A Unified Theory of the Term-Structure and Monetary Stabilization

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Bernanke (2014): "QE works in practice but not in theory"

Blanchard (2016): "Solution is to introduce two interest rates, the policy rate set by the central bank in the LM equation and the rate at which people and firms can borrow, which enters the IS equation, and then to discuss how the financial system determines the spread between the two."

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1. A need for a macro-finance framework addressing Bernanke (2014)
   - Perennial ZLB environment (e.g. Rachel and Smith (2017)) and indispensable LSAPs (QE1, QE2, Covid-19 responses)
   - Need for a deviation from the 'expectation hypothesis'

$\Longrightarrow$ quantity matters!

2. Addressing Blanchard (2016)
   - Term-structure + private bond market needed

This paper

A quantitative (very grand) macroeconomic framework that incorporates

1. **The general equilibrium term-structure of interest rates**
2. **Multiple asset classes (government bonds vs. private bond)**
3. **Endogenous portfolio shares among different kinds of assets**

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5. **Government and central bank's explicit balance sheets**
6. **A micro-founded welfare criterion**

which are necessary for quantitative policy experiments (ex. conventional vs. unconventional monetary policies)

1. **Provide** an efficient way to generate the market segmentation across bonds of different maturities based on Eaton and Kortum (2002)

- Each atomic investor subject to some expectation shock $\sim$ Fréchet: these shocks have a structural meaning (liquidity premium)
- $\exists$Downward-sloping demand curve for each asset (bond of each maturity) $\Longrightarrow$ quantity matters!

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2. **Compare conventional (standard)** monetary policy where
   - Central bank adjusts its balance sheet holding of the shortest-term bond to control the shortest-term yield
   - The shortest-term yield follows the Taylor rule (targeting business cycle)

   with the **unconventional (general)** monetary policy where
   - Central bank adjusts its entire bond portfolio along the yield curve to control yields (yields of which maturities to be controlled: chosen by central bank)
   - Controlled yields follow the Taylor rule (targeting business cycle)
   - Similar to a complete **yield-curve-control (YCC)** policy

Big Findings (Conventional vs. Unconventional)

1. Quantity matters! (confirm results in Krishnamurthy and Vissing-Jorgensen (2012) and Greenwood and Vayanos (2014) in theory)
2. Unconventional monetary policy is very powerful in terms of stabilization in both normal and ZLB periods
3. As a drawback, the economy gets addicted to its power under ZLB regimes

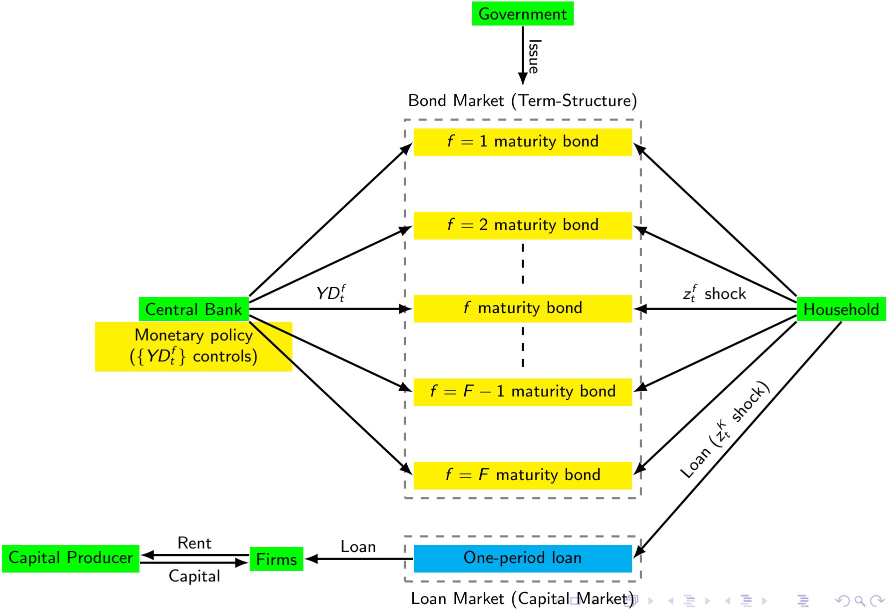
Why?: long term yields$\downarrow$ $\Longrightarrow$ downward pressure on short term yields$\downarrow$ $\Longrightarrow$ ZLB frequency and duration$\uparrow$ $\Longrightarrow$ more reliance on LSAPs

