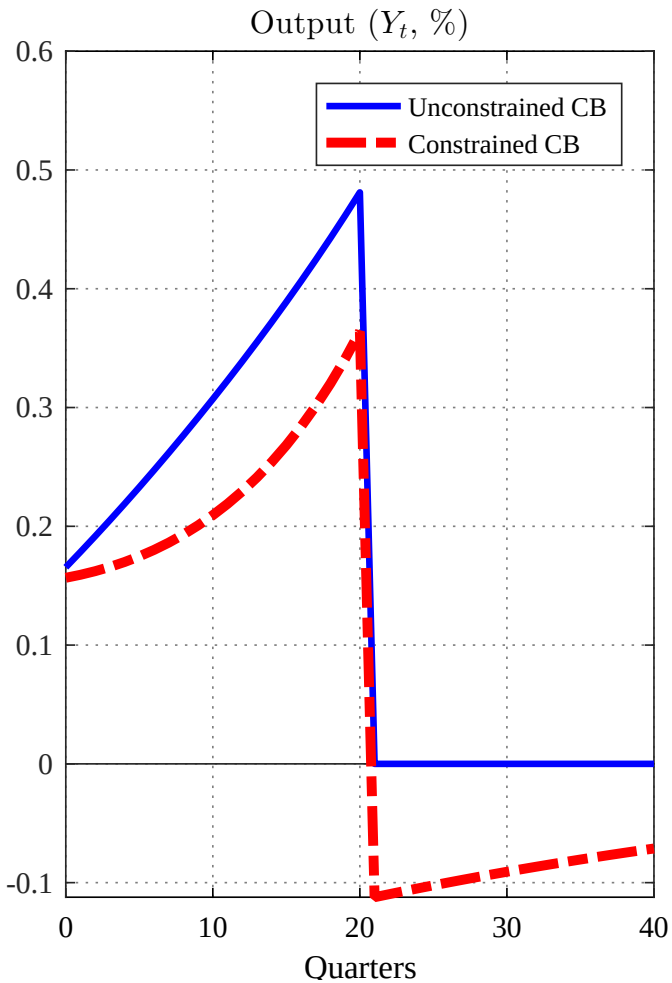


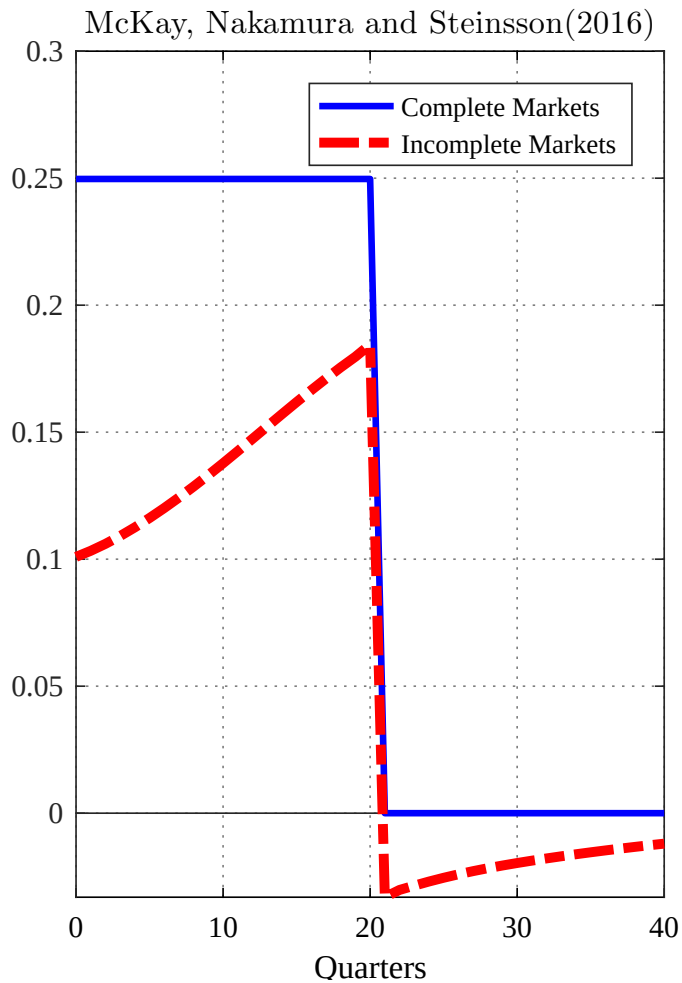
Forward guidance puzzle

- The standard sticky price model leads to large output/inflation effects of forward guidance policy (even very far out in the future)
- This has been dubbed the forward guidance puzzle
- Literature has emphasized the infinite horizon and forward looking behavior of firms/households as key reasons behind this result
- Proposed resolutions
  - Finite life-times (Del Negro, Giannoni, and Patterson (2015))
  - Sticky information instead of sticky prices (Kiley (2016))
  - Borrowing constraints (Mckay, Nakamura, and Steinsson (2016))
- Model here: infinite horizon, sticky prices, no borrowing constraints but a central bank constrained by balance sheet considerations

Forward guidance puzzle

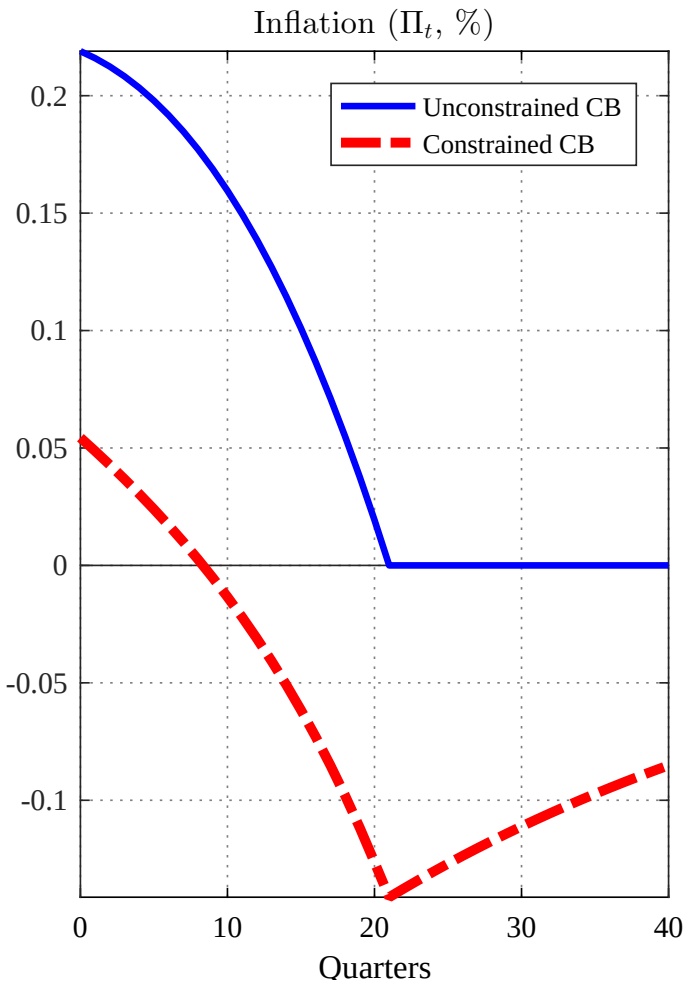
Comparison with Mckay, Nakamura, and Steinsson (2016) (Output)

