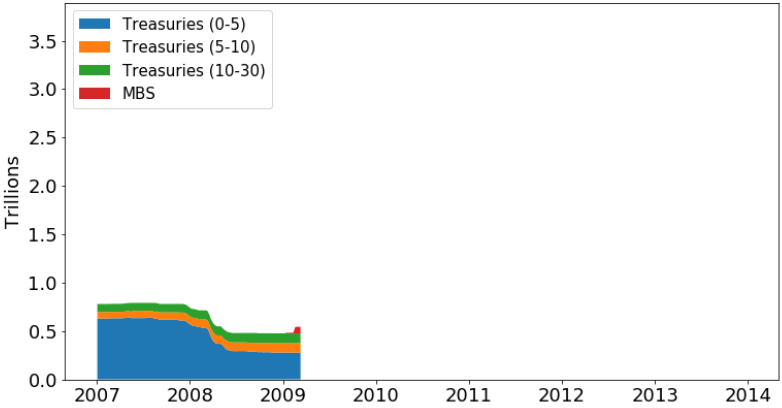
Monetary Policy and the Limits to Arbitrage: Insights from a New Keynesian Preferred Habitat Model

Walker Ray

June 27, 2019

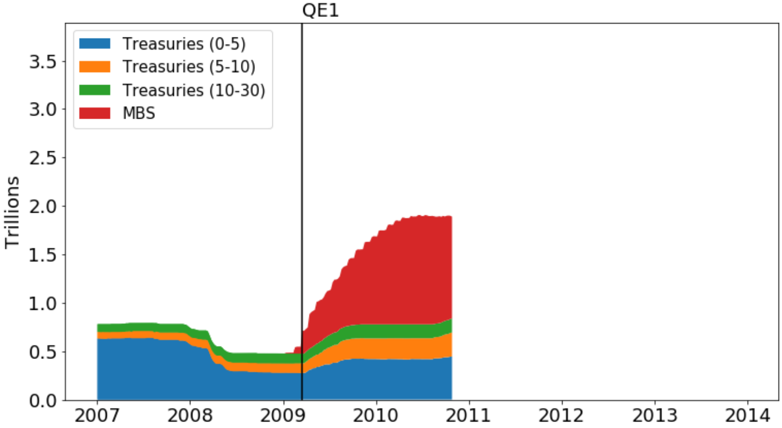
SED 2019

Policy Response to Great Recession



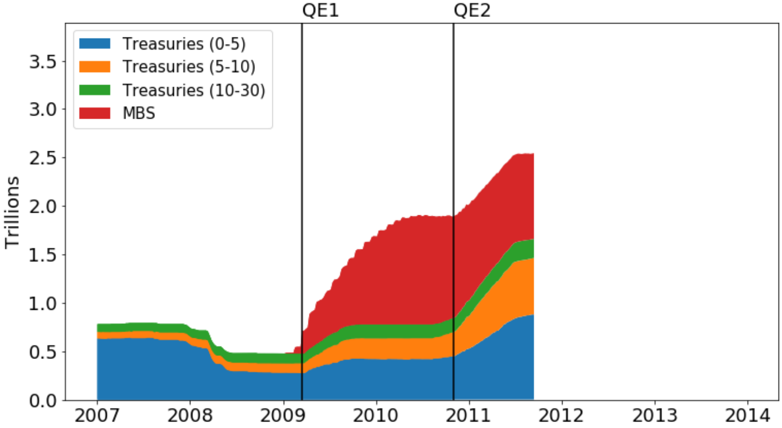
Notes: Federal Reserve holdings of Treasuries (by maturity) and Mortgage-Backed Securities. Vertical lines indicate the start of LSAP programs. Source: FRED.

Policy Response to Great Recession



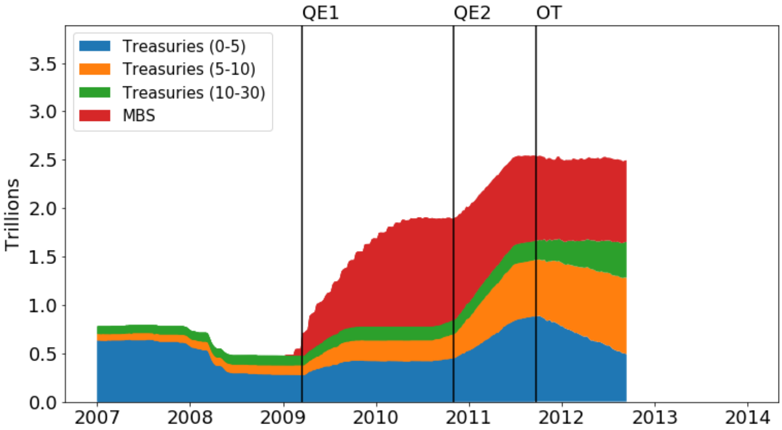
Notes: Federal Reserve holdings of Treasuries (by maturity) and Mortgage-Backed Securities. Vertical lines indicate the start of LSAP programs. Source: FRED.

Policy Response to Great Recession



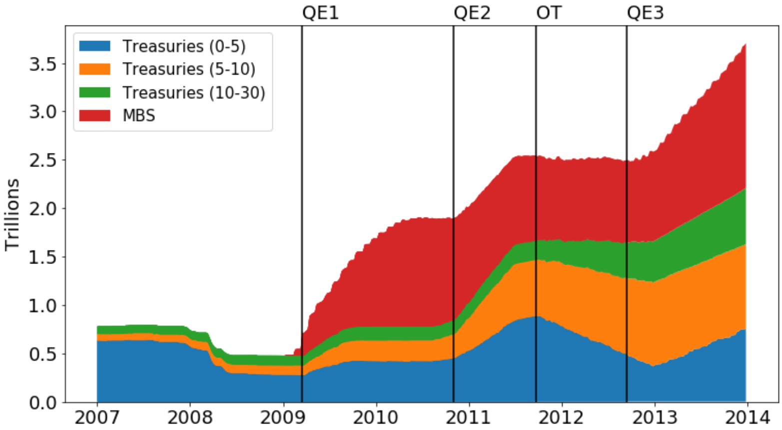
Notes: Federal Reserve holdings of Treasuries (by maturity) and Mortgage-Backed Securities. Vertical lines indicate the start of LSAP programs. Source: FRED.

Policy Response to Great Recession



Notes: Federal Reserve holdings of Treasuries (by maturity) and Mortgage-Backed Securities. Vertical lines indicate the start of LSAP programs. Source: FRED.

Policy Response to Great Recession



Notes: Federal Reserve holdings of Treasuries (by maturity) and Mortgage-Backed Securities. Vertical lines indicate the start of LSAP programs. Source: FRED.

Lingering Questions

Bernanke: "QE works in practice but not in theory"

Lingering Questions

Bernanke: "QE works in practice but not in theory"

- Develop a GE model which takes seriously limits to arbitrage
  - Derive **theoretical conditions** under which QE works
  - **Quantify** the aggregate effects of QE

Lingering Questions

Bernanke: "QE works in practice but not in theory"

- Develop a GE model which takes seriously limits to arbitrage
  - Derive **theoretical conditions** under which QE works
  - **Quantify** the aggregate effects of QE
- Bond market imperfections play a role in the transmission of **conventional** monetary policy

Lingering Questions

Bernanke: "QE works in practice but not in theory"

- Develop a GE model which takes seriously limits to arbitrage
  - Derive **theoretical conditions** under which QE works
  - **Quantify** the aggregate effects of QE
- Bond market imperfections play a role in the transmission of **conventional** monetary policy
- Crucial for designing monetary policy going forward

Model Overview

- Ingredients:
  - Households do not have full access to bond markets
  - Key investors have imperfect risk-bearing capacity

Model Overview

- Ingredients:
  - Households do not have full access to bond markets
  - Key investors have imperfect risk-bearing capacity
  - $\implies$ endogenous degree of segmentation/preferred habitat

Model Overview

- Ingredients:
  - Households do not have full access to bond markets
  - Key investors have imperfect risk-bearing capacity
  - $\implies$ endogenous degree of segmentation/preferred habitat
- Dual equilibrating role of the yield curve:
  1. **Macro channel:** Intertemporal decisions of long-lived agents
  2. **Finance channel:** Short-run portfolio demands from investors

Model Overview

- Ingredients:
  - Households do not have full access to bond markets
  - Key investors have imperfect risk-bearing capacity
  - $\implies$ endogenous degree of segmentation/preferred habitat
- Dual equilibrating role of the yield curve:
  1. **Macro channel:** Intertemporal decisions of long-lived agents
  2. **Finance channel:** Short-run portfolio demands from investors
- Monetary policy works through both channels

Preview: Implications

- Theoretical results:
  - QE works if and only if bond markets are disrupted

Preview: Implications

- Theoretical results:
  - QE works if and only if bond markets are disrupted
  - Declining risk-bearing capacity mitigates the transmission of conventional policy (and FG)

Preview: Implications

- Theoretical results:
  - QE works if and only if bond markets are disrupted
  - Declining risk-bearing capacity mitigates the transmission of conventional policy (and FG)
- Quantitative results:
  - QE $\approx$ 50-75 b.p. cut in policy rate in normal times

Preview: Implications

- Theoretical results:
  - QE works if and only if bond markets are disrupted
  - Declining risk-bearing capacity mitigates the transmission of conventional policy (and FG)
- Quantitative results:
  - QE $\approx$ 50-75 b.p. cut in policy rate in normal times
  - Conventional policy during crisis $\approx$ 80% as effective as in normal times

Preview: Implications

- Theoretical results:
  - QE works if and only if bond markets are disrupted
  - Declining risk-bearing capacity mitigates the transmission of conventional policy (and FG)
- Quantitative results:
  - QE $\approx$ 50-75 b.p. cut in policy rate in normal times
  - Conventional policy during crisis $\approx$ 80% as effective as in normal times
- Designing policy going forward:
  - Conventional policy: more aggressive in financial crises

Preview: Implications

- Theoretical results:
  - QE works if and only if bond markets are disrupted
  - Declining risk-bearing capacity mitigates the transmission of conventional policy (and FG)
- Quantitative results:
  - QE $\approx$ 50-75 b.p. cut in policy rate in normal times
  - Conventional policy during crisis $\approx$ 80% as effective as in normal times
- Designing policy going forward:
  - Conventional policy: more aggressive in financial crises
  - QE rule can be stabilizing

New Keynesian Preferred Habitat Framework

- Time $t \in [0, \infty)$ is continuous. Consumption and production:
  - Infinitely-lived **households** work and consume
  - **Firms** produce using labor, face price frictions

New Keynesian Preferred Habitat Framework

- Time $t \in [0, \infty)$ is continuous. Consumption and production:
  - Infinitely-lived **households** work and consume
  - **Firms** produce using labor, face price frictions
- Bonds with maturity $\tau \in [0, T]$. Bond market investors:
  - HHs save and borrow through a passive **index fund**
  - **Habitat investors** with maturity-specific demand
  - Short-lived **arbitrageurs** render term structure arbitrage-free

New Keynesian Preferred Habitat Framework

- Time $t \in [0, \infty)$ is continuous. Consumption and production:
  - Infinitely-lived **households** work and consume
  - **Firms** produce using labor, face price frictions
- Bonds with maturity $\tau \in [0, T]$. Bond market investors:
  - HHs save and borrow through a passive **index fund**
  - **Habitat investors** with maturity-specific demand
  - Short-lived **arbitrageurs** render term structure arbitrage-free
- Government:
  - **Central bank** sets the short nominal rate (and conducts QE)
  - Lump-sum taxes/transfers from investors to HHs

Aggregate Dynamics

- Modification of a benchmark NK model ($\pi_t \equiv 0$):

$$\mathrm{d}x_t = \varsigma^{-1}\left(r_t - \bar{r}\right)\mathrm{d}t \qquad \text{(IS)}$$

Aggregate Dynamics

- Modification of a benchmark NK model ($\pi_t \equiv 0$):

$$\mathrm{d}x_t = \varsigma^{-1}(r_t - \bar{r})\,\mathrm{d}t \qquad \text{(IS)}$$

Aggregate Dynamics

- Modification of a benchmark NK model ($\pi_t \equiv 0$):

$$\mathrm{d}x_t = \varsigma^{-1} (r_t - \bar{r}) \, \mathrm{d}t \tag{IS}$$

Aggregate Dynamics

- Modification of a benchmark NK model ($\pi_t \equiv 0$):

$$\mathrm{d}x_t = \varsigma^{-1}(r_t - \bar{r})\,\mathrm{d}t \tag{IS}$$

Aggregate Dynamics

- Modification of a benchmark NK model ($\pi_t \equiv 0$):

$$\mathrm{d}x_t = \varsigma^{-1}\left(r_t - \bar{r}\right)\mathrm{d}t \tag{IS}$$

Aggregate Dynamics

- Modification of a benchmark NK model ($\pi_t \equiv 0$):

$$\mathrm{d}x_t = \varsigma^{-1} \left(\tilde{r}_t - \bar{r} \right) \mathrm{d}t \tag{IS}$$

- "Effective" borrowing rate is a function of long rates $R_{t,\tau}$:

$$\tilde{r}_t \equiv \int_0^T \eta(\tau) R_{t,\tau} \, \mathrm{d}\tau \tag{ER}$$

Aggregate Dynamics

- Modification of a benchmark NK model ($\pi_t \equiv 0$):

$$\mathrm{d}x_t = \varsigma^{-1}\left(\tilde{r}_t - \bar{r}\right)\mathrm{d}t \tag{IS}$$

- "Effective" borrowing rate is a function of long rates $R_{t,\tau}$:

$$\tilde{r}_t \equiv \int_0^T \eta(\tau) R_{t,\tau}\,\mathrm{d}\tau \tag{ER}$$

Aggregate Dynamics

- Modification of a benchmark NK model ($\pi_t \equiv 0$):

$$\mathrm{d}x_t = \varsigma^{-1} \left(\tilde{r}_t - \bar{r} \right) \mathrm{d}t \tag{IS}$$