: from the household's endogenous portfolio choices

'ZLB+LSAPs addicted economy'

Literature

The Model


Government
Issue
Bond Market (Term-Structure)
f = 1 maturity bond
f = 2 maturity bond
f maturity bond
f = F − 1 maturity bond
f = F maturity bond
Central Bank
YD_t^f
Monetary policy
({YD_t^f} controls)
Household
z_t^f shock
Loan (z_t^K shock)
Capital Producer
Rent
Capital
Firms
Loan
One-period loan
Loan Market (Capital Market)

The representative household's problem (given B_0):

$$\max_{\{C_{t+j},N_{t+j}\}} \mathbb{E}_t \sum_{j=0}^{\infty} \beta^j \left[\log\left(C_{t+j}\right) - \left(\frac{\eta}{\eta+1}\right) \left(\frac{N_{t+j}}{\bar{N}_{t+j}}\right)^{1+\frac{1}{\eta}} \right]$$

subject to

Loans f-maturity rate   Loan rate

$$C_t + \frac{L_t}{P_t} + \frac{\sum_{f=1}^{F} B_t^{H,f}}{P_t} = \frac{\sum_{f=0}^{F-1} R_t^f \ B_{t-1}^{H,f+1}}{P_t} + \frac{R_t^K \ L_{t-1}}{P_t} + \int_0^1 \frac{W_t(\nu)N_t(\nu)}{P_t} \, d\nu + \frac{\Lambda_t}{P_t}$$

Nominal bond purchase
(f-maturity)

where

- ν: intermediate firm index such that:

$$N_t = \left(\int_0^1 N_t(\nu)^{\frac{\eta+1}{\eta}} \, d\nu \right)^{\frac{\eta}{\eta+1}}$$

- Q_t^f is the nominal price of f-maturity bond with:

$$(\text{Return}) \ R_t^f = \frac{Q_t^f}{Q_{t-1}^{f+1}}, \quad (\text{Yield}) \ YD_t^f = \left(\frac{1}{Q_t^f}\right)^{\frac{1}{f}}$$

Total savings: $S_t = B_t^H + L_t = \sum_{f=1}^{F} B_t^{H,f} + L_t$

Usual bond allocation problem (Ricardian):

$$\max \sum_{f=1}^{F} \mathbb{E}_t \left[Q_{t,t+1} R_{t+1}^{f-1} B_t^{H,f} \right] \quad \text{s.t.} \quad \sum_{f=1}^{F} B_t^{H,f} = B_t^H, \quad B_t^{H,f} \geq 0$$

which gives (in equilibrium):

$$\mathbb{E}_t \left[Q_{t,t+1} R_{t+1}^{f-1} \right] = \mathbb{E}_t \left[Q_{t,t+1} R_{t+1}^{0} \right], \quad \forall f \quad \Longrightarrow \quad \boxed{\mathbb{E}_t[\widehat{R}_{t+1}^{f-1}] = \widehat{R}_{t+1}^{0}}$$

'Expectation hypothesis'
$\Longrightarrow$ quantity does not matter!

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'Expectation hypothesis'

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Our approach:

- Split the household into a family $m \in [0,1]$, each of which decides whether to invest in bonds or loan, subject to expectation shock $\sim$ Fréchet Loan
- If a family m is a bond family, it is split into members $n \in [0,1]$, who decides maturity f to invest in, subject to expectation shock $\sim$ Fréchet Bond

Capital Producer, Firms, and Government

Bond market equilibrium:

$$\underbrace{B_t^{H,f}}_{\text{Depends on monetary policy}} + B_t^{G,f} + \boxed{\underbrace{B_t^{CB,f}}_{\text{Monetary policy}}} = 0, \quad \forall f = 1, \ldots, F$$

- **Central bank**: balance sheet adjustment $\Longleftrightarrow$ monetary policy