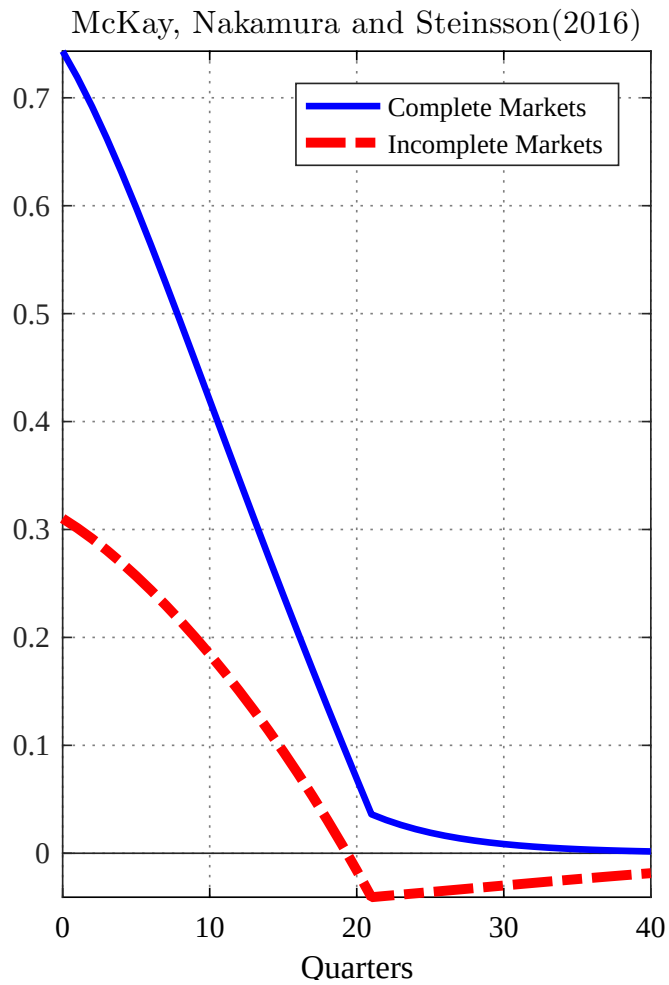




Forward guidance puzzle

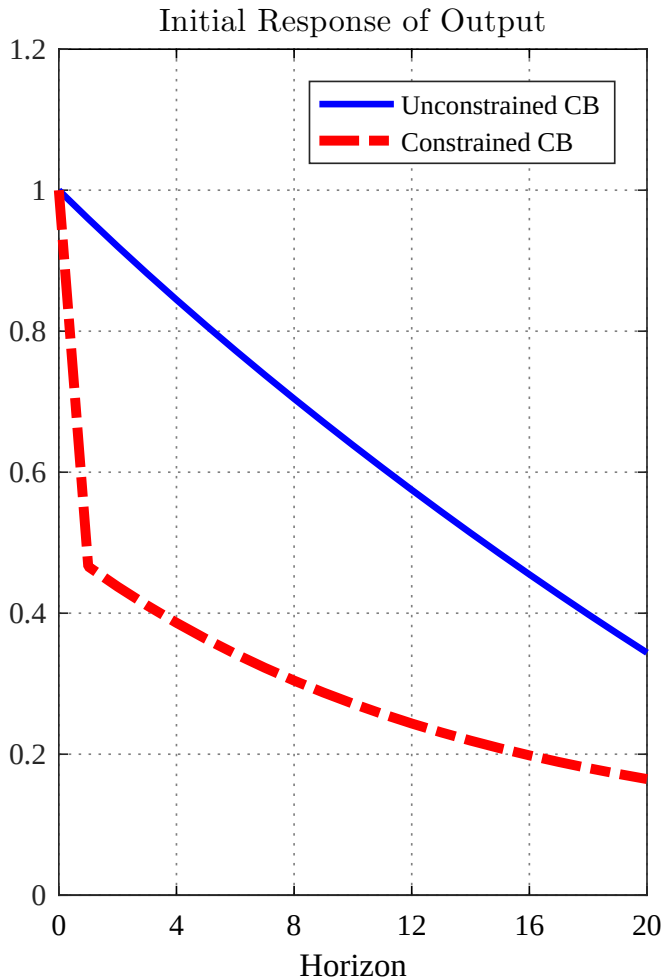
Comparison with Mckay, Nakamura, and Steinsson (2016) (Inflation)