- "Effective" borrowing rate is a function of long rates $R_{t,\tau}$:

$$\tilde{r}_t \equiv \int_0^T \eta(\tau) R_{t,\tau} \, \mathrm{d}\tau \tag{ER}$$

Aggregate Dynamics

- Modification of a benchmark NK model ($\pi_t \equiv 0$):

$$\mathrm{d}x_t = \varsigma^{-1}(\tilde{r}_t - \bar{r})\,\mathrm{d}t \tag{IS}$$

- "Effective" borrowing rate is a function of long rates $R_{t,\tau}$:

$$\tilde{r}_t \equiv \int_0^T \eta(\tau) R_{t,\tau}\,\mathrm{d}\tau \tag{ER}$$

- Rule for policy rate r_t ($= \lim_{\tau \to 0} R_{t,\tau}$):

$$\mathrm{d}r_t = -\kappa_r(r_t - \phi_x x_t - r^*)\,\mathrm{d}t + \sigma_r\,\mathrm{d}B_{r,t} \tag{TR}$$

Aggregate Dynamics

- Modification of a benchmark NK model ($\pi_t \equiv 0$):

$$\mathrm{d}x_t = \varsigma^{-1} (\tilde{r}_t - \bar{r}) \, \mathrm{d}t \qquad \text{(IS)}$$

- "Effective" borrowing rate is a function of long rates $R_{t,\tau}$:

$$\tilde{r}_t \equiv \int_0^T \eta(\tau) R_{t,\tau} \, \mathrm{d}\tau \qquad \text{(ER)}$$

- Rule for policy rate r_t ($= \lim_{\tau \to 0} R_{t,\tau}$):

$$\mathrm{d}r_t = -\kappa_r (r_t - \phi_x x_t - r^*) \, \mathrm{d}t + \sigma_r \, \mathrm{d}B_{r,t} \qquad \text{(TR)}$$

Aggregate Dynamics

- Modification of a benchmark NK model ($\pi_t \equiv 0$):

$$\mathrm{d}x_t = \varsigma^{-1}(\tilde{r}_t - \bar{r})\,\mathrm{d}t \tag{IS}$$

- "Effective" borrowing rate is a function of long rates $R_{t,\tau}$:

$$\tilde{r}_t \equiv \int_0^T \eta(\tau) R_{t,\tau}\,\mathrm{d}\tau \tag{ER}$$

- Rule for policy rate r_t ($= \lim_{\tau \to 0} R_{t,\tau}$):

$$\mathrm{d}r_t = -\kappa_r(r_t - \phi_x x_t - r^*)\,\mathrm{d}t + \sigma_r\,\mathrm{d}B_{r,t} \tag{TR}$$

Aggregate Dynamics

- Modification of a benchmark NK model ($\pi_t \equiv 0$):

$$\mathrm{d}x_t = \varsigma^{-1} (\tilde{r}_t - \bar{r}) \, \mathrm{d}t \tag{IS}$$

- "Effective" borrowing rate is a function of long rates $R_{t,\tau}$:

$$\tilde{r}_t \equiv \int_0^T \eta(\tau) R_{t,\tau} \, \mathrm{d}\tau \tag{ER}$$

- Rule for policy rate r_t ($= \lim_{\tau \to 0} R_{t,\tau}$):

$$\mathrm{d}r_t = -\kappa_r (r_t - \phi_x x_t - r^*) \, \mathrm{d}t + \sigma_r \, \mathrm{d}B_{r,t} \tag{TR}$$

Aggregate Dynamics

- Modification of a benchmark NK model ($\pi_t \equiv 0$):

$$\mathrm{d}x_t = \varsigma^{-1} (\tilde{r}_t - \bar{r}) \, \mathrm{d}t \tag{IS}$$

- "Effective" borrowing rate is a function of long rates $R_{t,\tau}$:

$$\tilde{r}_t \equiv \int_0^T \eta(\tau) R_{t,\tau} \, \mathrm{d}\tau \tag{ER}$$

- Rule for policy rate r_t ($= \lim_{\tau \to 0} R_{t,\tau}$):

$$\mathrm{d}r_t = -\kappa_r (r_t - \phi_x x_t - r^*) \, \mathrm{d}t + \sigma_r \, \mathrm{d}B_{r,t} \tag{TR}$$

Aggregate Dynamics

- Modification of a benchmark NK model ($\pi_t \equiv 0$):

$$\mathrm{d}x_t = \varsigma^{-1}(\tilde{r}_t - \bar{r})\,\mathrm{d}t \tag{IS}$$

- "Effective" borrowing rate is a function of long rates $R_{t,\tau}$:

$$\tilde{r}_t \equiv \int_0^T \eta(\tau) R_{t,\tau}\,\mathrm{d}\tau \tag{ER}$$

- Rule for policy rate r_t ($= \lim_{\tau \to 0} R_{t,\tau}$):

$$\mathrm{d}r_t = -\kappa_r(r_t - \phi_x x_t - r^*)\,\mathrm{d}t + \sigma_r\,\mathrm{d}B_{r,t} \tag{TR}$$

- Closing the model: equilibrium term structure determination

Term Structure and Preferred Habitat

Zero-coupon bond yields and prices $R_{t,\tau} = -\frac{\log P_{t,\tau}}{\tau}$ determined by interactions of two types of investors [Vayanos and Vila 2009]:

Term Structure and Preferred Habitat

Zero-coupon bond yields and prices $R_{t,\tau} = -\frac{\log P_{t,\tau}}{\tau}$ determined by interactions of two types of investors [Vayanos and Vila 2009]:

- Preferred habitat investors with idiosyncratic demand:

$$\begin{aligned} \tilde{b}_{t,\tau} &= -\alpha(\tau) \log P_{t,\tau} + \varepsilon_{t,\tau} \\ &= \alpha(\tau)\tau(R_{t,\tau} - \beta_{t,\tau}) \end{aligned} \tag{PH}$$

Term Structure and Preferred Habitat

Zero-coupon bond yields and prices $R_{t,\tau} = -\frac{\log P_{t,\tau}}{\tau}$ determined by interactions of two types of investors [Vayanos and Vila 2009]:

- Preferred habitat investors with idiosyncratic demand:

$$\begin{aligned} \tilde{b}_{t,\tau} &= -\alpha(\tau) \log P_{t,\tau} + \varepsilon_{t,\tau} \\ &= \alpha(\tau)\tau(R_{t,\tau} - \beta_{t,\tau}) \end{aligned} \tag{PH}$$

Term Structure and Preferred Habitat

Zero-coupon bond yields and prices $R_{t,\tau} = -\frac{\log P_{t,\tau}}{\tau}$ determined by interactions of two types of investors [Vayanos and Vila 2009]:

- Preferred habitat investors with idiosyncratic demand:

$$\begin{aligned} \tilde{b}_{t,\tau} &= -\alpha(\tau) \log P_{t,\tau} + \varepsilon_{t,\tau} \\ &= \alpha(\tau)\tau(R_{t,\tau} - \beta_{t,\tau}) \end{aligned} \tag{PH}$$

Term Structure and Preferred Habitat

Zero-coupon bond yields and prices $R_{t,\tau} = -\frac{\log P_{t,\tau}}{\tau}$ determined by interactions of two types of investors [Vayanos and Vila 2009]:

- Preferred habitat investors with idiosyncratic demand:

$$\begin{aligned} \tilde{b}_{t,\tau} &= -\alpha(\tau) \log P_{t,\tau} + \varepsilon_{t,\tau} \\ &= \alpha(\tau)\tau(R_{t,\tau} - \beta_{t,\tau}) \end{aligned} \tag{PH}$$

- Arbitrageurs with mean-variance trade-off in wealth:

$$\max_{b_{t,\tau}} E_t \, \mathrm{d}W_t - \frac{a}{2} Var_t \, \mathrm{d}W_t$$

$$\begin{aligned} \text{s.t. } \mathrm{d}W_t = & \left(W_t - \int_0^T b_{t,\tau} \, \mathrm{d}\tau \right) r_t \, \mathrm{d}t \\ & + \int_0^T b_{t,\tau} \frac{\mathrm{d}P_{t,\tau}}{P_{t,\tau}} \, \mathrm{d}\tau \end{aligned} \tag{BC}$$

Term Structure and Preferred Habitat

Zero-coupon bond yields and prices $R_{t,\tau} = -\frac{\log P_{t,\tau}}{\tau}$ determined by interactions of two types of investors [Vayanos and Vila 2009]:

- Preferred habitat investors with idiosyncratic demand:

$$\begin{aligned} \tilde{b}_{t,\tau} &= -\alpha(\tau) \log P_{t,\tau} + \varepsilon_{t,\tau} \\ &= \alpha(\tau)\tau(R_{t,\tau} - \beta_{t,\tau}) \end{aligned} \tag{PH}$$

- Arbitrageurs with mean-variance trade-off in wealth:

$$\max_{b_{t,\tau}} E_t \, \mathrm{d}W_t - \frac{a}{2} Var_t \, \mathrm{d}W_t$$

$$\begin{aligned} \text{s.t.} \ \ \mathrm{d}W_t = \left(W_t - \int_0^T b_{t,\tau} \, \mathrm{d}\tau \right) r_t \, \mathrm{d}t & \\ + \int_0^T b_{t,\tau} \frac{\mathrm{d}P_{t,\tau}}{P_{t,\tau}} \, \mathrm{d}\tau & \end{aligned} \tag{BC}$$

Term Structure and Preferred Habitat

Zero-coupon bond yields and prices $R_{t,\tau} = -\frac{\log P_{t,\tau}}{\tau}$ determined by interactions of two types of investors [Vayanos and Vila 2009]:

- Preferred habitat investors with idiosyncratic demand:

$$\begin{aligned} \tilde{b}_{t,\tau} &= -\alpha(\tau)\log P_{t,\tau} + \varepsilon_{t,\tau} \\ &= \alpha(\tau)\tau(R_{t,\tau} - \beta_{t,\tau}) \end{aligned} \tag{PH}$$

- Arbitrageurs with mean-variance trade-off in wealth:

$$\max_{b_{t,\tau}} E_t \, \mathrm{d}W_t - \frac{a}{2} Var_t \, \mathrm{d}W_t$$

$$\begin{aligned} \text{s.t. } \mathrm{d}W_t = &\left(W_t - \int_0^T b_{t,\tau} \, \mathrm{d}\tau \right) r_t \, \mathrm{d}t \\ &+ \int_0^T b_{t,\tau} \frac{\mathrm{d}P_{t,\tau}}{P_{t,\tau}} \, \mathrm{d}\tau \end{aligned} \tag{BC}$$

Term Structure and Preferred Habitat

Zero-coupon bond yields and prices $R_{t,\tau} = -\frac{\log P_{t,\tau}}{\tau}$ determined by interactions of two types of investors [Vayanos and Vila 2009]:

- Preferred habitat investors with idiosyncratic demand:

$$\begin{aligned} \tilde{b}_{t,\tau} &= -\alpha(\tau) \log P_{t,\tau} + \varepsilon_{t,\tau} \\ &= \alpha(\tau)\tau(R_{t,\tau} - \beta_{t,\tau}) \end{aligned} \tag{PH}$$

- Arbitrageurs with mean-variance trade-off in wealth:

$$\begin{aligned} &\max_{b_{t,\tau}} E_t \, \mathrm{d}W_t - \frac{a}{2} Var_t \, \mathrm{d}W_t \\ \text{s.t. } \mathrm{d}W_t &= \left(W_t - \int_0^T b_{t,\tau} \, \mathrm{d}\tau \right) r_t \, \mathrm{d}t \\ &\quad + \int_0^T b_{t,\tau} \frac{\mathrm{d}P_{t,\tau}}{P_{t,\tau}} \, \mathrm{d}\tau \end{aligned} \tag{BC}$$

Term Structure and Preferred Habitat

Zero-coupon bond yields and prices $R_{t,\tau} = -\frac{\log P_{t,\tau}}{\tau}$ determined by interactions of two types of investors [Vayanos and Vila 2009]:

- Preferred habitat investors with idiosyncratic demand:

$$\begin{aligned} \tilde{b}_{t,\tau} &= -\alpha(\tau) \log P_{t,\tau} + \varepsilon_{t,\tau} \\ &= \alpha(\tau)\tau(R_{t,\tau} - \beta_{t,\tau}) \end{aligned} \tag{PH}$$

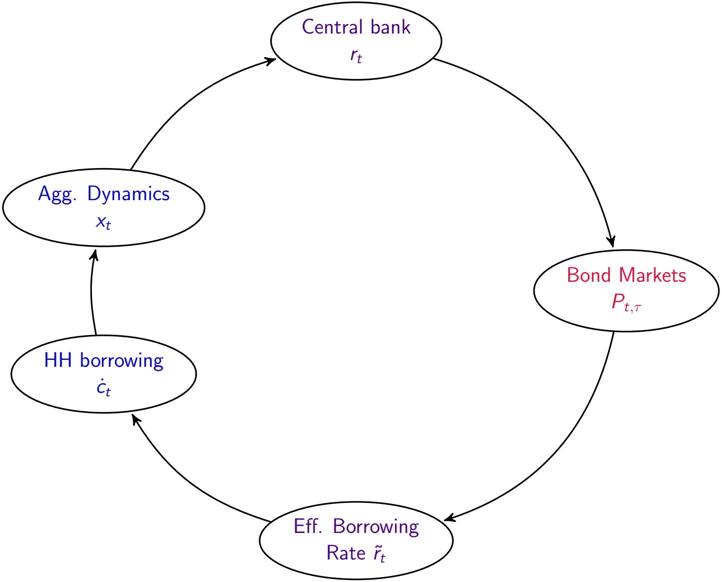
- Arbitrageurs with mean-variance trade-off in wealth:

$$\max_{b_{t,\tau}} E_t \, \mathrm{d}W_t - \frac{a}{2} Var_t \, \mathrm{d}W_t$$

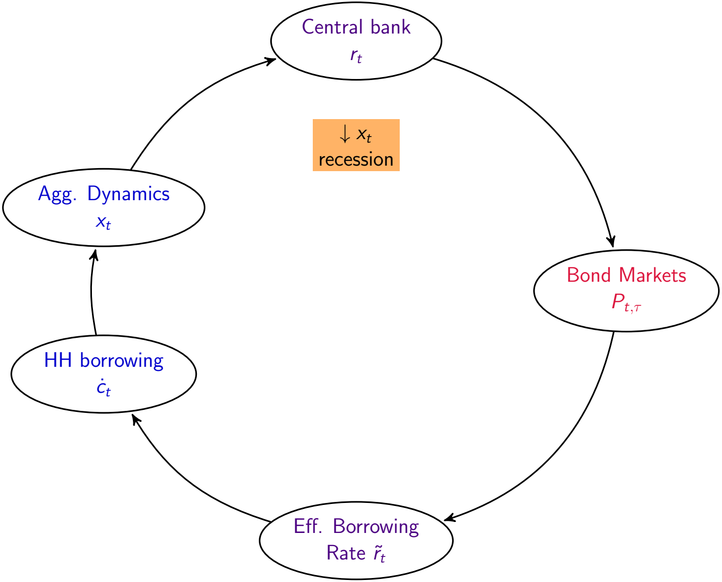
$$\begin{aligned} \text{s.t. } \mathrm{d}W_t = &\left(W_t - \int_0^T b_{t,\tau} \, \mathrm{d}\tau \right) r_t \, \mathrm{d}t \\ &+ \int_0^T b_{t,\tau} \frac{\mathrm{d}P_{t,\tau}}{P_{t,\tau}} \, \mathrm{d}\tau \end{aligned} \tag{BC}$$