Market clearing:

$$C_t = (1 - \zeta_t^G) Y_t + (1 - \delta) K_t - K_{t+1}.$$

Monetary Policy (Conventional vs. Unconventional)

In the standard monetary policy case, central bank sets Taylor-type rules on YD_t^1 (the shortest yield) while not manipulating longer term bonds holdings

- Long-term yields fluctuate endogenously (in response to shocks + changes in short-term rate)

$$R_{t+1}^0 \equiv YD_t^1 = \max\left\{YD_t^{1*},\ \underset{\text{ZLB}}{1}\right\}$$

$$YD_t^{1*} = \overline{YD}^1 \underbrace{\left(\frac{\Pi_t}{\bar{\Pi}}\right)^{\gamma_\pi^1}\left(\frac{Y_t}{\bar{Y}}\right)^{\gamma_y^1}}_{\text{Targeting}} \cdot \exp\left(\underset{\text{MP shock } (f=1)}{\tilde{\varepsilon}_t^{YD^1}}\right)$$

$$\underbrace{\frac{B_t^{CB,f}}{A_t\bar{N}_tP_t} = \frac{\overline{B^{CB,f}}}{A\bar{N}P}}_{\text{Normalized holding of } f>1 \text{ fixed}} \qquad \forall f = 2,\ldots,F$$

In the general monetary policy case, central bank targets all yields along the yield curve, assuming the Taylor-type rule for each maturity yield

- Back out the needed purchases of each maturity $\forall f$ (endogenous)

$$R^0_{t+1} \equiv YD^1_t = \max\left\{ YD^{1*}_t,\ 1 \right\}$$

ZLB

$$YD^{1*}_t = \overline{YD}^1 \underbrace{\left(\frac{\Pi_t}{\bar{\Pi}}\right)^{\gamma_\pi} \left(\frac{Y_t}{\bar{Y}}\right)^{\gamma_y}}_{\text{Targeting}} \cdot \exp\left(\tilde{\varepsilon}^{YD^1}_t \right)$$

MP shock ($f = 1$)

$$YD^{GP,f}_t = \overline{YD}^{GP,f} \left(\frac{\Pi_t}{\bar{\Pi}}\right)^{\gamma^f_\pi} \left(\frac{Y_t}{\bar{Y}}\right)^{\gamma^f_y} \cdot \exp\left(\tilde{\varepsilon}^{YD^f}_t \right), \quad f \geq 2$$

MP shock ($\forall f \geq 2$)

- **Yield-curve-control (YCC)** policy

Steady-state (long-run) analysis

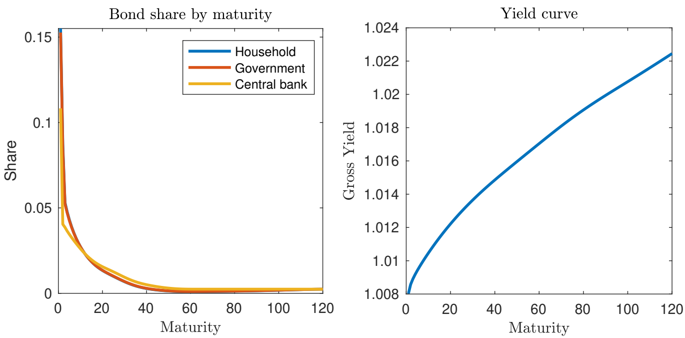

Figure: Steady-state bond portfolios of household, government, and central bank and the resultant yield curve

Calibration

- Given κ_B, κ_S (degrees of market segmentations), calibrate $\underline{\{z^f\}_{f=1}^F}$ (preference for a maturity-f bond) and $\underline{z^K}$ (preference for loan)
  $\Longrightarrow$ match the U.S. average yield curve (before 2007)
- **Result**: $\underline{z^1 = 1}$ is much higher than $\underline{z^f}$ for $f \geq 2$ (safety - liquidity premium)