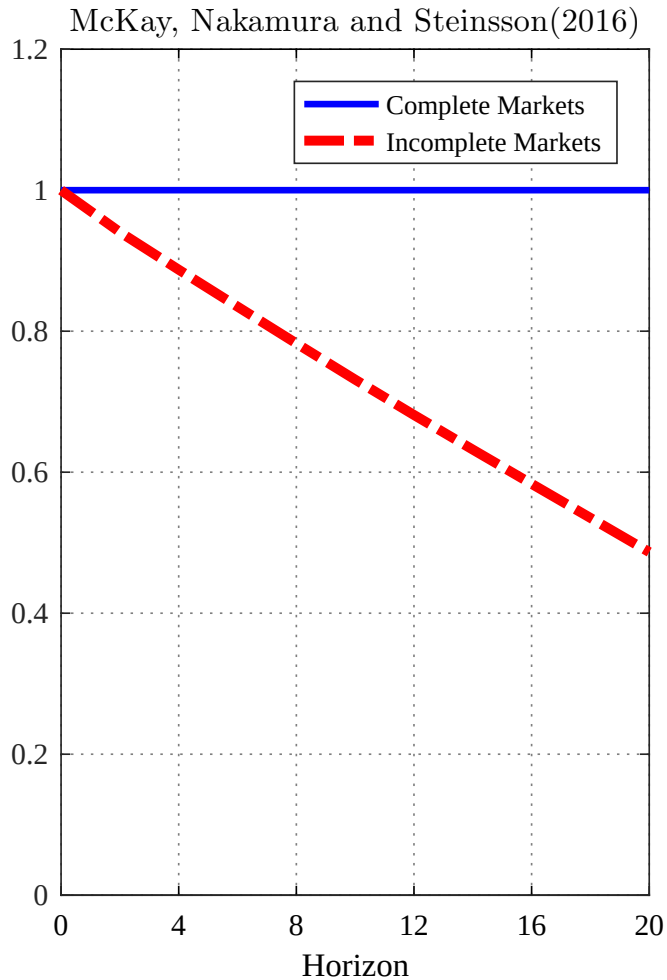




Forward guidance puzzle

Comparison with Mckay, Nakamura, and Steinsson (2016) (Output-FG Horizon)





Extensions

- Open economy model with currency mismatch
  - Domestic currency liability and foreign currency asset
- Alternate model of balance sheet constrained central bank
  - A lower bound on transfers to the Treasury that binds endogenously
  - Central bank regime switches endogenously
- A binding zero lower bound on the nominal rate

Open economy model

- Model of currency mismatch
- Nominal central bank flow budget constraint

$$S_t B^*_{t-1} - L_{t-1} - M_{t-1} - P_t T_t = S_t Q_{B^* t} B^*_t - Q_{Lt} L_t - M_t$$

  where S_t is the nominal exchange rate
- Balance sheet variables
  - L_t : one-period domestic currency liabilities with $Q_{L,t}$ its price
  - B_t : one-period foreign currency assets with $Q_{B^* t}$ its price
- Monetary/fiscal policy interaction variable
  - T_t : central bank transfer to the Treasury
- Conventional monetary policy instrument
  - $Q_{L,t}$: one-period domestic bond price

Open economy model

- Real flow budget constraint

$$\varsigma_t b^*_{t-1}\Pi^{*-1}_t - l_{t-1}\Pi^{-1}_t - m_{t-1}\Pi^{-1}_t - T_t = \varsigma_t Q_{B^*t} b^*_t - Q_{Lt} l_t - m_t$$

  where $\varsigma_t \equiv S_t \frac{P^*_t}{P_t}$ is the real exchange rate
- Complete market asset-pricing and PPP
- Approximate the budget constraint and asset pricing conditions
- Budget constraint

$$b_{N,t} = \frac{1}{\beta} b_{N,t-1} - \frac{1}{\beta} \hat{T}_t + b^* R_{N,t}$$

  where net interest income

$$R_{N,t} \equiv \hat{S}_t - \beta E_t \hat{S}_{t+1}$$

Open economy model

- PV form

$$b_{N,t-1} = \sum_{t=0}^{\infty} \beta^t \hat{T}_t - \beta b^* \sum_{t=0}^{\infty} \beta^t R_{N,t}$$

  where net interest income

$$R_{N,t} \equiv \hat{S}_t - \beta E_t \hat{S}_{t+1}$$

- When an open economy central bank is *balance sheet constrained*
  - Increase in $R_{N,t}$ today leads to a decrease in future
  - Exchange rate path in future gets constrained
  - *Unpleasant central bank balance sheet arithmetic in an open economy*

Alternate model of balance sheet constraint

- A lower bound on central bank transfers: $T_t - T \geq -\chi$
- If this bound not reached, then

$$\beta Q_{1,t}^{-1} = \left(\frac{\Pi_t}{\Pi}\right)^{\phi_\pi} \exp(\varepsilon_{lt}),\ T_t - T = \psi_T \left[\beta \left(b_{t-1} - b\right) - \left(l_{t-1} - l\right)\right]$$