- Market clearing: $b_{t,\tau} = -\tilde{b}_{t,\tau}$

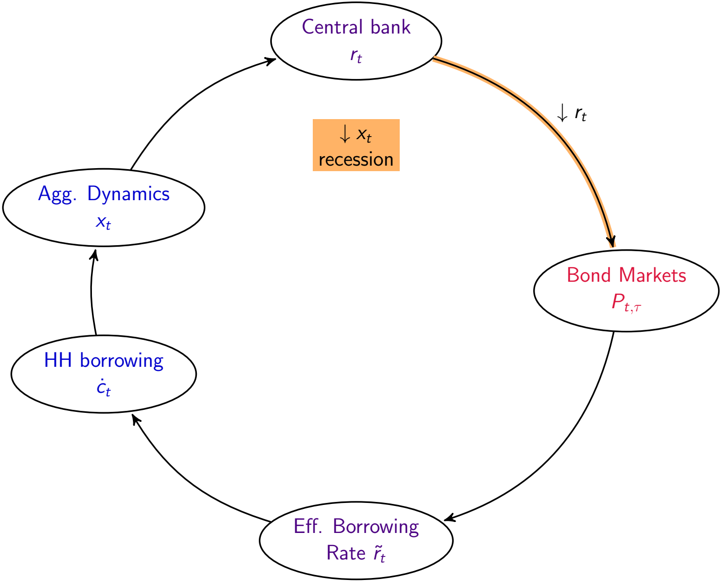
Equilibrium Under Perfect Arbitrage



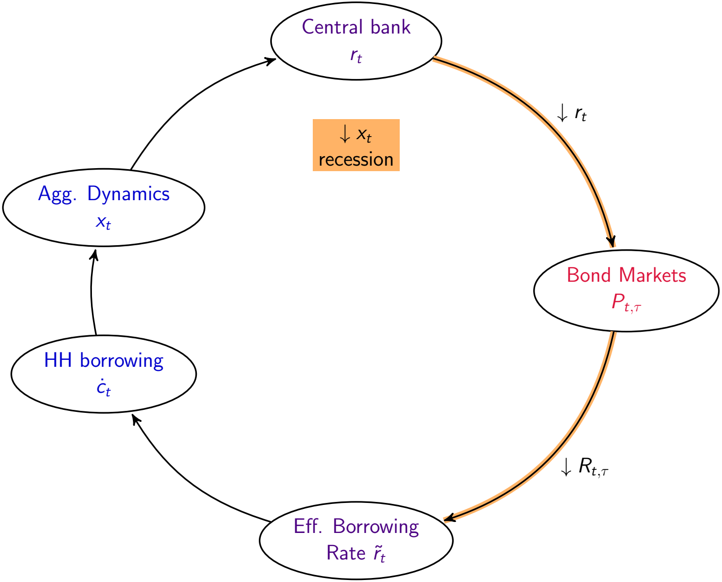
Equilibrium Under Perfect Arbitrage



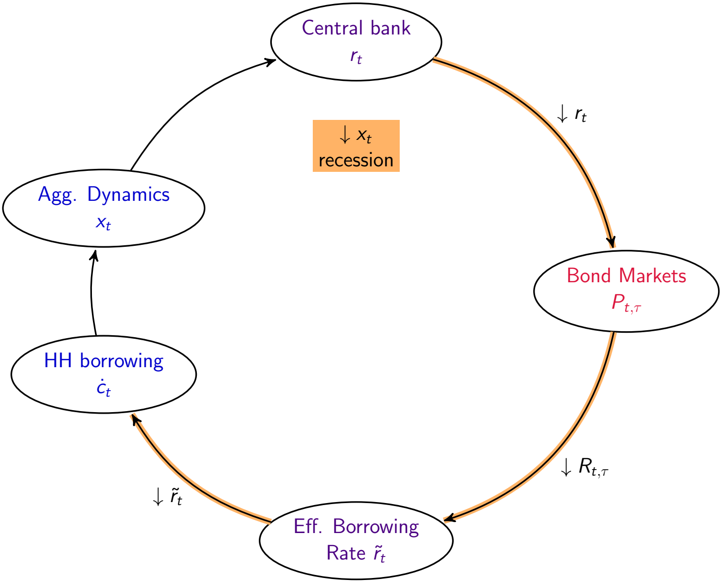
Equilibrium Under Perfect Arbitrage



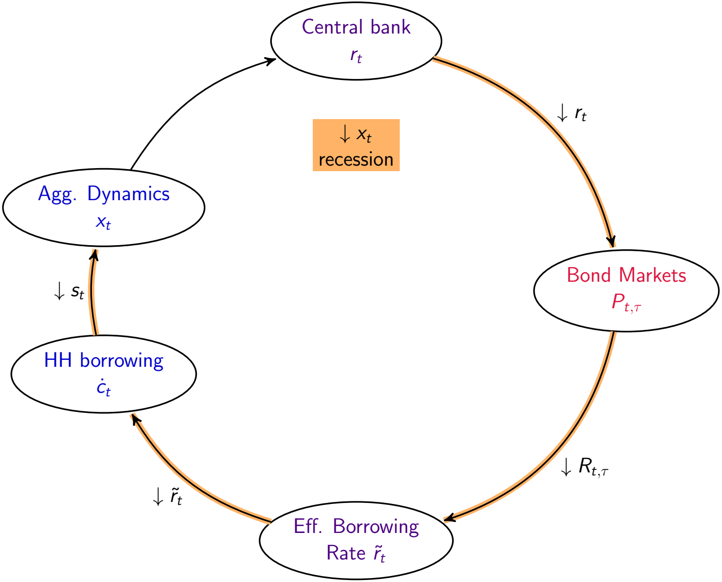
Equilibrium Under Perfect Arbitrage



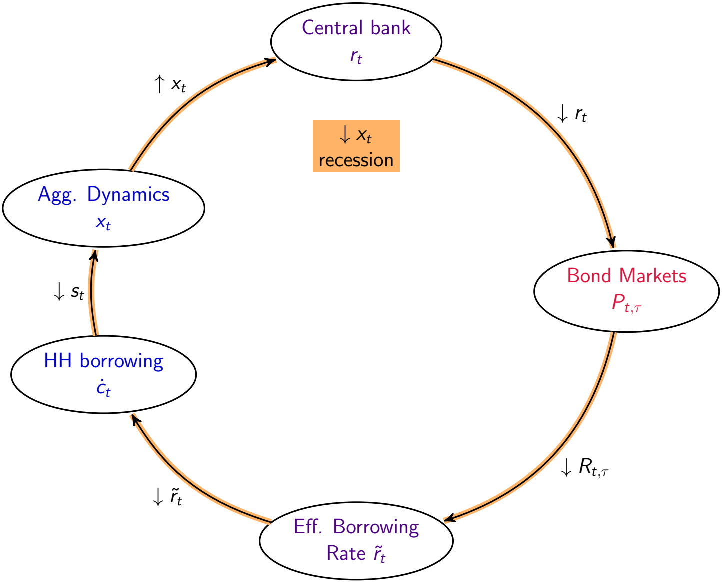
Equilibrium Under Perfect Arbitrage



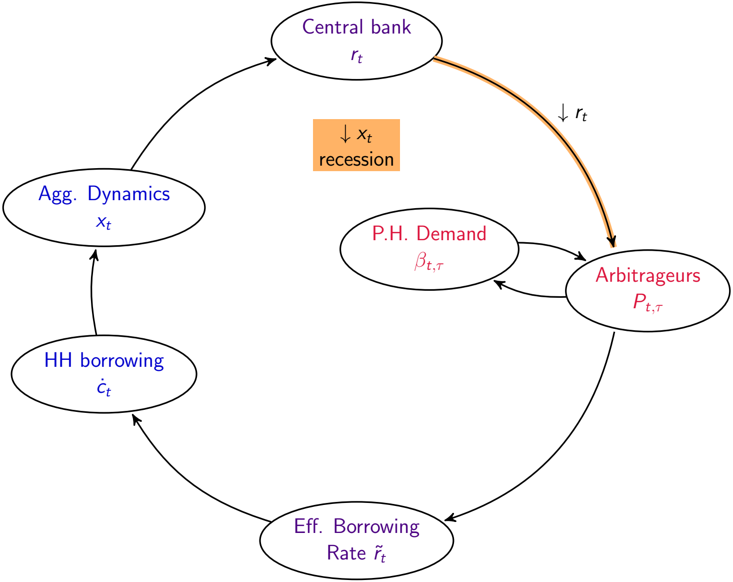
Equilibrium Under Perfect Arbitrage



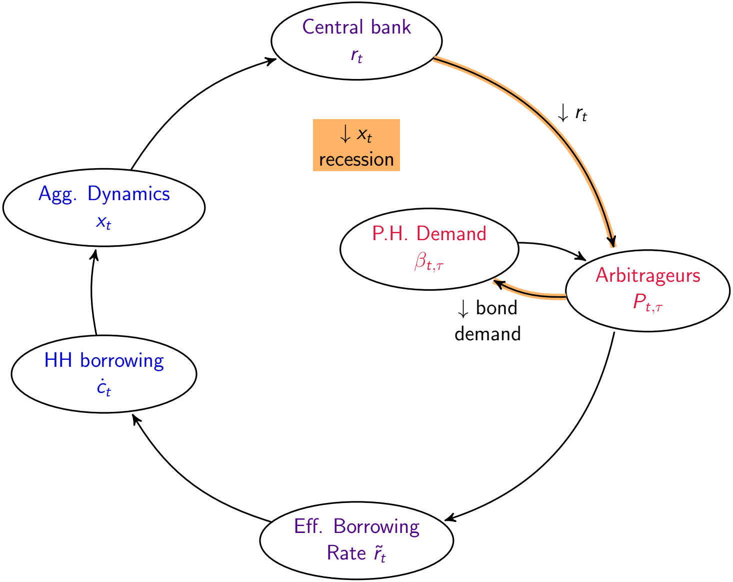
Equilibrium Under Perfect Arbitrage



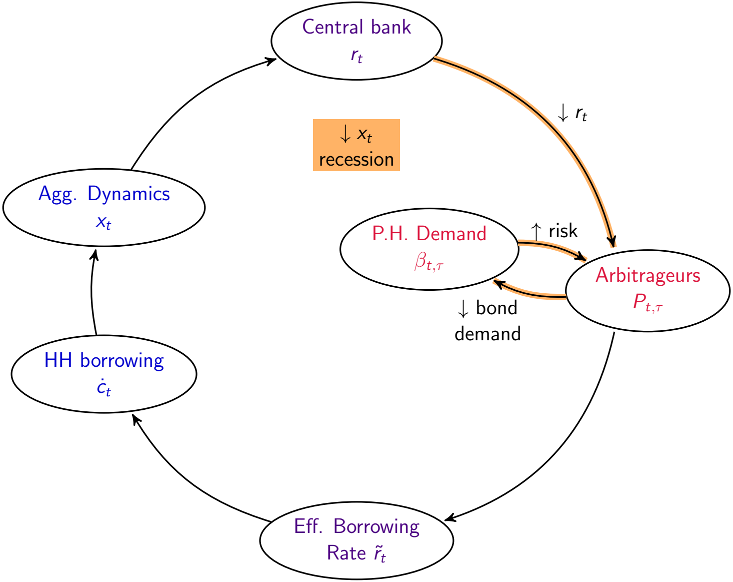
Limited Risk-Bearing Capacity



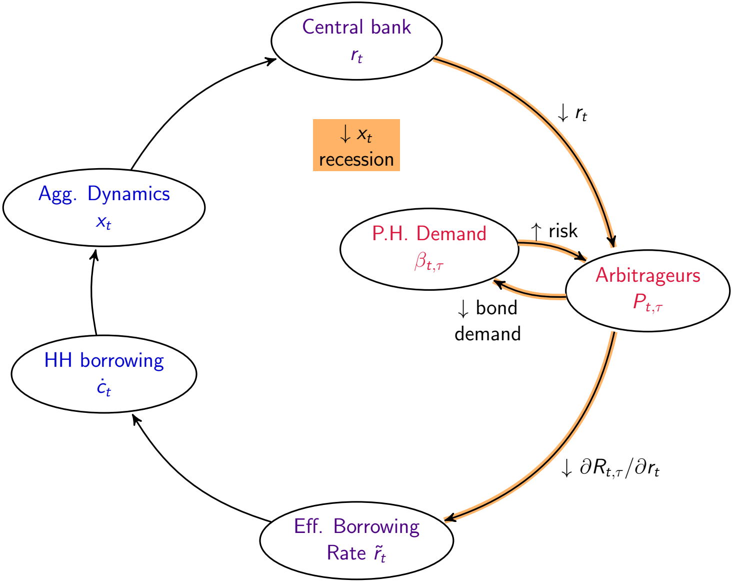
Limited Risk-Bearing Capacity



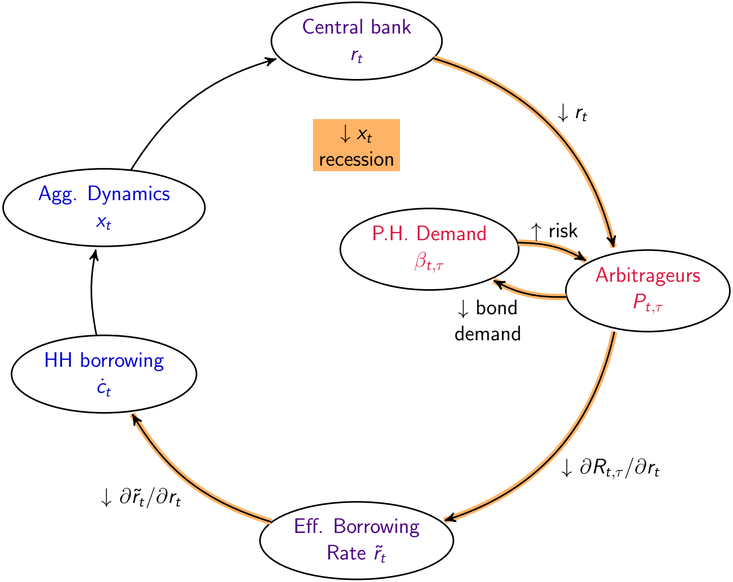
Limited Risk-Bearing Capacity



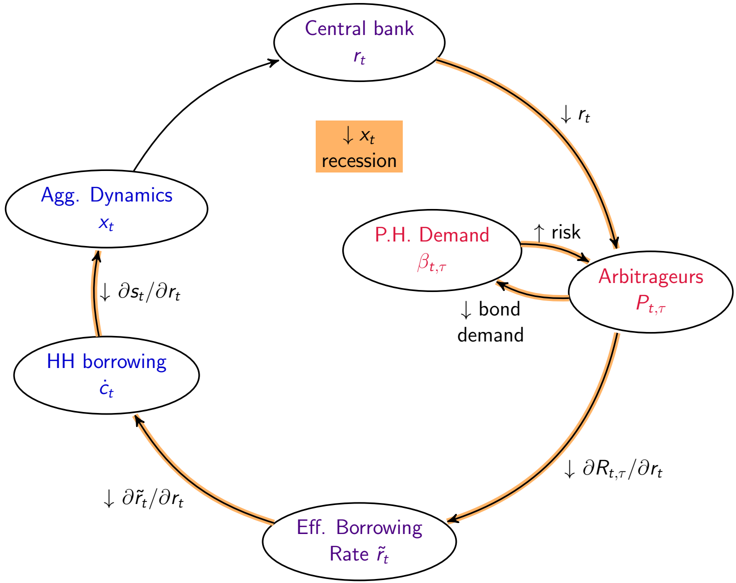
Limited Risk-Bearing Capacity



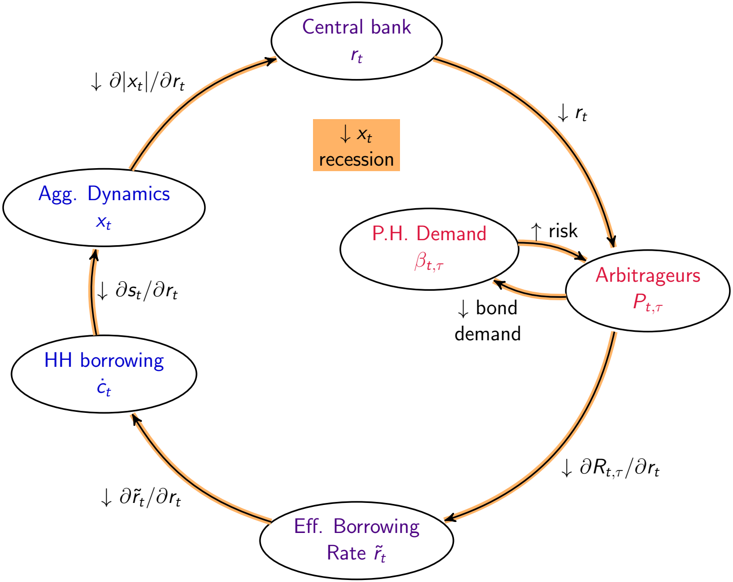
Limited Risk-Bearing Capacity



Limited Risk-Bearing Capacity



Limited Risk-Bearing Capacity



Solving the Model

- Equilibrium affine term structure

$$-\log P_{t,\tau} = A_r(\tau) r_t + C(\tau)$$

Solving the Model

- Equilibrium affine term structure

$$-\log P_{t,\tau} = A_r(\tau) r_t + C(\tau)$$

- Effective borrowing rate:

$$\tilde{r}_t = \underbrace{\left[\int_0^T \frac{\eta(\tau)}{\tau} A_r(\tau)\,\mathrm{d}\tau\right]}_{\equiv \hat{A}_r} r_t + \underbrace{\left[\int_0^T \frac{\eta(\tau)}{\tau} C(\tau)\,\mathrm{d}\tau\right]}_{\equiv \hat{C}}$$

- Aggregate dynamics

$$\mathrm{d}r_t = -\kappa_r(r_t - \phi_x x_t - r^*)\,\mathrm{d}t + \sigma_r\,\mathrm{d}B_{r,t}$$
$$\mathrm{d}x_t = \varsigma^{-1}\left(\hat{A}_r r_t + \hat{C} - \bar{r}\right)\mathrm{d}t$$

Solving the Model

- Equilibrium affine term structure

$$-\log P_{t,\tau} = A_r(\tau) r_t + C(\tau)$$

- Effective borrowing rate:

$$\tilde{r}_t = \underbrace{\left[\int_0^T \frac{\eta(\tau)}{\tau} A_r(\tau)\,\mathrm{d}\tau\right]}_{\equiv \hat{A}_r} r_t + \underbrace{\left[\int_0^T \frac{\eta(\tau)}{\tau} C(\tau)\,\mathrm{d}\tau\right]}_{\equiv \hat{C}}$$

- Aggregate dynamics

$$\mathrm{d}r_t = -\kappa_r (r_t - \phi_x x_t - r^*)\,\mathrm{d}t + \sigma_r\,\mathrm{d}B_{r,t}$$
$$\mathrm{d}x_t = \varsigma^{-1}\left(\hat{A}_r r_t + \hat{C} - \bar{r}\right)\mathrm{d}t$$

Solving the Model

- Equilibrium affine term structure

$$-\log P_{t,\tau} = A_r(\tau) r_t + C(\tau)$$

- Effective borrowing rate:

$$\tilde{r}_t = \underbrace{\left[\int_0^T \frac{\eta(\tau)}{\tau} A_r(\tau)\,\mathrm{d}\tau\right]}_{\equiv \hat{A}_r} r_t + \underbrace{\left[\int_0^T \frac{\eta(\tau)}{\tau} C(\tau)\,\mathrm{d}\tau\right]}_{\equiv \hat{C}}$$

- Aggregate dynamics

$$\mathrm{d}r_t = -\kappa_r (r_t - \phi_x x_t - r^*)\,\mathrm{d}t + \sigma_r\,\mathrm{d}B_{r,t}$$