Government's bond supply effects

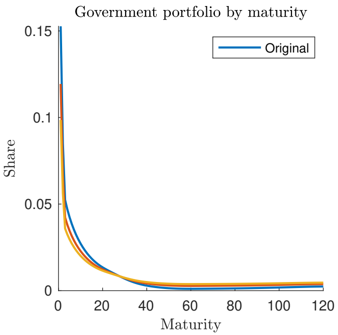

Figure: Government's bond issuance portfolio and yield curve

- Government's supply of f-maturity bond$\uparrow$ $\Rightarrow$ its yield$\uparrow$ (price effect)
- Similar to Krishnamurthy and Vissing-Jorgensen (2012) and Greenwood and Vayanos (2014)

Central bank's bond demand effects

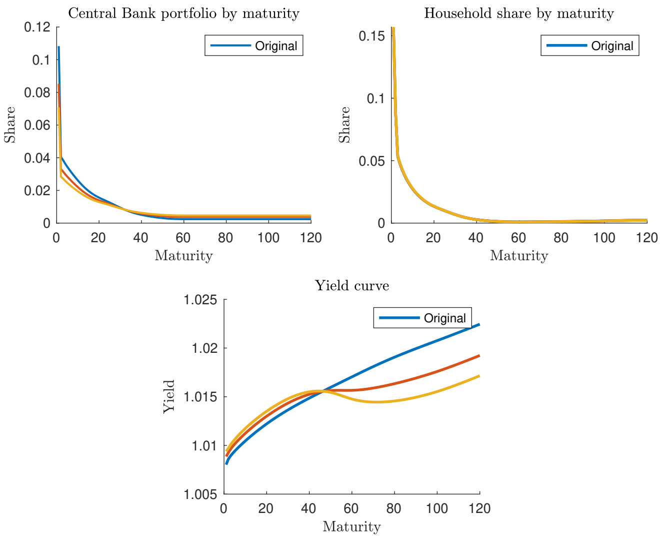

Figure: Central bank's bond demand portfolio and yield curve

- **Segmented** markets ⇒ QE matters

▸▸ Deficit ratio

Short-run analysis (Impulse-responses)

Again...

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Welfare (similar to Coibion et al. (2012))

Trend inflation term

$$\mathbb{E}U_t - \bar{U}^F = \Omega_0 + \Omega_n \mathrm{Var}(\hat{n}_t) + \Omega_\pi \mathrm{Var}(\hat{\pi}_t) + \text{t.i.p} + \text{h.o.t}$$

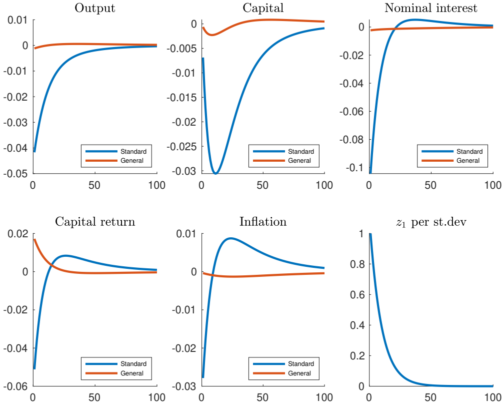

Figure: Impulse response to z_t^1 shock

With standard (conventional) policy

- Short yields↓ ⇒ yields, capital return, and wage↓ ⇒ output↓ (labor supply↓) and inflation↓

With general (unconventional) policy: stabilizing (filling gaps in bond demand)

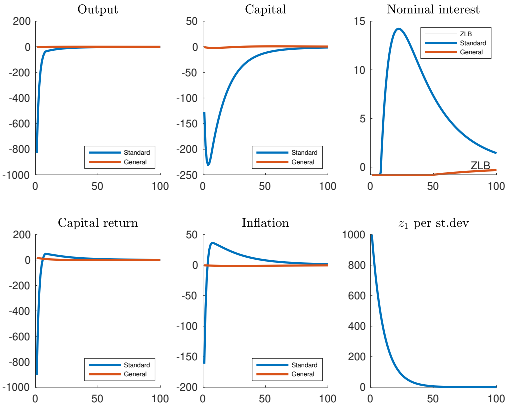

Figure: ZLB impulse response to z_t^1 shock

With general (unconventional) policy: stabilizing (filling gaps in bond demand)

- But duration of ZLB episodes↑

$$\text{ZLB} \Longrightarrow \text{long-term rates}\downarrow \Longrightarrow \text{ZLB possibility}\uparrow$$

ZLB IRF (z_t^K)