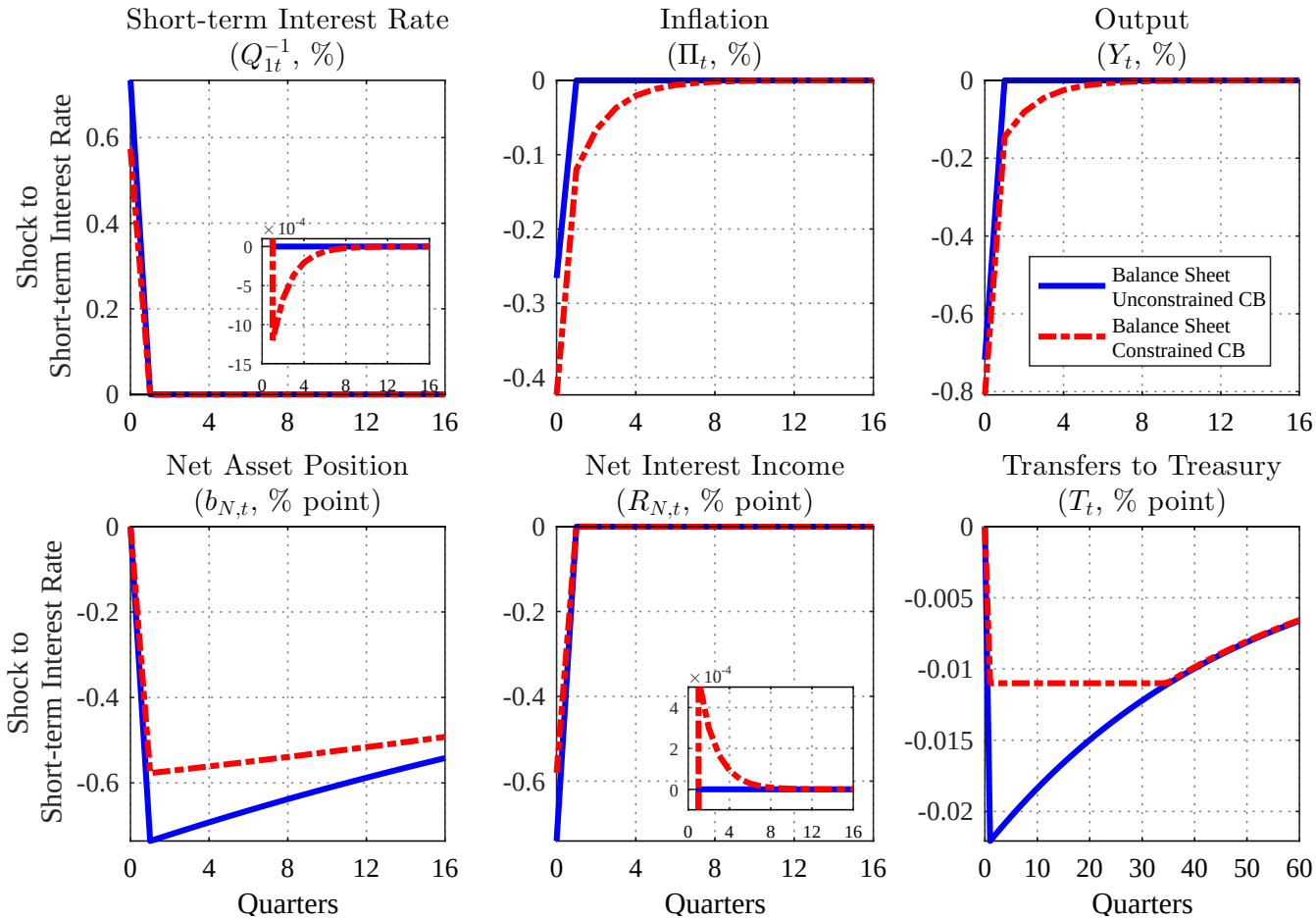
  where $\phi_\pi > 1$ and ψ_T sufficiently large
- If this bound is reached, then

$$\beta Q_{1,t}^{-1} = \left(\frac{\Pi_t}{\Pi}\right)^{\phi_\pi} \exp(\varepsilon_{lt}),\ T_t - T = -\chi$$

  where $\phi_\pi < 1$
- Whether and how long this constraint binds determined endogenously

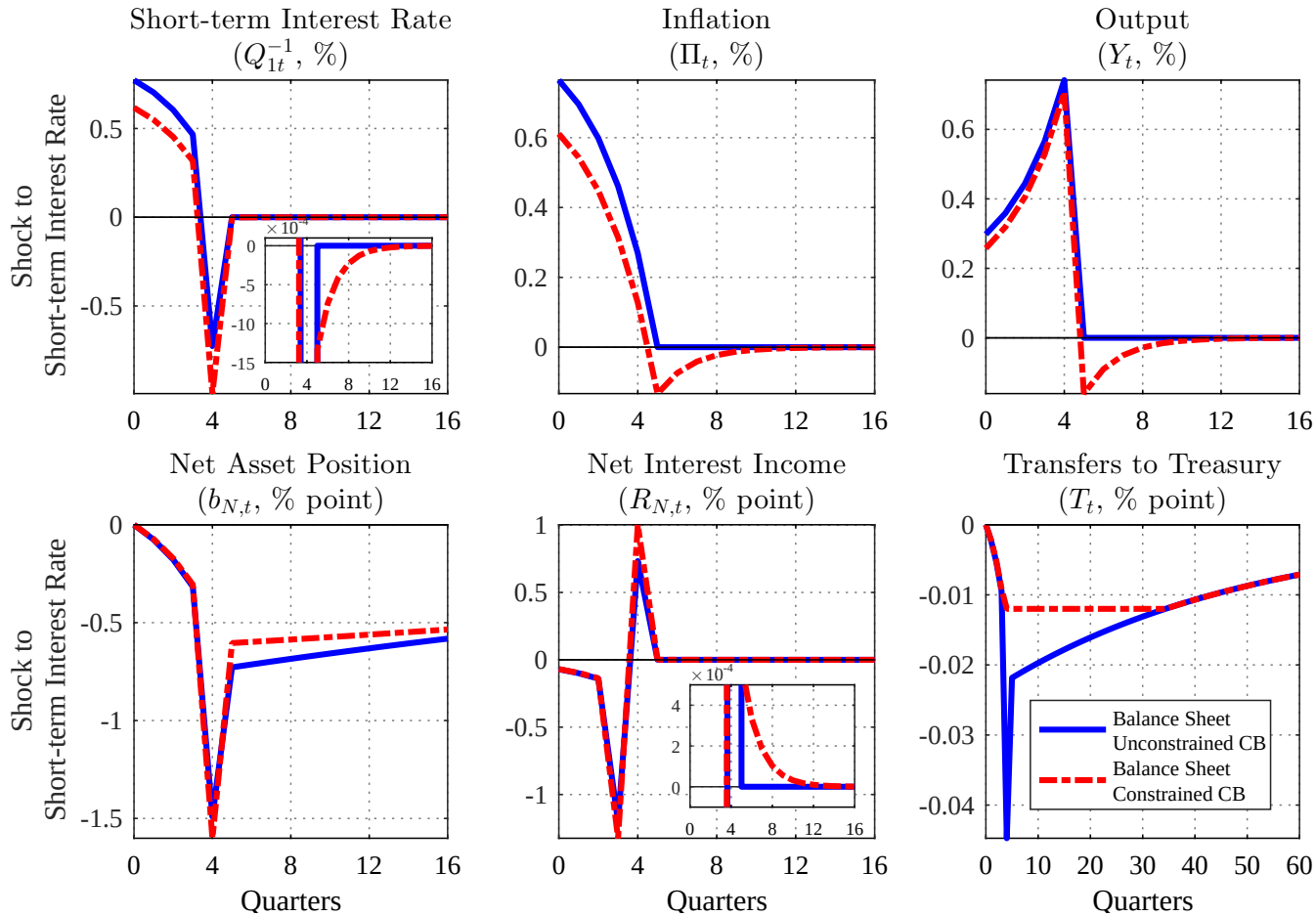
Alternate model of balance sheet constraint