$$\mathrm{d}x_t = \varsigma^{-1}\left(\hat{A}_r r_t + \hat{C} - \bar{r}\right)\mathrm{d}t$$

- If determinacy conditions are met:

$$\mathrm{d}r_t = -\lambda_1 (r_t - r^{SS})\,\mathrm{d}t + \sigma_r\,\mathrm{d}B_{r,t}$$
$$x_t = \omega_x (r_t - r^{SS})$$

Solving the Model

- Equilibrium affine term structure

$$-\log P_{t,\tau} = A_r(\tau) r_t + C(\tau)$$

- Effective borrowing rate:

$$\tilde{r}_t = \underbrace{\left[\int_0^T \frac{\eta(\tau)}{\tau} A_r(\tau)\,\mathrm{d}\tau\right]}_{\equiv \hat{A}_r} r_t + \underbrace{\left[\int_0^T \frac{\eta(\tau)}{\tau} C(\tau)\,\mathrm{d}\tau\right]}_{\equiv \hat{C}}$$

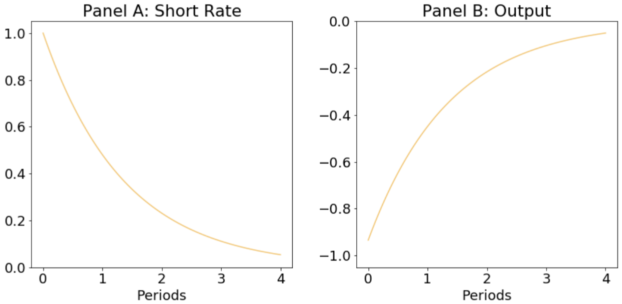
- Aggregate dynamics

$$\mathrm{d}r_t = -\kappa_r(r_t - \phi_x x_t - r^*)\,\mathrm{d}t + \sigma_r\,\mathrm{d}B_{r,t}$$
$$\mathrm{d}x_t = \varsigma^{-1}\left(\hat{A}_r r_t + \hat{C} - \bar{r}\right)\mathrm{d}t$$

- If determinacy conditions are met:

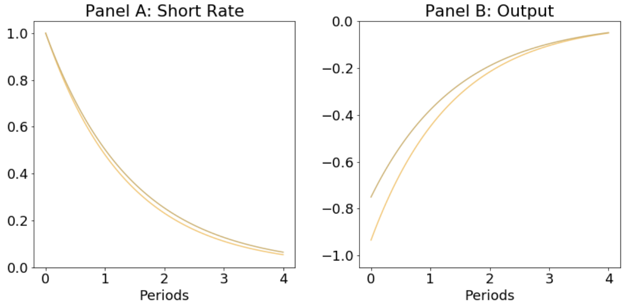
$$\mathrm{d}r_t = -\lambda_1(r_t - r^{SS})\,\mathrm{d}t + \sigma_r\,\mathrm{d}B_{r,t}$$
$$x_t = \omega_x(r_t - r^{SS})$$

Dynamics and Output Growth Sensitivity



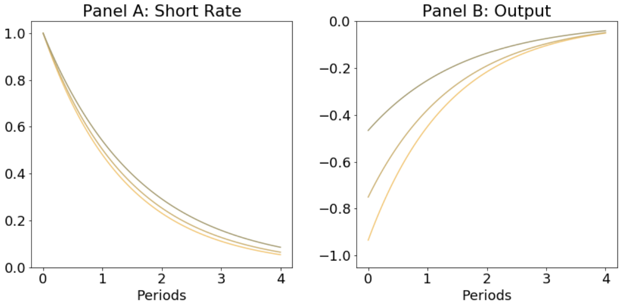
Notes: impulse response functions of the policy rate and output in response to a unit monetary shock, as equilibrium output growth sensitivity to the policy rate falls. Darker lines correspond to lower output growth sensitivity $\hat{A}_r$. phase diagrams

Dynamics and Output Growth Sensitivity



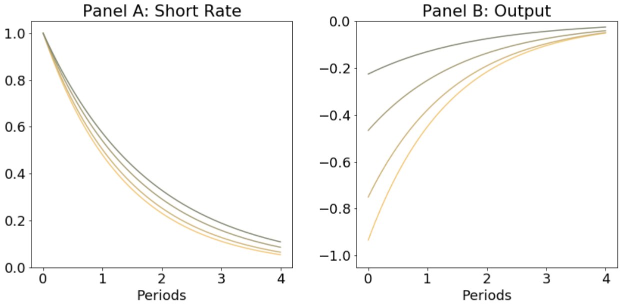
Notes: impulse response functions of the policy rate and output in response to a unit monetary shock, as equilibrium output growth sensitivity to the policy rate falls. Darker lines correspond to lower output growth sensitivity $\hat{A}_r$. phase diagrams

Dynamics and Output Growth Sensitivity



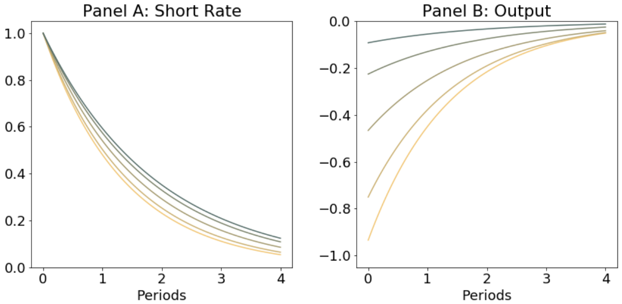
Notes: impulse response functions of the policy rate and output in response to a unit monetary shock, as equilibrium output growth sensitivity to the policy rate falls. Darker lines correspond to lower output growth sensitivity $\hat{A}_r$. phase diagrams

Dynamics and Output Growth Sensitivity



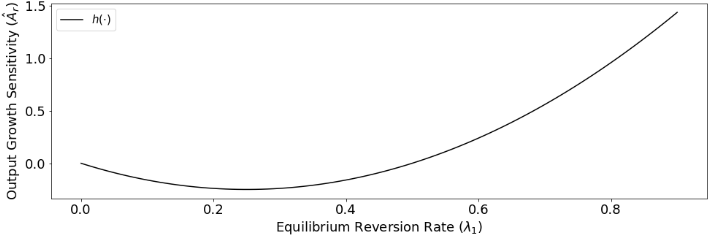
Notes: impulse response functions of the policy rate and output in response to a unit monetary shock, as equilibrium output growth sensitivity to the policy rate falls. Darker lines correspond to lower output growth sensitivity $\hat{A}_r$. phase diagrams

Dynamics and Output Growth Sensitivity



Notes: impulse response functions of the policy rate and output in response to a unit monetary shock, as equilibrium output growth sensitivity to the policy rate falls. Darker lines correspond to lower output growth sensitivity $\hat{A}_r$. phase diagrams