 Normal IRF (tax)

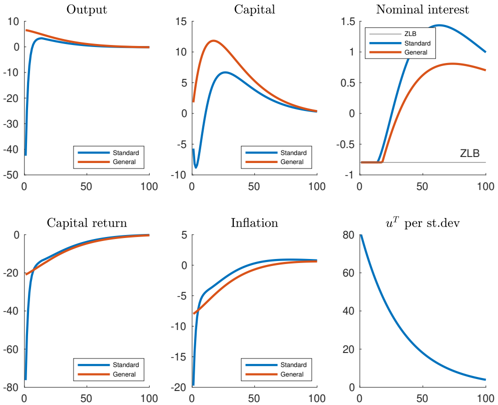

Figure: ZLB impulse response to ϵ_t^T shock

With standard (conventional) policy

- Tax↑ $\Longrightarrow$ bond supply↓ $\Longrightarrow$ ZLB $\Rightarrow$ recessions (Caballero and Farhi (2017))

With general (unconventional) policy: stabilizing (even creating a boom)

- But duration of ZLB episodes↑

We also consider:

- Mixed policy: central bank starts controlling long-term rates only when FFR hits ZLB, thus General (unconventional) only at the ZLB

	Standard Policy	**General Policy**	**Mixed Policy**
Mean ZLB duration	1.6511 quarters	6.3355 quarters	7.9672 quarters
Median ZLB duration	1 quarters	1 quarters	1 quarters
ZLB frequency	8.2556%	21.8222%	21.6%
Welfare	-1.3503%	-0.90471%	-0.90302%

Table: Policy comparisons (ex-ante)

ZLB duration: General $<$ Mixed (Mixed is less stabilizing)

ZLB frequency: General $>$ Mixed (General: long-term rates$\downarrow$ even before ZLB)

Welfare: Standard $<<$ General $<$ Mixed

Thank you very much!
(Appendix)

Key previous works (only a few among many) ⏩ Go back

- The term-structure and macroeconomy: Ang and Piazzesi (2003), Rudebush and Wu (2008), Bekaert et al. (2010)
- Central bank's endogenous balance sheet size as an another form of monetary policy: Gertler and Karadi (2011), Cúrdia and Woodford (2011), Christensen and Krogstrup (2018, 2019), Karadi and Nakov (2021), Sims and Wu (2021)

Our paper: general equilibrium term-structure (without relying on factor models) + balance sheet quantities of government and central bank + yield-curve-control

- Zero lower bound (ZLB) and issuance of safe bonds: Swanson and Williams (2014), Caballero and Farhi (2017), Caballero et al. (2021)
- Welfare criterion with a trend inflation: Coibion et al. (2012)
- Preferred-habitat term-structure (and limited risk-bearing): Vayanos and Vila (2021), Greenwood et al. (2020), Gourinchas et al. (2021)
- Preferred-habitat term-structure in New-Keynesian macroeconomics: Ray (2019), Droste, Gorodnichenko, and Ray (2021)

Our paper: create a quantitative framework providing implications of prior works + new policy implications + novel way to generate market segmentation

Bond family m: a member n has the following expectation shock:

$$\mathbb{E}_{m,n,t}\left[Q_{t,t+1}R_{t+1}^{f-1}\right] = z_{n,t}^{f} \cdot \mathbb{E}_t\left[Q_{t,t+1}R_{t+1}^{f-1}\right], \quad \forall f = 1, \ldots, F$$

with $z_{n,t}^{f}$ follows a Fréchet distribution with location parameter 0, scale parameter z_t^f, and shape parameter κ_B

- Note: $z_t^f = 1$, $\kappa_B \to \infty$, then $\mathbb{E}_{m,n,t} \to \mathbb{E}_t$ (rational expectation)