Surprise monetary policy shock



Alternate model of balance sheet constraint

Anticipated monetary policy shock

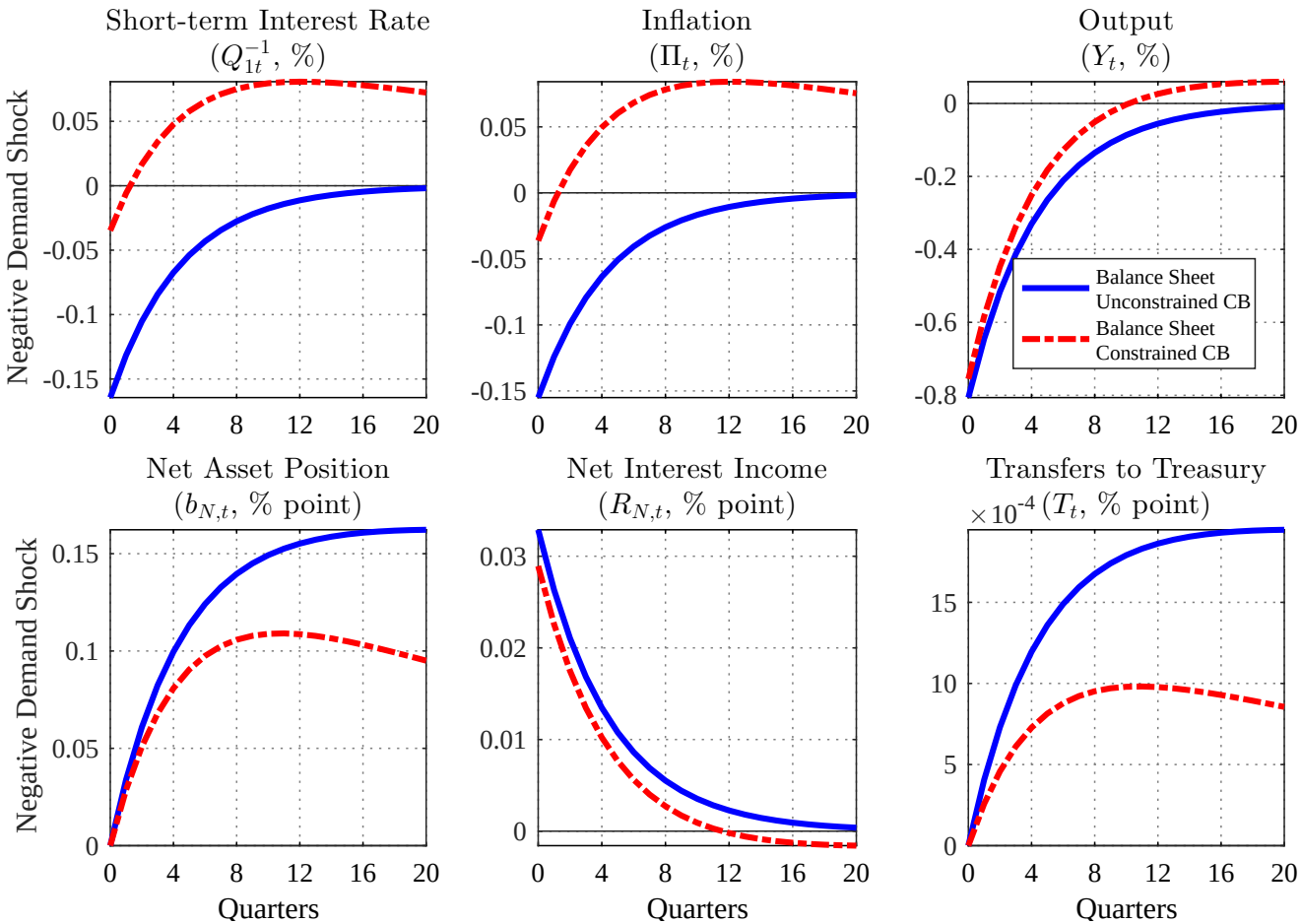


Zero lower bound

- How do the two central bank models compare at the ZLB?
- Introduce a preference/demand shock in the model
- But the comparison not straightforward at all
  - For a negative demand shock, nominal rate falls slightly initially for the balance sheet constrained central bank, but increases next period
  - ZLB can bind in future for a positive demand shock for the balance sheet constrained central bank
  - As emphasized before, nominal and real rate correlation different along the transition across the two regimes