Rational Expectations Equilibrium

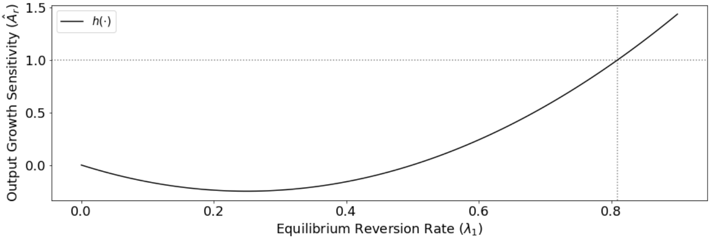


Characterizing $\hat{A}_r$ (Output Sensitivity)

The equilibrium reversion rate λ and the sensitivity of output growth to the policy rate $\hat{A}_r$ are related as follows:

$$\hat{A}_r = h(\lambda) = \frac{\lambda(\lambda - \kappa_r)}{\varsigma^{-1}\kappa_r\phi_x}$$

Rational Expectations Equilibrium

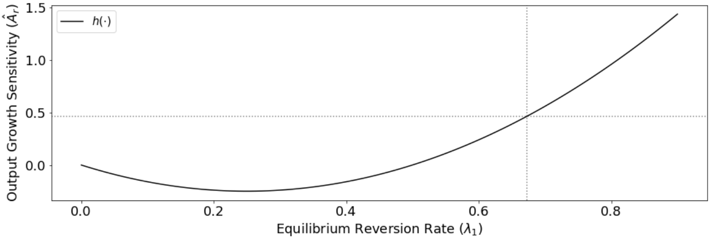


Characterizing $\hat{A}_r$ (Output Sensitivity)

The equilibrium reversion rate λ and the sensitivity of output growth to the policy rate $\hat{A}_r$ are related as follows:

$$\hat{A}_r = h(\lambda) = \frac{\lambda(\lambda - \kappa_r)}{\varsigma^{-1}\kappa_r\phi_x}$$

Rational Expectations Equilibrium

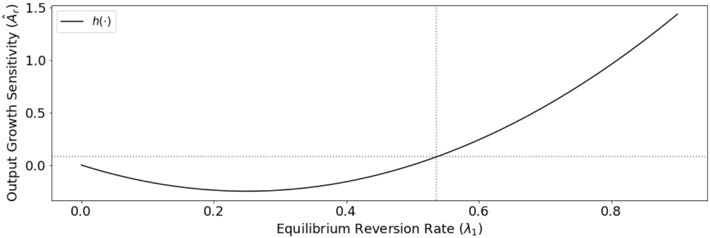


Characterizing $\hat{A}_r$ (Output Sensitivity)

The equilibrium reversion rate λ and the sensitivity of output growth to the policy rate $\hat{A}_r$ are related as follows:

$$\hat{A}_r = h(\lambda) = \frac{\lambda(\lambda - \kappa_r)}{\varsigma^{-1}\kappa_r\phi_x}$$

Rational Expectations Equilibrium

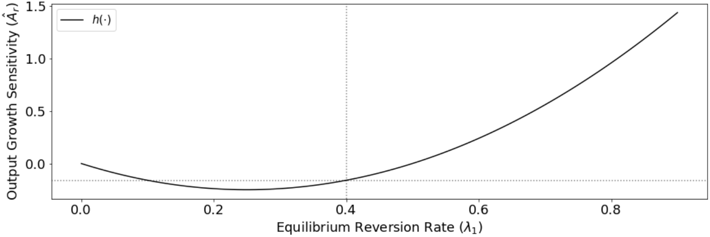


Characterizing $\hat{A}_r$ (Output Sensitivity)

The equilibrium reversion rate λ and the sensitivity of output growth to the policy rate $\hat{A}_r$ are related as follows:

$$\hat{A}_r = h(\lambda) = \frac{\lambda(\lambda - \kappa_r)}{\varsigma^{-1}\kappa_r\phi_x}$$

Rational Expectations Equilibrium



Characterizing $\hat{A}_r$ (Output Sensitivity)

The equilibrium reversion rate λ and the sensitivity of output growth to the policy rate $\hat{A}_r$ are related as follows:

$$\hat{A}_r = h(\lambda) = \frac{\lambda(\lambda - \kappa_r)}{\varsigma^{-1}\kappa_r\phi_x}$$

Arbitrageur Portfolio Choice

- Take as given equilibrium dynamics of the short rate

$$\mathrm{d}r_t = -\lambda(r_t - r^{SS})\,\mathrm{d}t + \sigma_r\,\mathrm{d}B_{r,t}$$

Arbitrageur Portfolio Choice

- Take as given equilibrium dynamics of the short rate

$$\mathrm{d}r_t = -\lambda(r_t - r^{SS})\,\mathrm{d}t + \sigma_r\,\mathrm{d}B_{r,t}$$

- Optimality conditions:

$$\begin{aligned} \mu_{t,\tau} - r_t &= A_r(\tau)\zeta_t \\ \zeta_t &\equiv a\sigma_r^2 \int_0^T b_{t,\tau} A_r(\tau)\,\mathrm{d}\tau \end{aligned}$$

Arbitrageur Portfolio Choice

- Take as given equilibrium dynamics of the short rate

$$\mathrm{d}r_t = -\lambda(r_t - r^{SS})\,\mathrm{d}t + \sigma_r\,\mathrm{d}B_{r,t}$$

- Optimality conditions:

$$\mu_{t,\tau} - r_t = A_r(\tau)\zeta_t$$

$$\zeta_t \equiv a\sigma_r^2 \int_0^T b_{t,\tau} A_r(\tau)\,\mathrm{d}\tau$$

- Non-zero excess expected returns required to compensate for riskier allocations

Arbitrageur Portfolio Choice

- Take as given equilibrium dynamics of the short rate

$$\mathrm{d}r_t = -\lambda(r_t - r^{SS})\,\mathrm{d}t + \sigma_r\,\mathrm{d}B_{r,t}$$

- Optimality conditions:

$$\mu_{t,\tau} - r_t = A_r(\tau)\zeta_t$$

$$\zeta_t \equiv a\sigma_r^2 \int_0^T b_{t,\tau} A_r(\tau)\,\mathrm{d}\tau$$

- Non-zero excess expected returns required to compensate for riskier allocations

Arbitrageur Portfolio Choice

- Take as given equilibrium dynamics of the short rate

$$\mathrm{d}r_t = -\lambda(r_t - r^{SS})\,\mathrm{d}t + \sigma_r\,\mathrm{d}B_{r,t}$$

- Optimality conditions:

$$\mu_{t,\tau} - r_t = A_r(\tau)\zeta_t$$

$$\zeta_t \equiv a\sigma_r^2 \int_0^T b_{t,\tau} A_r(\tau)\,\mathrm{d}\tau$$

- Non-zero excess expected returns required to compensate for riskier allocations

Arbitrageur Portfolio Choice

- Take as given equilibrium dynamics of the short rate

$$\mathrm{d}r_t = -\lambda(r_t - r^{SS})\,\mathrm{d}t + \sigma_r\,\mathrm{d}B_{r,t}$$

- Optimality conditions:

$$\mu_{t,\tau} - r_t = A_r(\tau)\zeta_t$$
$$\zeta_t \equiv a\sigma_r^2 \int_0^T b_{t,\tau} A_r(\tau)\,\mathrm{d}\tau$$

- Non-zero excess expected returns required to compensate for riskier allocations

Arbitrageur Portfolio Choice

- Take as given equilibrium dynamics of the short rate

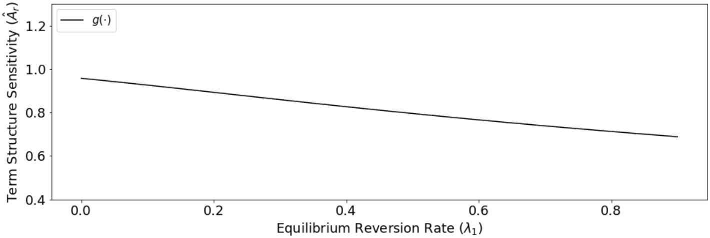
$$\mathrm{d}r_t = -\lambda(r_t - r^{SS})\,\mathrm{d}t + \sigma_r\,\mathrm{d}B_{r,t}$$

- Optimality conditions:

$$\mu_{t,\tau} - r_t = A_r(\tau)\zeta_t$$
$$\zeta_t \equiv a\sigma_r^2 \int_0^T b_{t,\tau} A_r(\tau)\,\mathrm{d}\tau$$

- Non-zero excess expected returns required to compensate for riskier allocations

Term Structure Equilibrium



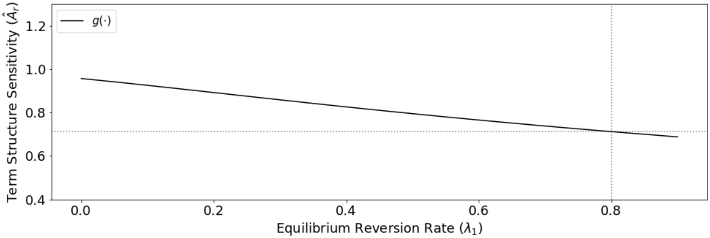
Characterizing $\hat{A}_r$ (Term Structure Sensitivity)

The equilibrium reversion rate λ and the sensitivity of the term structure to the policy rate $\hat{A}_r$ are related as follows:

$$\hat{A}_r = g(\lambda) = \int_0^T \eta(\tau) f\left(\nu(\lambda)\tau\right) \mathrm{d}\tau$$

where $f(x) = \frac{1-e^{-x}}{x}$ and $\nu(\lambda) = \lambda + a\sigma_r^2 \int_0^T \alpha(\tau)\tau^2 f\left(\nu(\lambda)\tau\right)^2 \mathrm{d}\tau$

Term Structure Equilibrium



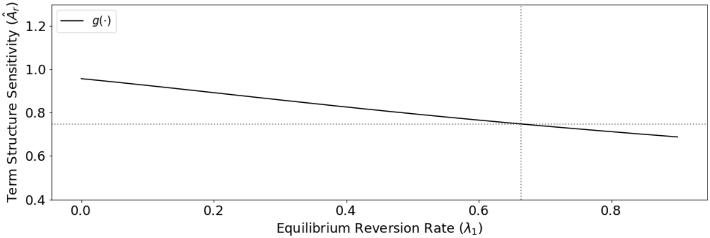
Characterizing $\hat{A}_r$ (Term Structure Sensitivity)

The equilibrium reversion rate λ and the sensitivity of the term structure to the policy rate $\hat{A}_r$ are related as follows:

$$\hat{A}_r = g(\lambda) = \int_0^T \eta(\tau) f\left(\nu(\lambda)\tau\right) \mathrm{d}\tau$$

where $f(x) = \frac{1-e^{-x}}{x}$ and $\nu(\lambda) = \lambda + a\sigma_r^2 \int_0^T \alpha(\tau)\tau^2 f\left(\nu(\lambda)\tau\right)^2 \mathrm{d}\tau$

Term Structure Equilibrium



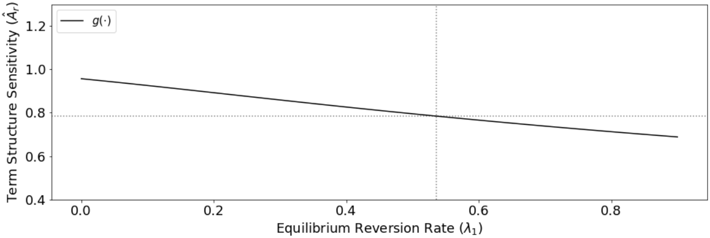
Characterizing $\hat{A}_r$ (Term Structure Sensitivity)

The equilibrium reversion rate λ and the sensitivity of the term structure to the policy rate $\hat{A}_r$ are related as follows:

$$\hat{A}_r = g(\lambda) = \int_0^T \eta(\tau) f\left(\nu(\lambda)\tau\right) \mathrm{d}\tau$$

where $f(x) = \frac{1-e^{-x}}{x}$ and $\nu(\lambda) = \lambda + a\sigma_r^2 \int_0^T \alpha(\tau)\tau^2 f\left(\nu(\lambda)\tau\right)^2 \mathrm{d}\tau$

Term Structure Equilibrium



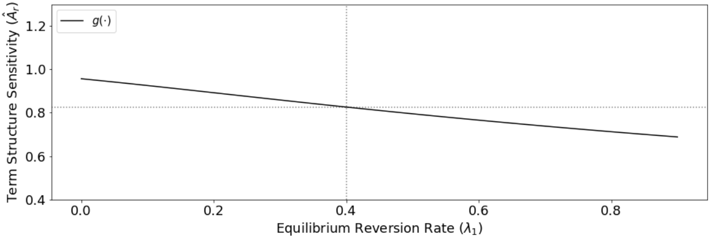
Characterizing $\hat{A}_r$ (Term Structure Sensitivity)

The equilibrium reversion rate λ and the sensitivity of the term structure to the policy rate $\hat{A}_r$ are related as follows:

$$\hat{A}_r = g(\lambda) = \int_0^T \eta(\tau) f\left(\nu(\lambda)\tau\right) \mathrm{d}\tau$$

where $f(x) = \frac{1-e^{-x}}{x}$ and $\nu(\lambda) = \lambda + a\sigma_r^2 \int_0^T \alpha(\tau)\tau^2 f\left(\nu(\lambda)\tau\right)^2 \mathrm{d}\tau$

Term Structure Equilibrium



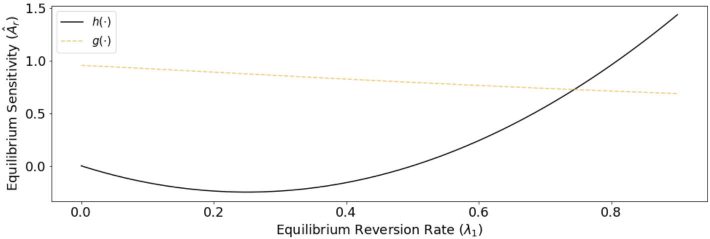
Characterizing $\hat{A}_r$ (Term Structure Sensitivity)