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Aggregation (Eaton and Kortum (2002))

$$\begin{aligned} \lambda_t^{HB,f} &\equiv \mathbb{P}\left(\mathbb{E}_{m,n,t}\left[Q_{t,t+1}R_{t+1}^{f-1}\right] = \max_j\left\{\mathbb{E}_{m,n,t}\left[Q_{t,t+1}R_{t+1}^{j-1}\right]\right\}\right) \\ &= \left(\frac{z_t^f\mathbb{E}_t\left[Q_{t,t+1}R_{t+1}^{f-1}\right]}{\Phi_t^B}\right)^{\kappa_B} \end{aligned}$$

f-maturity share

- Deviate from expectation hypothesis $\Longrightarrow$ $\exists$downward-sloping demand curve after log-linearization (market segmentation effect)
- Shape parameter κ_B: (inverse of) a degree of bonds market segmentation

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$$= \left(\frac{z_t^f \mathbb{E}_t\left[Q_{t,t+1}R_{t+1}^{f-1}\right]}{\Phi_t^B}\right)^{\kappa_B}$$

f-maturity share

- Deviate from expectation hypothesis $\Longrightarrow$ $\exists$downward-sloping demand curve after log-linearization (market segmentation effect)
- Shape parameter κ_B: (inverse of) a degree of bonds market segmentation

Effective bond market rates

$$R_{t+1}^{HB} = \sum_{f=0}^{F-1} \lambda_t^{HB,f+1} R_{t+1}^{f}$$

Go back

Loan vs. bond decision: a family m solves the following problem

$$\max\ \mathbb{E}_t\left[Q_{t,t+1}R^{HB}_{t+1}B^H_{m,t}\right] + z^K_{m,t}\cdot\mathbb{E}_t\left[Q_{t,t+1}R^K_{t+1}L_{m,t}\right] \quad \text{s.t.}$$

$$B^H_{m,t} + L_{m,t} = S_t, \quad B^H_{m,t} \geq 0, \quad \text{and} \quad L_{m,t} \geq 0$$

with $z^K_{m,t}$ follows a Fréchet distribution with location parameter 0, scale parameter z^K_t, and shape parameter κ_S

Loan vs. bond decision: a family m solves the following problem

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Aggregation (Eaton and Kortum (2002))

$$\lambda^{K}_{t} = \left(\frac{z^{K}_{t}\mathbb{E}_t\left[Q_{t,t+1}R^{K}_{t+1}\right]}{\Phi^{S}_{t}}\right)^{\kappa_S}$$

Loan share

- ∃downward-sloping demand curve after log-linearization (for loan and bonds)
- Shape parameter κ_S: (inverse of) a degree of market segmentation between government bonds vs loan

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Loan share

- $\exists$downward-sloping demand curve after log-linearization (for loan and bonds)
- Shape parameter κ_S: (inverse of) a degree of market segmentation between government bonds vs loan

Effective savings rate: governs intertemporal substitution

$$R^S_t = \left(1 - \lambda^K_{t-1}\right) R^{HB}_t + \lambda^K_{t-1} R^K_t$$

$$= \left(1 - \lambda^K_{t-1}\right) \sum_{f=0}^{F-1} \lambda^{HB,f+1}_{t-1} R^f_t + \lambda^K_{t-1} R^K_t$$

Go back

Capital producer: competitive producer of capital (lend capital to intermediate firms at price P_t^K)

Firms: standard with Cobb-Douglas production (pricing à la Calvo (1983))

- One financial friction: firms need secure loans from the household to borrow capital from the capital producer:

$$\underbrace{L_t(\nu)}_{\text{Loan of firm } \nu} \geq \underbrace{P_t^K K_t(\nu)}_{\text{Capital borrowing expense}} \quad , \forall \nu$$

Government: with the following budget constraint

$$\frac{B_t^G}{P_t} = \frac{R_t^G B_{t-1}^G}{P_t} - \Big[\underbrace{\zeta_t^G}_{\frac{G_t}{Y_t}\text{ (Exogenous)}} + \underbrace{\zeta^F}_{\text{Production subsidy}} - \underbrace{\zeta_t^T}_{\frac{T_t}{Y_t}\text{ (Exogenous)}} \Big] Y_t, \quad R_t^G = \sum_{f=0}^{F-1} \underbrace{\lambda_{t-1}^{G,f+1}}_{\text{(Exogenous)}} R_t^f$$