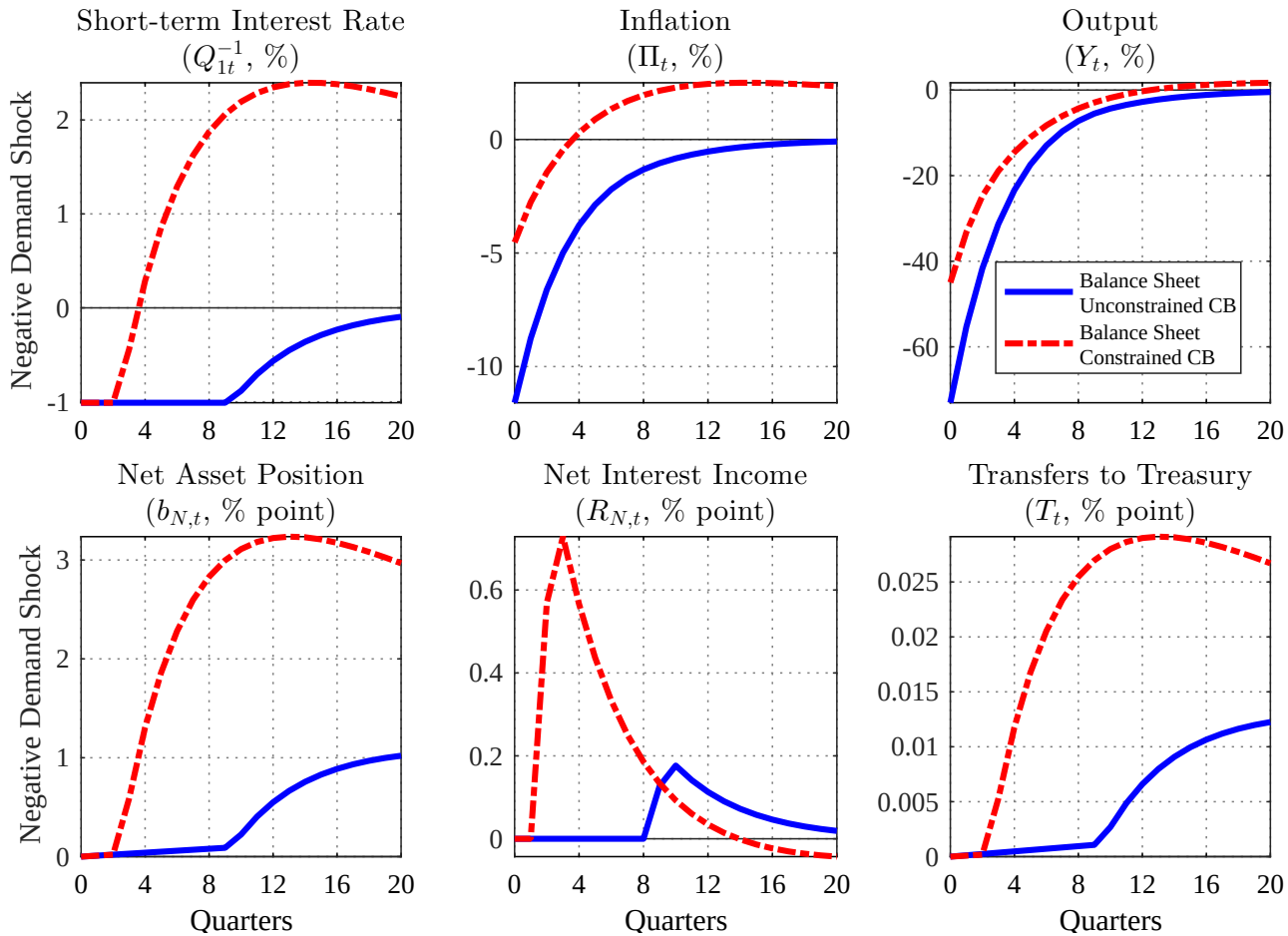
Negative demand shock

Positive interest rates



Negative demand shock

Zero lower bound

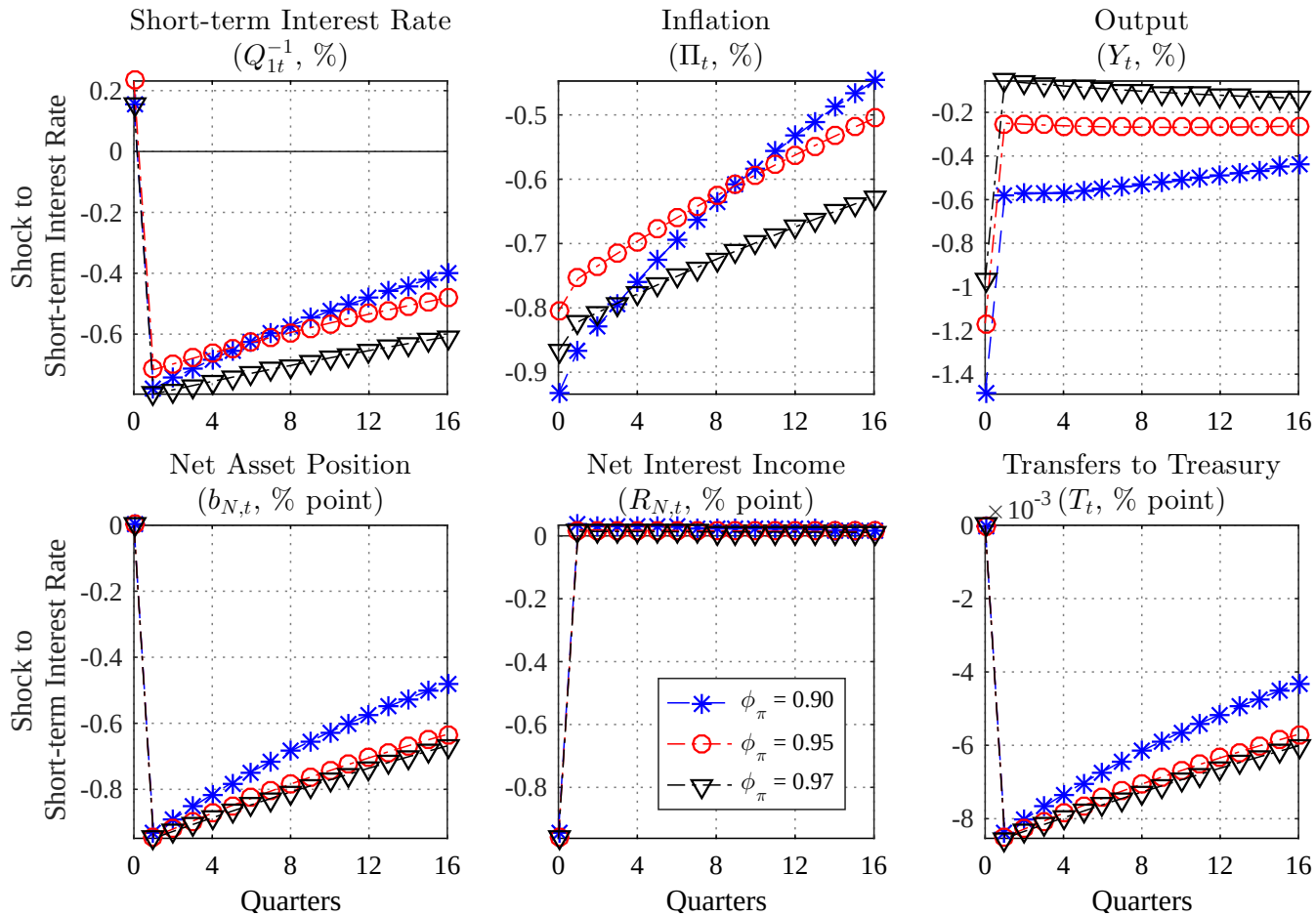


Sensitivity analysis

- Different interest rate and transfer policy rule parameters
- More general central bank transfer rule
  - $T_t - T = \psi_{bT}\beta\left(b_{t-1} - b\right) - \psi_{lT}\left(l_{t-1} - l\right)$
  - $\psi_{bT} = 0.009$ and $\psi_{lT} = 0.005$
- Stochastic solution method (second-order perturbation)
  - Results not specific to a deterministic solution method
  - In principle, incorporates a term premium

