Unwinding Quantitative Easing: State Dependency and Household Heterogeneity

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Motivation

- Monetary policy **normalization**: CB balance sheet reduction
  - Need to create sufficient scope for monetary stimulus against future shocks
- **Lack of evidence** on Quantitative Tightening (QT)
  - Study it theoretically
- **Debate on timing** of unwinding Quantitative Easing (QE)
  - Raising policy rates or unwinding stocks of asset purchases: what comes first?
- Idea of **state dependency**
  - Effectiveness of (unwinding) QE might be linked to the state of the economy / financial markets

This paper

Research focus

- Study macroeconomic **effects of state dependency** of QE/QT
  - Different states through existence of occasionally binding ZLB
- Study **interaction** of state dependency **with household heterogeneity**

Approach

- Tractable **New Keynesian model** with borrowers and savers, two types of bonds, and two monetary policy instruments
  - QE/QT operates via portfolio rebalancing between government bonds
  - Simulations for shocks at, close to, and above the ZLB

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Quantitative Tightening = *active* asset sales to the secondary market

Preview of results

- In or close to liquidity trap, central bank can *minimize* economic costs of MP normalization by raising policy rate prior to unwinding QE
  - Short-term real rate increase depresses aggregate demand
- Asymmetry between (absolute) effects of state-dependent QE and QT
- HH heterogeneity does *not* amplify QE/QT per se, but amplifies asymmetry *when* combined with state dependency
  - Borrowers more exposed through direct (portfolio) and indirect (wage) effects

Related literature

- **Borrowers and Savers – TANK**: Eggertsson and Krugman (2012), Bilbiie, Monacelli, and Perotti (2013)
- **QE in RANK**: Chen, Cúrdia, and Ferrero (2012), Harrison (2012), Gertler and Karadi (2013), Harrison (2017), Harrison, Seneca, and Waldron (2021), Sims and Wu (2021)
- **QE in HANK**: Cui and Sterk (2021), Nisticò and Seccareccia (2022), Sims, Wu, and Zhang (2022a), Sims, Wu, and Zhang (2022b), Wu and Xie (2022)
- **QT**: Wen (2014), Cui and Sterk (2021), Karadi and Nakov (2021), Benigno and Benigno (2022), Sims et al. (2022a), Wei (2022), Airaudo (2023)
- **State dependency**: Haldane, Roberts-Sklar, Wieladek, and Young (2016), Bailey, Bridges, Harrison, Jones, and Mankodi (2020), Vlieghe (2021)

Model

Two-agent New Keynesian DSGE model (**TANK-BS**)

↪ **Households:**

- Two types: **B**orrowers (debt-constrained, impatient) and **S**avers (RA type)
- Consume, work, save/borrow, earn labor and profit income, pay taxes ▸ More
- Access to short- and long-term bonds, s.t. (portfolio) adjustment cost ▸ More
  - → Friction creates a wedge between bond returns
- Portfolio balance channel: QE/QT ⇒ Δ relative asset supply ⇒ Δ relative asset prices and returns ⇒ rebalance

Model structure

- ↪ **Firms:** standard NK setting, nominal frictions (Rotemberg) ▸ More
- ↪ **Government:** issues bonds, levies taxes, redistributive policies ▸ More
- ↪ **Monetary authority:** Two policy tools
  - Policy rate: Conventional interest rate setting (Taylor rule)
  - Asset market operations: Buy/sell fraction of total long-term bonds

▸ Market Clearing ▸ Model ▸ Calibration

Simulations

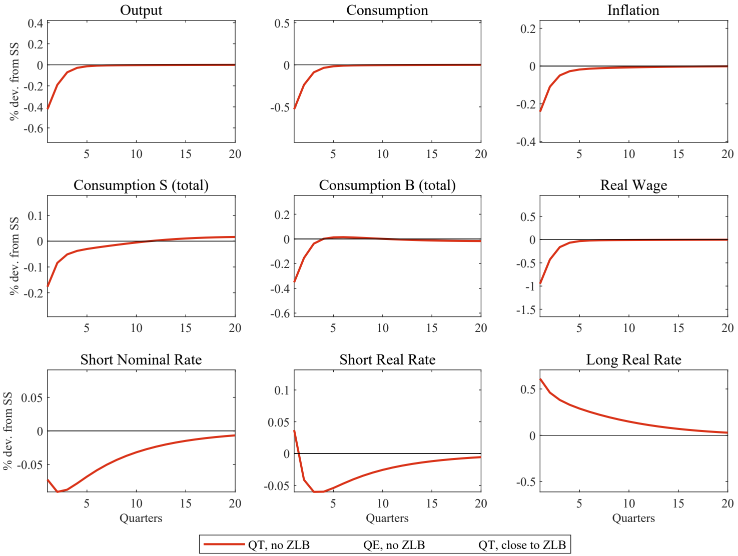
Central bank purchases/sells long-term bonds
worth **1% of (annualized) GDP**