- **Government**: a natural issuer of the entire bond market

A deficit ratio: comparative statics

Go back

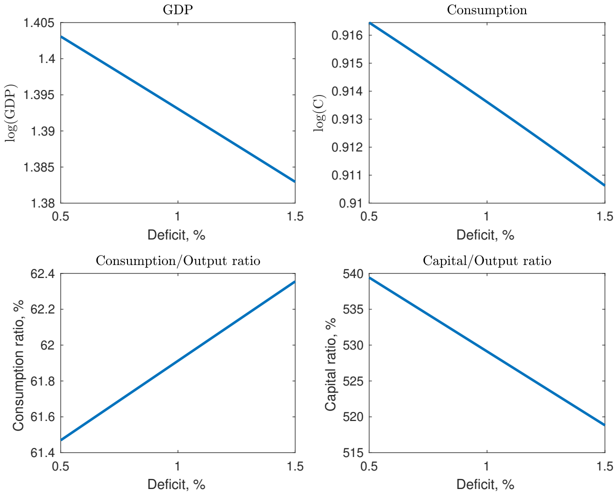
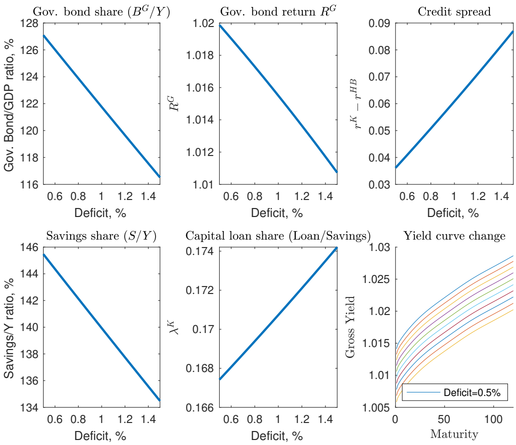


Figure: Variations in a deficit ratio $\zeta_t^G + \zeta^F - \zeta_t^T$

- A higher deficit ratio $\Rightarrow$ depressed economy (for $R^G \downarrow$)

A deficit ratio: comparative statics



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- A higher deficit ratio $\Rightarrow$ depressed economy (for $R^G\downarrow$)
  - An entire yield curve$\downarrow$

Impulse-response to an exogenous tax hike shock

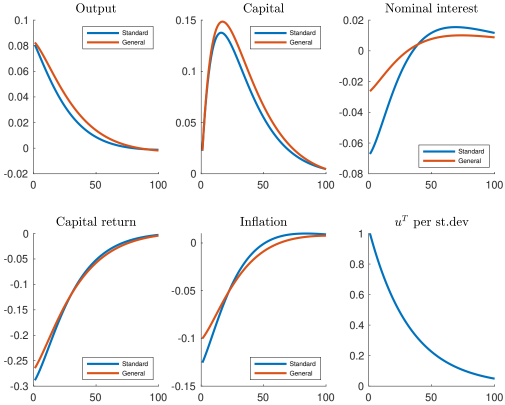

Figure: Impulse response to ϵ_t^T shock

Tax↑ $\Rightarrow$ bond supply↓ $\Rightarrow$ downward pressures on yields, loan rates, and wages

- Monetary response (policy rate↓) $\Longrightarrow$ output↑ (even creating a boom)
- Standard: policy rate↓ more (cannot control long-term yields)

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ZLB impulse response to z_t^K

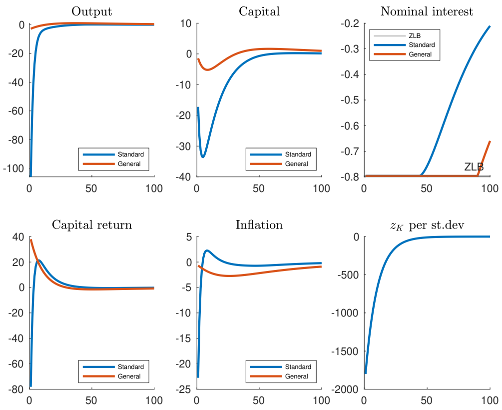

Figure: ZLB impulse response to z_t^K shock

With general (unconventional) policy: stabilizing (filling gaps in bond demand)

- But duration of ZLB episodes↑

ZLB $\Longrightarrow$ long-term rates↓ $\Longrightarrow$ ZLB possibility↑

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