The equilibrium reversion rate λ and the sensitivity of the term structure to the policy rate $\hat{A}_r$ are related as follows:

$$\hat{A}_r = g(\lambda) = \int_0^T \eta(\tau) f\left(\nu(\lambda)\tau\right) \mathrm{d}\tau$$

where $f(x) = \frac{1-e^{-x}}{x}$ and $\nu(\lambda) = \lambda + a\sigma_r^2 \int_0^T \alpha(\tau)\tau^2 f\left(\nu(\lambda)\tau\right)^2 \mathrm{d}\tau$

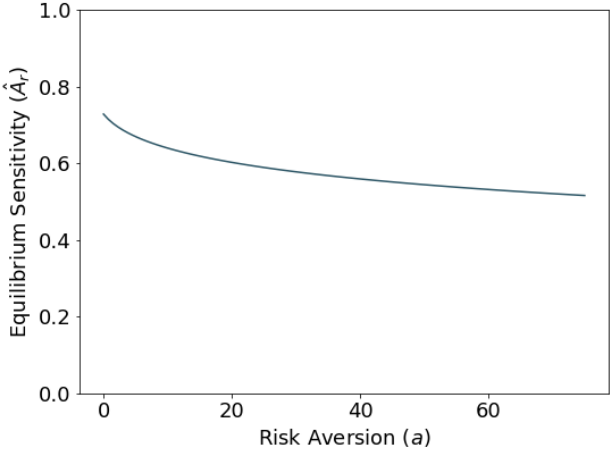
General Equilibrium



Existence and Uniqueness

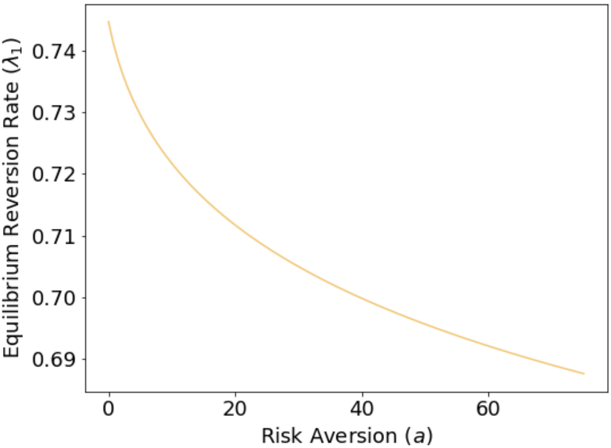
There exists a unique positive eigenvalue of Υ $\lambda_1 > 0$ for which $g(\lambda_1) = h(\lambda_1)$, which fully characterizes the model equilibrium. Further, this implies $0 < \hat{A}_r < 1$.

Conventional Policy and Financial Disruptions



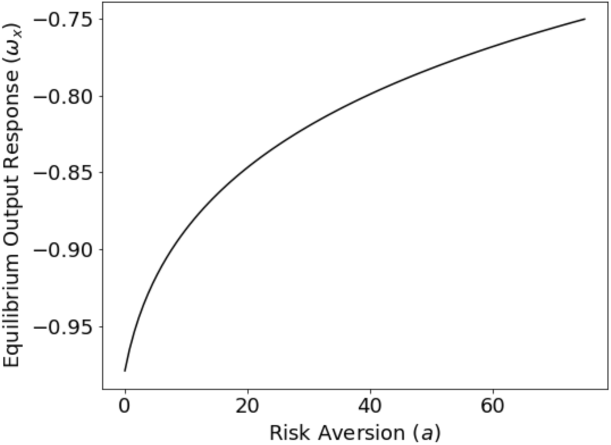
Notes: equilibrium changes in sensitivity to the short rate $\hat{A}_r$ as risk aversion a increases.

Conventional Policy and Financial Disruptions



Notes: equilibrium changes in monetary shock reversion λ_1 as risk aversion a increases.

Conventional Policy and Financial Disruptions



Notes: equilibrium changes in output response ω_x to monetary shocks as risk aversion a increases.

Policy Implications

- More aggressive response to output ϕ_x results
- Higher inertia κ_r results
- Shifts in effective rate weights $\eta(\tau)$ results
- Forward guidance less effective as risk aversion increases details

Modeling LSAPs

- Suppose the central bank directly purchases bonds through open market operations
- Change to the demand shifter in PH demand

$$\tilde{b}_{t,\tau} = \alpha(\tau)\tau(R_{t,\tau} - \beta_{t,\tau})$$

Modeling LSAPs

- Suppose the central bank directly purchases bonds through open market operations
- Change to the demand shifter in PH demand

$$
\begin{aligned}
\tilde{b}_{t,\tau} &= \alpha(\tau)\tau(R_{t,\tau} - \beta_{t,\tau}) \\
\beta_{t,\tau} &= \bar{\beta}(\tau) + \theta(\tau)\beta_t \\
\mathrm{d}\beta_t &= -\kappa_\beta \beta_t \,\mathrm{d}t
\end{aligned}
$$

Modeling LSAPs

- Suppose the central bank directly purchases bonds through open market operations
- Change to the demand shifter in PH demand

$$
\begin{aligned}
\tilde{b}_{t,\tau} &= \alpha(\tau)\tau(R_{t,\tau} - \beta_{t,\tau}) \\
\beta_{t,\tau} &= \bar{\beta}(\tau) + \theta(\tau)\beta_t \\
\mathrm{d}\beta_t &= -\kappa_\beta \beta_t \,\mathrm{d}t
\end{aligned}
$$

Modeling LSAPs

- Suppose the central bank directly purchases bonds through open market operations
- Change to the demand shifter in PH demand

$$
\begin{aligned}
\tilde{b}_{t,\tau} &= \alpha(\tau)\tau(R_{t,\tau} - \beta_{t,\tau}) \\
\beta_{t,\tau} &= \bar{\beta}(\tau) + \theta(\tau)\beta_t \\
\mathrm{d}\beta_t &= -\kappa_\beta \beta_t \,\mathrm{d}t
\end{aligned}
$$

Modeling LSAPs

- Suppose the central bank directly purchases bonds through open market operations
- Change to the demand shifter in PH demand

$$
\begin{aligned}
\tilde{b}_{t,\tau} &= \alpha(\tau)\tau(R_{t,\tau} - \beta_{t,\tau}) \\
\beta_{t,\tau} &= \bar{\beta}(\tau) + \theta(\tau)\beta_t \\
\mathrm{d}\beta_t &= -\kappa_\beta \beta_t \, \mathrm{d}t
\end{aligned}
$$

Modeling LSAPs

- Suppose the central bank directly purchases bonds through open market operations
- Change to the demand shifter in PH demand

$$
\begin{aligned}
\tilde{b}_{t,\tau} &= \alpha(\tau)\tau(R_{t,\tau} - \beta_{t,\tau}) \\
\beta_{t,\tau} &= \bar{\beta}(\tau) + \theta(\tau)\beta_t \\
\mathrm{d}\beta_t &= -\kappa_\beta \beta_t \, \mathrm{d}t
\end{aligned}
$$

- Affine functional form of bond prices

$$
-\log P_{t,\tau} = A_r(\tau) r_t + A_\beta(\tau)\beta_t + C(\tau)
$$

Modeling LSAPs

- Suppose the central bank directly purchases bonds through open market operations
- Change to the demand shifter in PH demand

$$
\begin{aligned}
\tilde{b}_{t,\tau} &= \alpha(\tau)\tau(R_{t,\tau} - \beta_{t,\tau}) \\
\beta_{t,\tau} &= \bar{\beta}(\tau) + \theta(\tau)\beta_t \\
\mathrm{d}\beta_t &= -\kappa_\beta \beta_t \,\mathrm{d}t
\end{aligned}
$$

- Affine functional form of bond prices

$$
-\log P_{t,\tau} = A_r(\tau) r_t + A_\beta(\tau)\beta_t + C(\tau)
$$

Modeling LSAPs

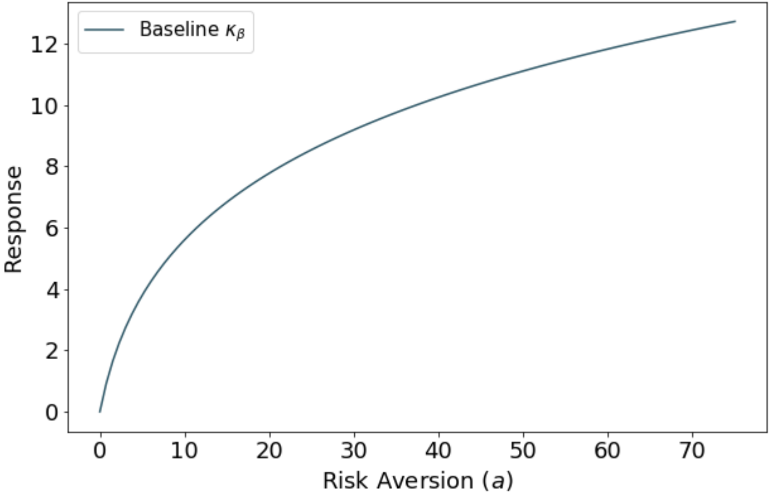
- Suppose the central bank directly purchases bonds through open market operations
- Change to the demand shifter in PH demand

$$
\begin{aligned}
\tilde{b}_{t,\tau} &= \alpha(\tau)\tau(R_{t,\tau} - \beta_{t,\tau}) \\
\beta_{t,\tau} &= \bar{\beta}(\tau) + \theta(\tau)\beta_t \\
\mathrm{d}\beta_t &= -\kappa_\beta \beta_t \, \mathrm{d}t
\end{aligned}
$$

- Affine functional form of bond prices

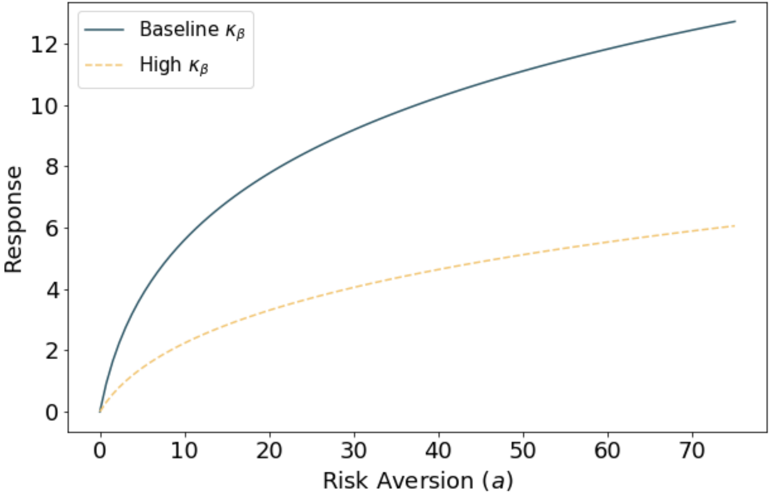
$$
\begin{aligned}
-\log P_{t,\tau} &= A_r(\tau) r_t + A_\beta(\tau)\beta_t + C(\tau) \\
\implies \tilde{r}_t &= \hat{A}_r r_t + \hat{A}_\beta \beta_t + \hat{C}
\end{aligned}
$$

Output Response to QE



Notes: plots of output gap response to a QE shock as risk aversion increases.

Output Response to QE



Notes: plots of output gap response to a QE shock as risk aversion increases.

Generalized Model

- Sticky price model with shocks

$$
\begin{aligned}
\mathrm{d}x_t &= \varsigma^{-1}\left(\tilde{r}_t - \pi_t - \bar{r} - z_{x,t}\right)\mathrm{d}t \\
\mathrm{d}\pi_t &= \left(\rho\pi_t - \delta x_t - z_{\pi,t}\right)\mathrm{d}t \\
\mathrm{d}r_t &= -\kappa_r(r_t - \phi_\pi\pi_t - \phi_x x_t - r^*)\,\mathrm{d}t + \sigma_r\,\mathrm{d}B_{r,t}
\end{aligned}
$$

Generalized Model

- Sticky price model with shocks

$$\begin{aligned}
\mathrm{d}x_t &= \varsigma^{-1}\left(\tilde{r}_t - \pi_t - \bar{r} - z_{x,t}\right)\mathrm{d}t \\
\mathrm{d}\pi_t &= \left(\rho\pi_t - \delta x_t - z_{\pi,t}\right)\mathrm{d}t \\
\mathrm{d}r_t &= -\kappa_r(r_t - \phi_\pi \pi_t - \phi_x x_t - r^*)\,\mathrm{d}t + \sigma_r\,\mathrm{d}B_{r,t}
\end{aligned}$$

Generalized Model

- Sticky price model with shocks

$$\begin{aligned}
\mathrm{d}x_t &= \varsigma^{-1}\left(\tilde{r}_t - \pi_t - \bar{r} - z_{x,t}\right)\mathrm{d}t \\
\mathrm{d}\pi_t &= \left(\rho\pi_t - \delta x_t - z_{\pi,t}\right)\mathrm{d}t \\
\mathrm{d}r_t &= -\kappa_r\left(r_t - \phi_\pi \pi_t - \phi_x x_t - r^*\right)\mathrm{d}t + \sigma_r\,\mathrm{d}B_{r,t}
\end{aligned}$$

- Shocks

$$d z_{i,t} = -\kappa_{z_i} z_{i,t}\,\mathrm{d}t + \sigma_{z_i}\,\mathrm{d}B_{z_i,t}$$

Generalized Model

- Sticky price model with shocks

$$
\begin{aligned}
\mathrm{d}x_t &= \varsigma^{-1}\left(\tilde{r}_t - \pi_t - \bar{r} - z_{x,t}\right)\mathrm{d}t \\
\mathrm{d}\pi_t &= \left(\rho\pi_t - \delta x_t - z_{\pi,t}\right)\mathrm{d}t \\
\mathrm{d}r_t &= -\kappa_r(r_t - \phi_\pi\pi_t - \phi_x x_t - r^*)\,\mathrm{d}t + \sigma_r\,\mathrm{d}B_{r,t}
\end{aligned}
$$