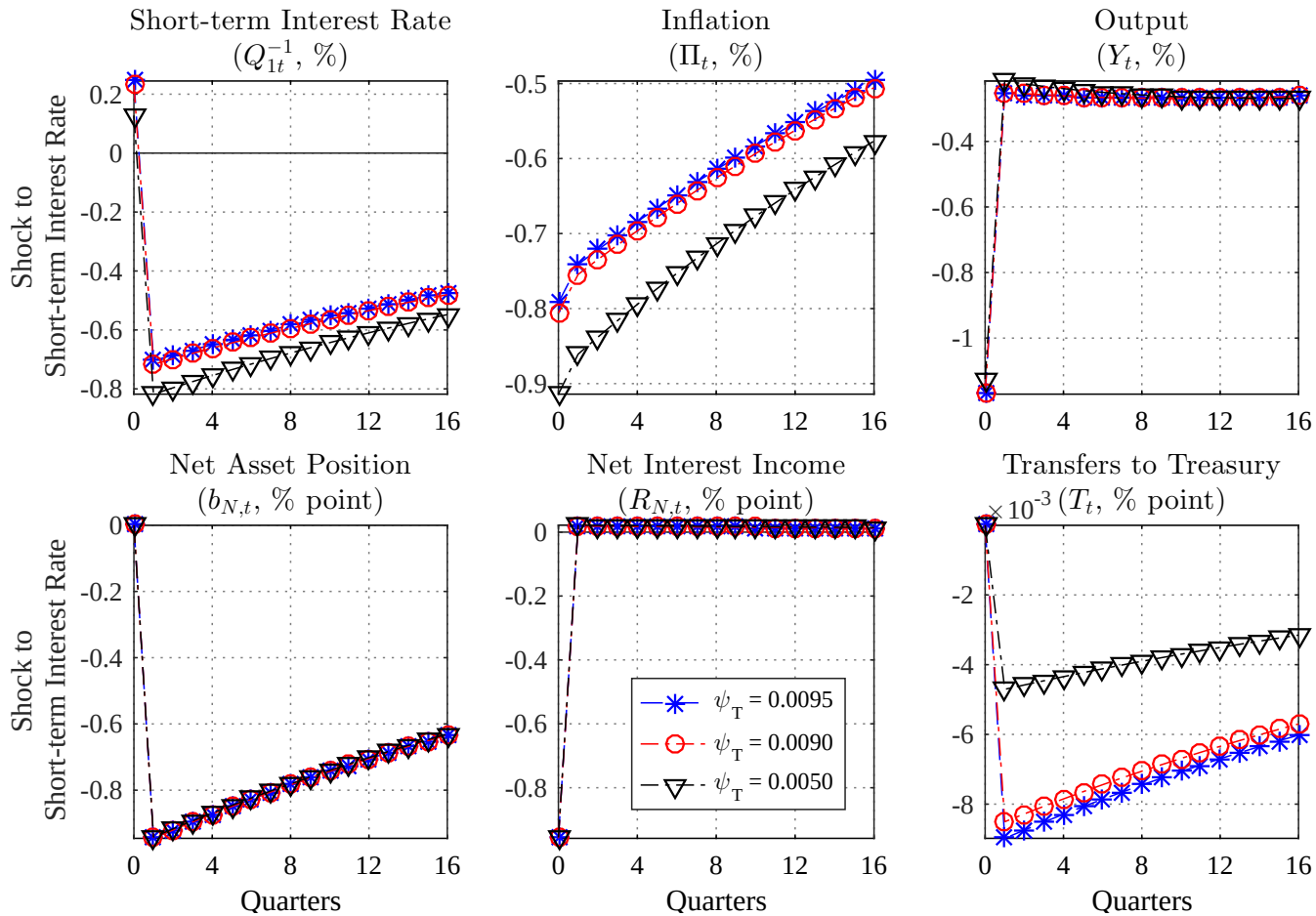
Interest rate rule parameter

Balance sheet constrained central bank



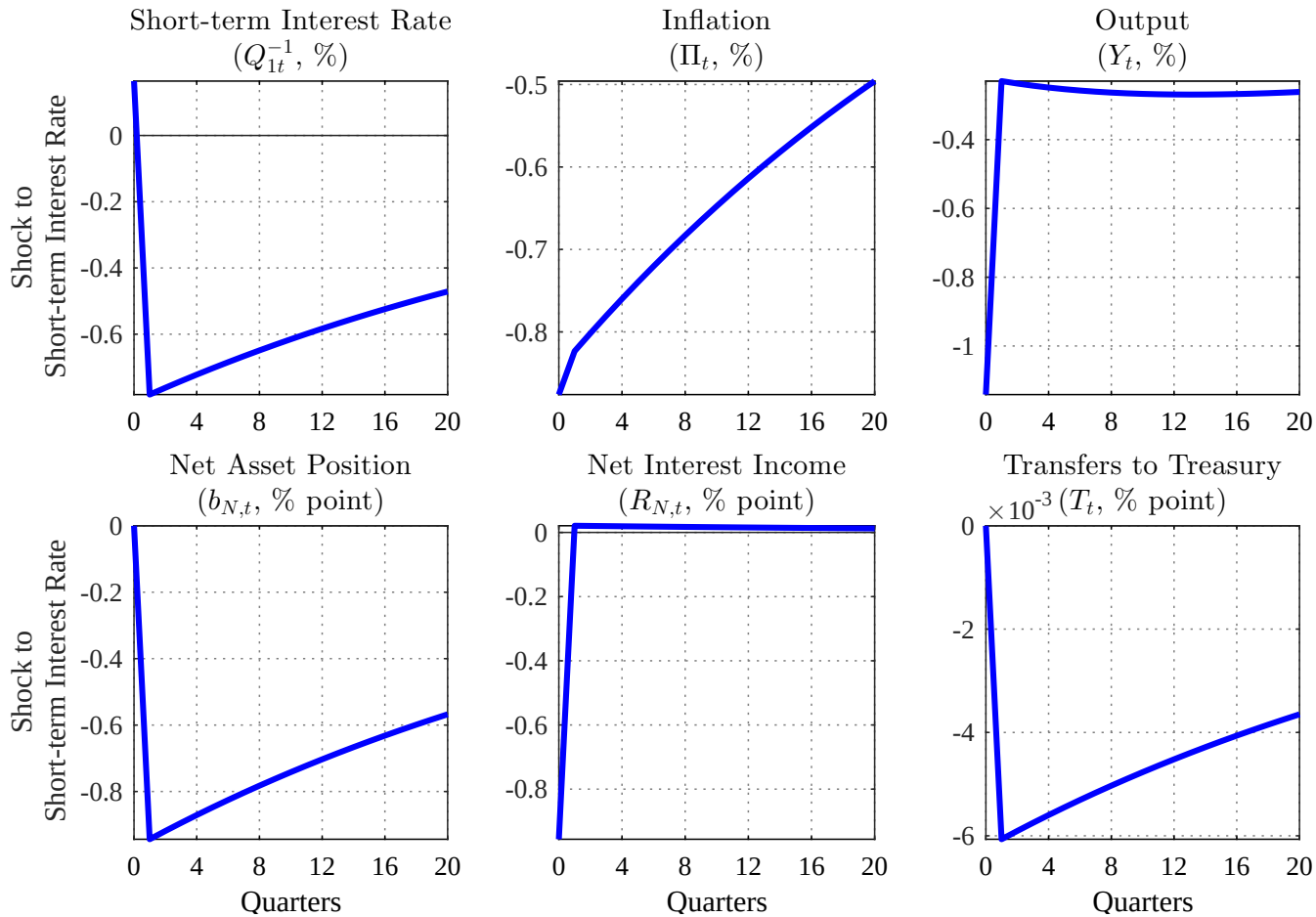
Transfer rule parameter

Balance sheet constrained central bank



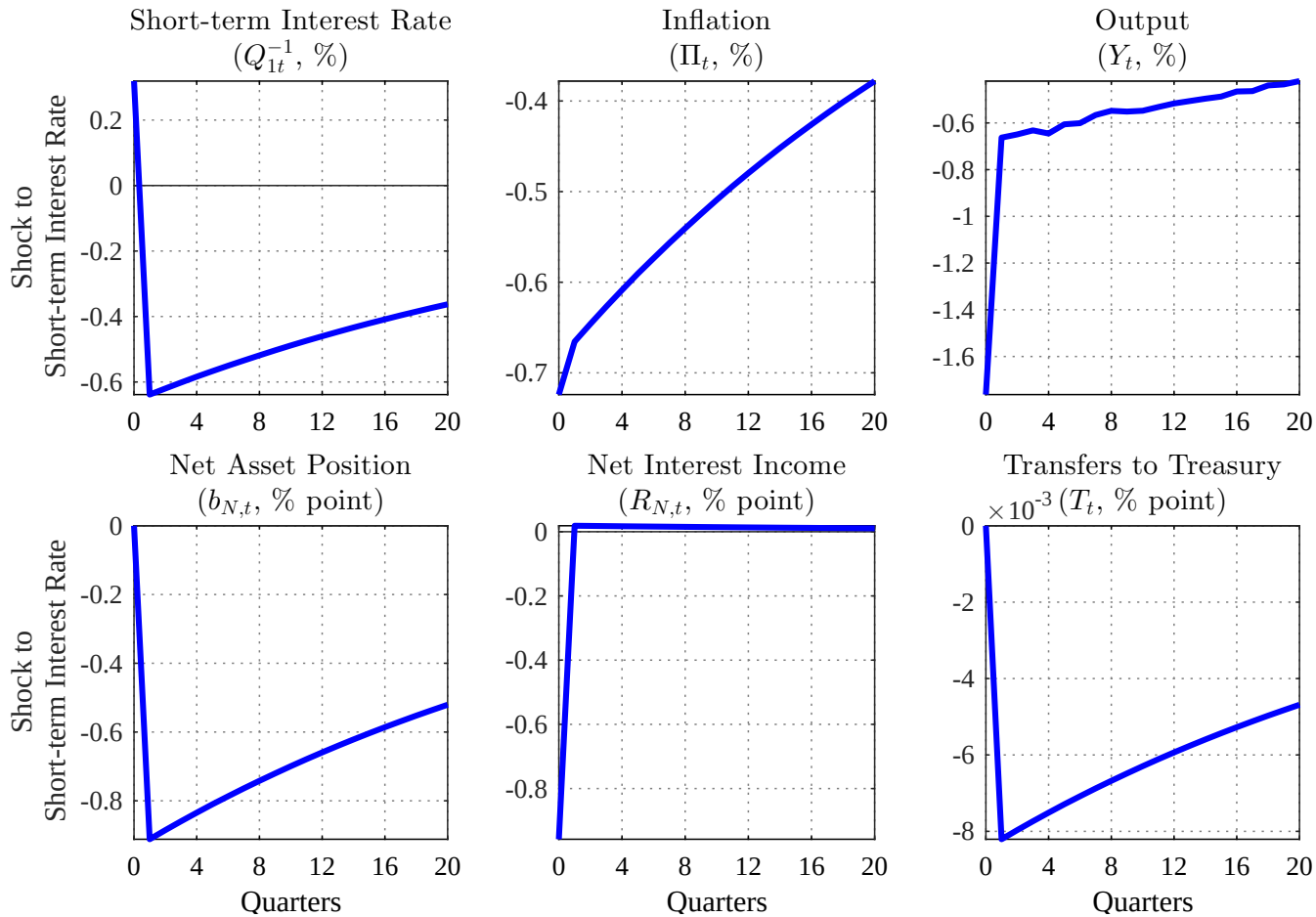
General central bank transfer rule

Balance sheet constrained central bank



Stochastic solution method

Balance sheet constrained central bank



Conclusion

- Whether or not the central bank faces a balance sheet constraint can alter standard results on monetary policy
- Key driver is if the path of remittances to Treasury is constrained when central bank balance sheet has maturity (or currency) mismatch
- Future path of monetary policy instrument gets affected non-trivially under central bank balance sheet constraints
  - Significantly alters the transmission of monetary policy shock (both surprise and anticipated)
  - Changes the correlation of the nominal and real rate