- Shocks

$$
dz_{i,t} = -\kappa_{z_i} z_{i,t}\,\mathrm{d}t + \sigma_{z_i}\,\mathrm{d}B_{z_i,t}
$$

- Demand factors

$$
\begin{aligned}
\beta_{t,\tau} &= \bar{\beta}(\tau) + \sum_k \beta_{k,t}\theta_k(\tau) \\
\mathrm{d}\beta_{k,t} &= -\kappa_{\beta_k}\beta_{k,t}\,\mathrm{d}t + \sigma_{\beta_k}\,\mathrm{d}B_{\beta_k,t}
\end{aligned}
$$

Generalized Model

- Sticky price model with shocks

$$
\begin{aligned}
\mathrm{d}x_t &= \varsigma^{-1}\left(\tilde{r}_t - \pi_t - \bar{r} - z_{x,t}\right)\mathrm{d}t \\
\mathrm{d}\pi_t &= \left(\rho\pi_t - \delta x_t - z_{\pi,t}\right)\mathrm{d}t \\
\mathrm{d}r_t &= -\kappa_r\left(r_t - \phi_\pi\pi_t - \phi_x x_t - r^*\right)\mathrm{d}t + \sigma_r\,\mathrm{d}B_{r,t}
\end{aligned}
$$

- Shocks

$$
dz_{i,t} = -\kappa_{z_i} z_{i,t}\,\mathrm{d}t + \sigma_{z_i}\,\mathrm{d}B_{z_i,t}
$$

- Demand factors

$$
\beta_{t,\tau} = \bar{\beta}(\tau) + \sum_k \beta_{k,t}\theta_k(\tau)
$$

$$
\mathrm{d}\beta_{k,t} = -\kappa_{\beta_k}\beta_{k,t}\,\mathrm{d}t + \sigma_{\beta_k}\,\mathrm{d}B_{\beta_k,t}
$$

Generalized Model

- Sticky price model with shocks

$$\begin{aligned}
\mathrm{d}x_t &= \varsigma^{-1}\left(\tilde{r}_t - \pi_t - \bar{r} - z_{x,t}\right)\mathrm{d}t \\
\mathrm{d}\pi_t &= \left(\rho\pi_t - \delta x_t - z_{\pi,t}\right)\mathrm{d}t \\
\mathrm{d}r_t &= -\kappa_r(r_t - \phi_\pi \pi_t - \phi_x x_t - r^*)\,\mathrm{d}t + \sigma_r\,\mathrm{d}B_{r,t}
\end{aligned}$$

- Shocks

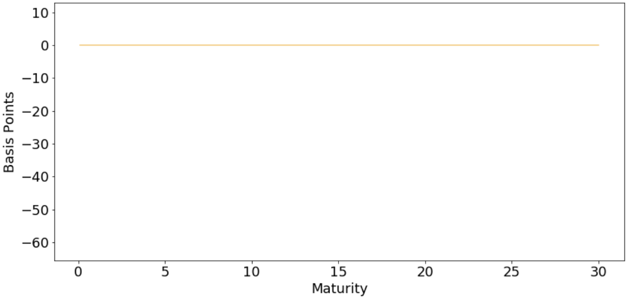
$$dz_{i,t} = -\kappa_{z_i} z_{i,t}\,\mathrm{d}t + \sigma_{z_i}\,\mathrm{d}B_{z_i,t}$$

- Demand factors

$$\beta_{t,\tau} = \bar{\beta}(\tau) + \sum_k \beta_{k,t}\theta_k(\tau)$$

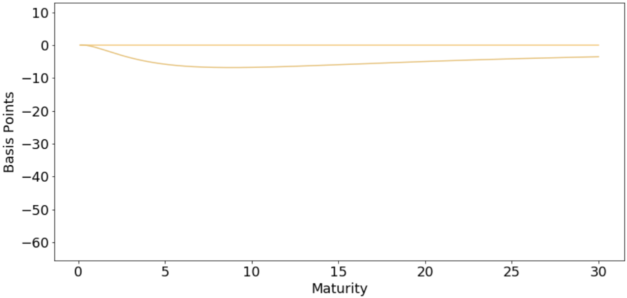
$$\mathrm{d}\beta_{k,t} = -\kappa_{\beta_k}\beta_{k,t}\,\mathrm{d}t + \sigma_{\beta_k}\,\mathrm{d}B_{\beta_k,t}$$

Yield Curve (QE, long end)



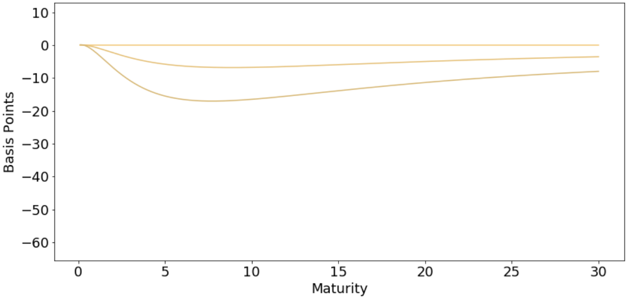
Notes: yield curve response to a "long" QE shock, for different levels of risk aversion *a*. Darker lines correspond to higher levels of risk aversion.

Yield Curve (QE, long end)



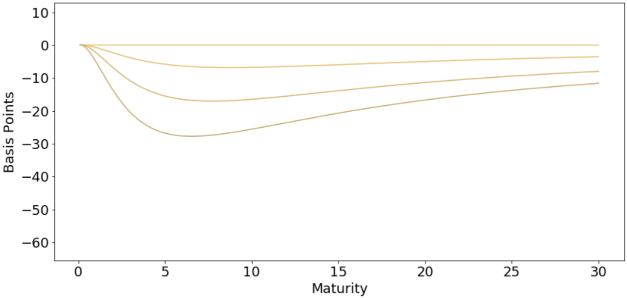
Notes: yield curve response to a "long" QE shock, for different levels of risk aversion *a*. Darker lines correspond to higher levels of risk aversion.

Yield Curve (QE, long end)



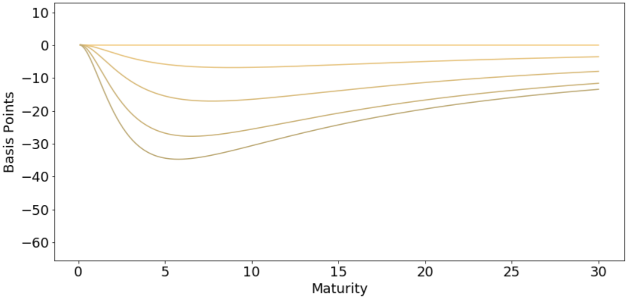
Notes: yield curve response to a "long" QE shock, for different levels of risk aversion *a*. Darker lines correspond to higher levels of risk aversion.

Yield Curve (QE, long end)



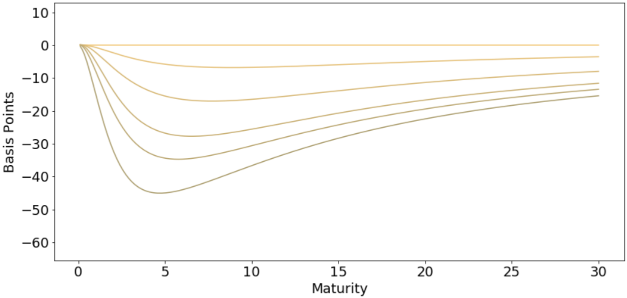
Notes: yield curve response to a "long" QE shock, for different levels of risk aversion *a*. Darker lines correspond to higher levels of risk aversion.

Yield Curve (QE, long end)



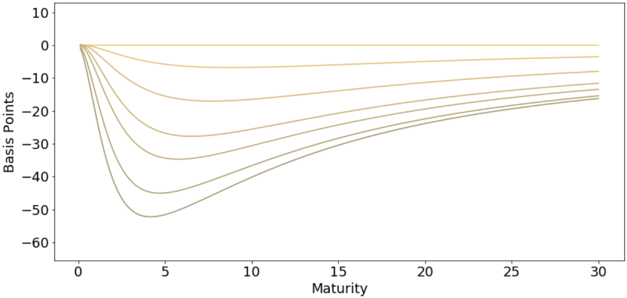
Notes: yield curve response to a "long" QE shock, for different levels of risk aversion *a*. Darker lines correspond to higher levels of risk aversion.

Yield Curve (QE, long end)



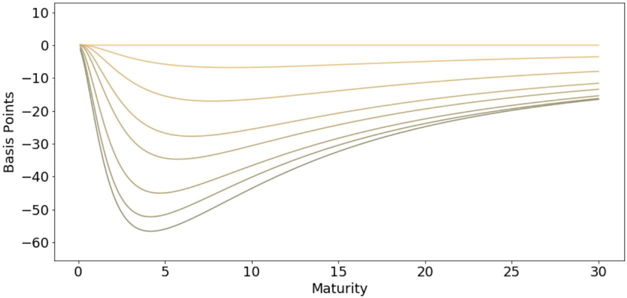
Notes: yield curve response to a "long" QE shock, for different levels of risk aversion *a*. Darker lines correspond to higher levels of risk aversion.

Yield Curve (QE, long end)



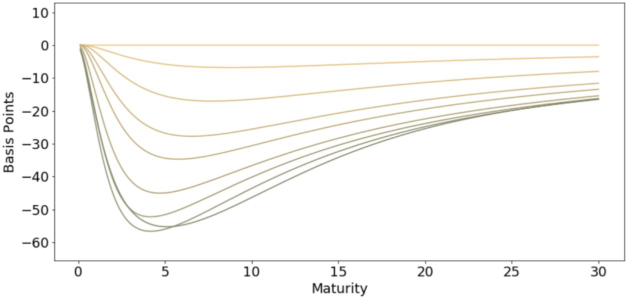
Notes: yield curve response to a "long" QE shock, for different levels of risk aversion *a*. Darker lines correspond to higher levels of risk aversion.

Yield Curve (QE, long end)



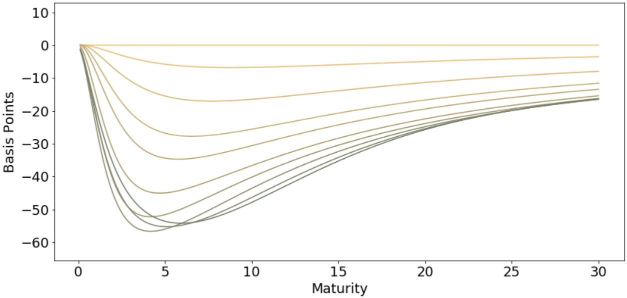
Notes: yield curve response to a "long" QE shock, for different levels of risk aversion *a*. Darker lines correspond to higher levels of risk aversion.

Yield Curve (QE, long end)



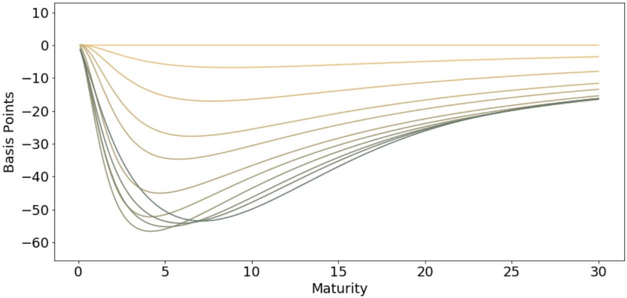
Notes: yield curve response to a "long" QE shock, for different levels of risk aversion *a*. Darker lines correspond to higher levels of risk aversion.

Yield Curve (QE, long end)



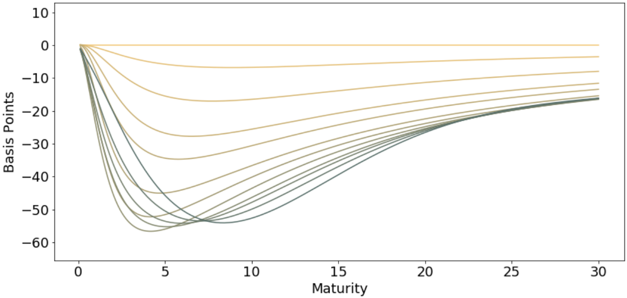
Notes: yield curve response to a "long" QE shock, for different levels of risk aversion *a*. Darker lines correspond to higher levels of risk aversion.

Yield Curve (QE, long end)



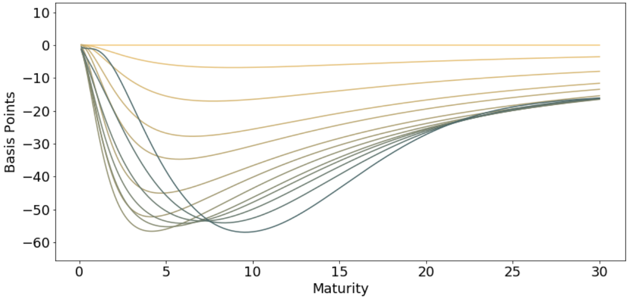
Notes: yield curve response to a "long" QE shock, for different levels of risk aversion *a*. Darker lines correspond to higher levels of risk aversion.

Yield Curve (QE, long end)



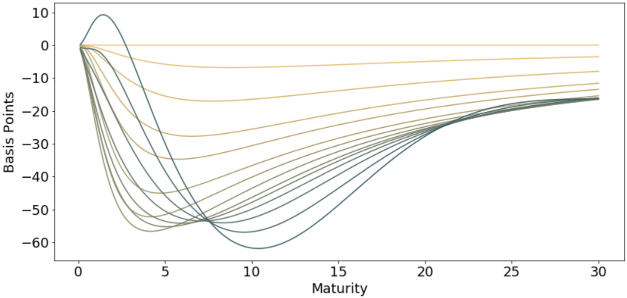
Notes: yield curve response to a "long" QE shock, for different levels of risk aversion *a*. Darker lines correspond to higher levels of risk aversion.

Yield Curve (QE, long end)



Notes: yield curve response to a "long" QE shock, for different levels of risk aversion *a*. Darker lines correspond to higher levels of risk aversion.

Yield Curve (QE, long end)



Notes: yield curve response to a "long" QE shock, for different levels of risk aversion *a*. Darker lines correspond to higher levels of risk aversion.

Stabilizing LSAPs

- Can LSAPs be used to ensure determinacy?
- Endogenous QE purchases:

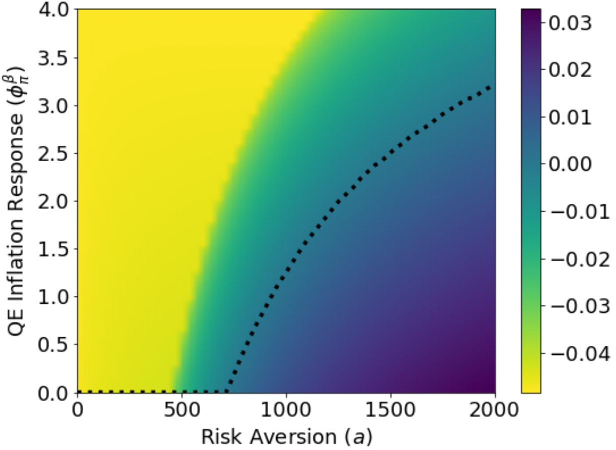
$$\mathrm{d}\beta_t = -\kappa_\beta \left(\beta_t - \phi_\pi^\beta \pi_t\right) \mathrm{d}t$$

Stabilizing LSAPs

- Can LSAPs be used to ensure determinacy?
- Endogenous QE purchases:

$$\mathrm{d}\beta_t = -\kappa_\beta \left(\beta_t - \phi_\pi^\beta \pi_t\right) \mathrm{d}t$$

QE and Determinacy



Notes: determinacy conditions as a function of risk aversion (x-axis) and endogenous response of QE to inflation (y-axis). Darker colors correspond to larger values of the unstable eigenvalue. The dotted black line demarcates the region of determinacy.

Concluding Remarks

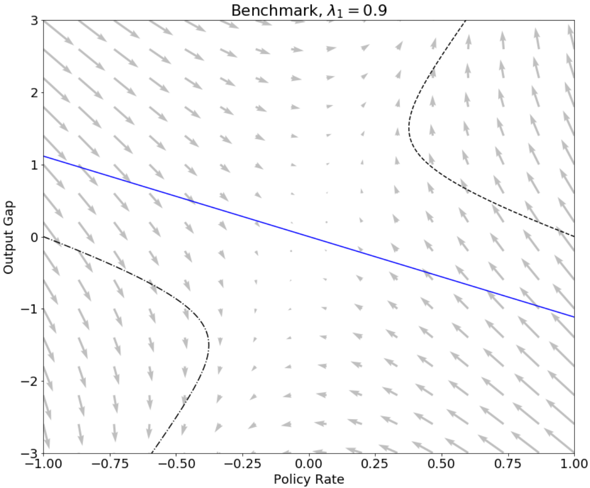
- Develops a unified, parsimonious framework to study conventional and unconventional monetary policies
- Transmission depends crucially on the risk-bearing capacity of financial markets

Concluding Remarks

- Develops a unified, parsimonious framework to study conventional and unconventional monetary policies
- Transmission depends crucially on the risk-bearing capacity of financial markets
- Future work:
  - Macroprudential policies, default risk
  - Monetary policy in open economies
  - Debt management

APPENDIX

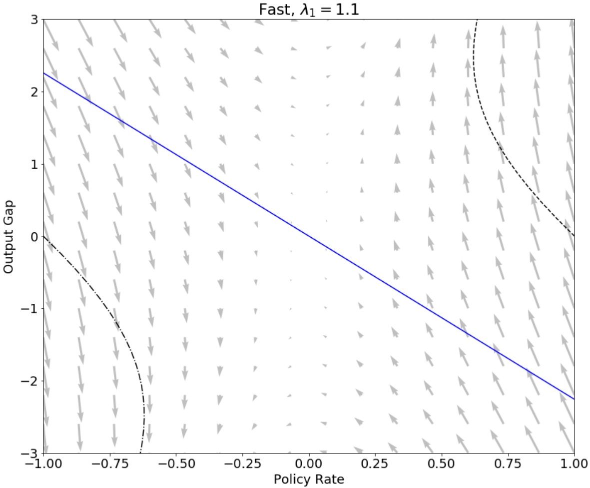
Phase Diagrams



Notes: phase diagrams of the dynamics of output and the policy rate as the equilibrium mean reversion rate of shocks varies.

back

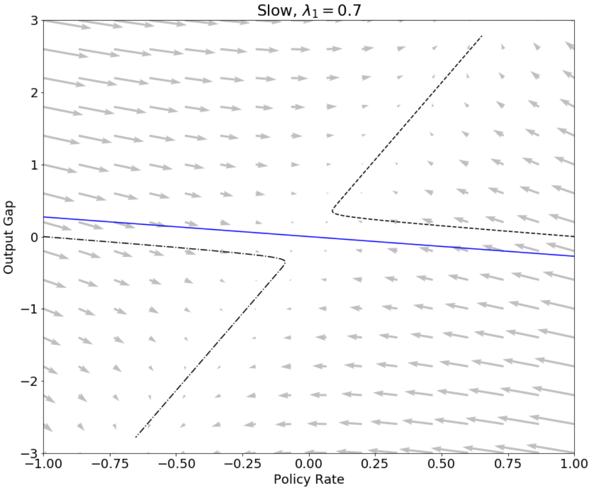
Phase Diagrams



Notes: phase diagrams of the dynamics of output and the policy rate as the equilibrium mean reversion rate of shocks varies.

back

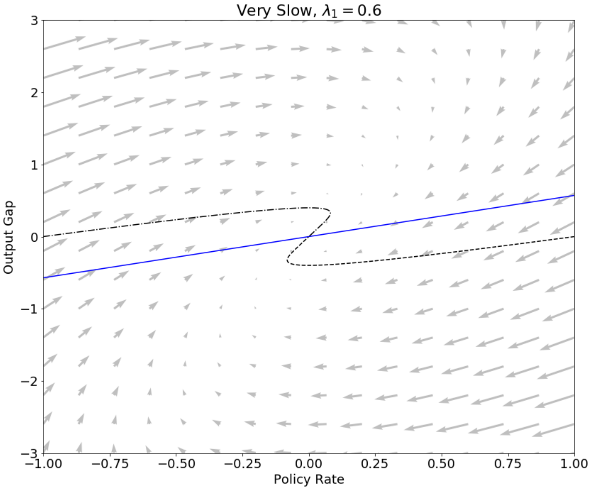
Phase Diagrams



Notes: phase diagrams of the dynamics of output and the policy rate as the equilibrium mean reversion rate of shocks varies.

back

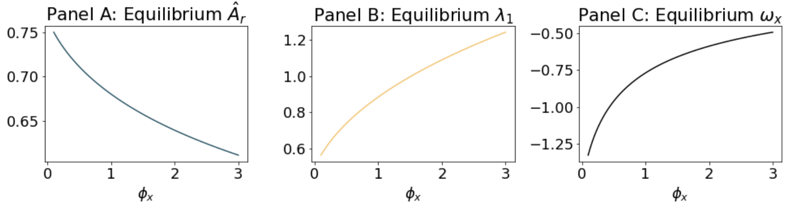
Phase Diagrams



Notes: phase diagrams of the dynamics of output and the policy rate as the equilibrium mean reversion rate of shocks varies.

back

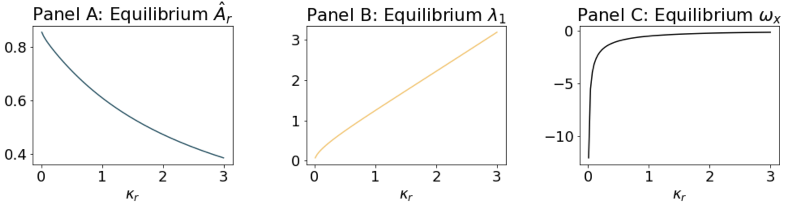
Implications – Conventional Policy



Notes: equilibrium changes in sensitivity to the short rate $\hat{A}_r$ and monetary shock reversion λ_1 as central bank response to output ϕ_x increases.

back

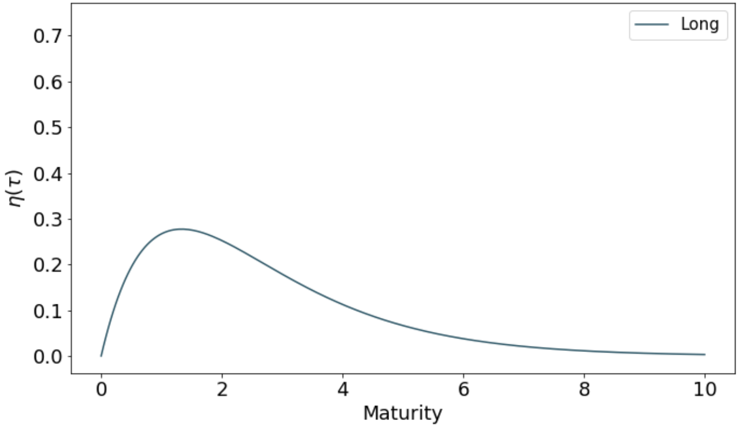
Implications – Conventional Policy



Notes: equilibrium changes in sensitivity to the short rate $\hat{A}_r$ and monetary shock reversion λ_1 as central bank inertia κ_r increases.

back

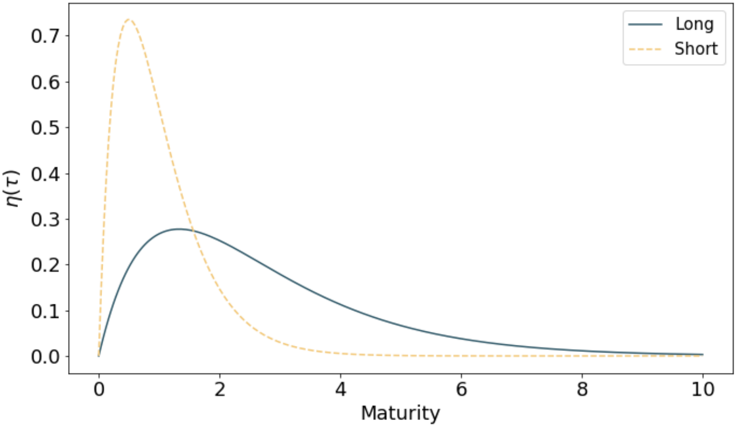
Sensitivity to Long Rates



Notes: different weighting function $\eta(\tau)$ in the determination of the effective borrowing rate $\tilde{r}_t$.

back

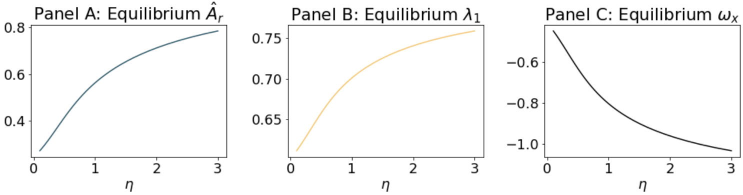
Sensitivity to Long Rates



Notes: different weighting function $\eta(\tau)$ in the determination of the effective borrowing rate $\tilde{r}_t$.

back

Implications – Sensitivity to Long Rates



Notes: equilibrium changes in sensitivity to the short rate $\hat{A}_r$ and monetary shock reversion λ_1 as the weighting function $\eta(\tau)$ shifts towards short-term bonds.

back

Forward Guidance

- Central bank announces a peg: $r_0 = r^\diamond$ and

$$\mathrm{d}r_t = \begin{cases} -\kappa_r^\diamond(r_t - r^\diamond)\,\mathrm{d}t + \sigma_r^\diamond\,\mathrm{d}B_{r,t} & \text{if } 0 < t < t^\diamond \\ -\kappa_r(r_t - \phi_x x_t - r^*)\,\mathrm{d}t + \sigma_r\,\mathrm{d}B_{r,t} & \text{if } t \geq t^\diamond \end{cases}$$

- Affine coefficient functions during peg:

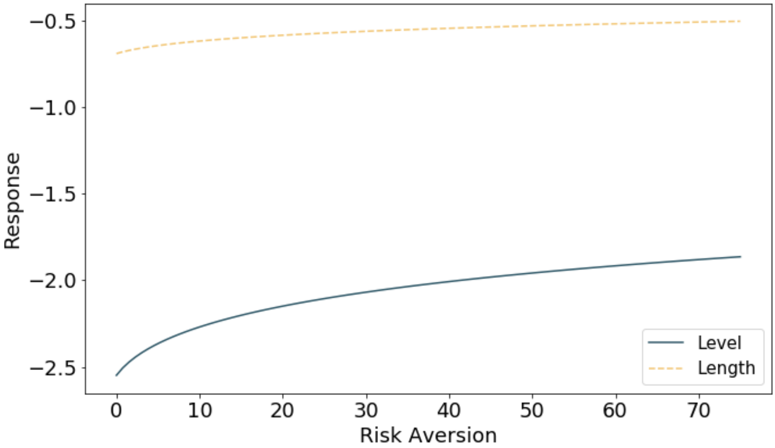
$$-\log P_{t,\tau} = A_r^\diamond(\tau) r_t + C^\diamond(\tau)$$
$$\implies \tilde{r}_t = \hat{A}_r^\diamond r_t + \hat{C}^\diamond$$

- Rational expectations dynamics for output:

$$\frac{\partial x_0}{\partial r^\diamond} = \omega_x - t^\diamond \varsigma^{-1} \hat{A}_r^\diamond\,, \quad \frac{\partial^2 x_0}{\partial r^\diamond \partial t^\diamond} = -\varsigma^{-1} \hat{A}_r^\diamond$$

back

Response to Forward Guidance



Notes: plots of $\frac{\partial x_0}{\partial r^\diamond}$ ("level") and $\frac{\partial^2 x_0}{\partial r^\diamond \partial t^\diamond}$ ("length") as risk aversion increases.

back