- Target: U.S. evidence on the peak impact of an asset purchase on real output
  $\rightarrow$ Weale and Wieladek (2016): 0.58%

Different states of the economy:

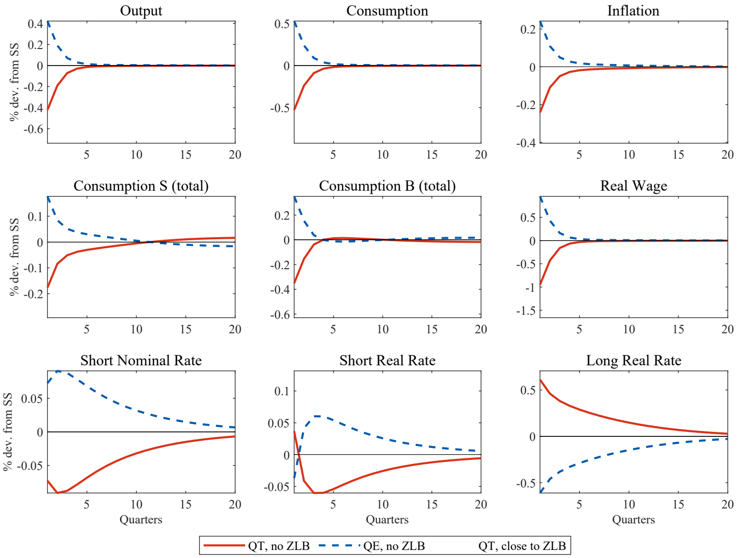
1. Off the ZLB: Nominal interest rate unconstrained
2. Close to ZLB: Contractionary shock pushes economy into liquidity trap

Macroeconomic impact of unwinding QE

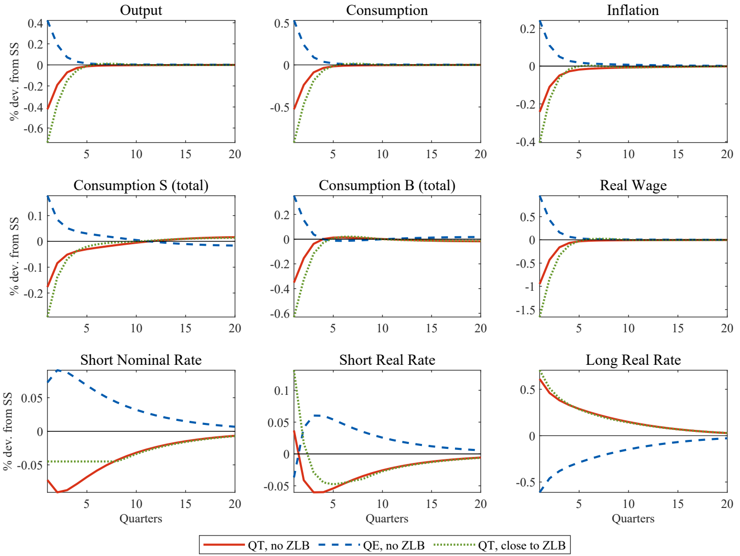


▸ More ▸ HH components ▸ Peg ▸ bgc

Symmetric effects away from the ZLB



What if the economy is close to the ZLB?



▸ More ▸ HH components

Timing of QT

When should central banks unwind?

- First normalize policy rate before starting active asset sales
  - → minimizes the economic costs associated with MP normalization
- To prevent that tightening brings the policy rate back to zero
  - ◦ Timing and pace: avoid “too early”, “too big”, and “too fast”

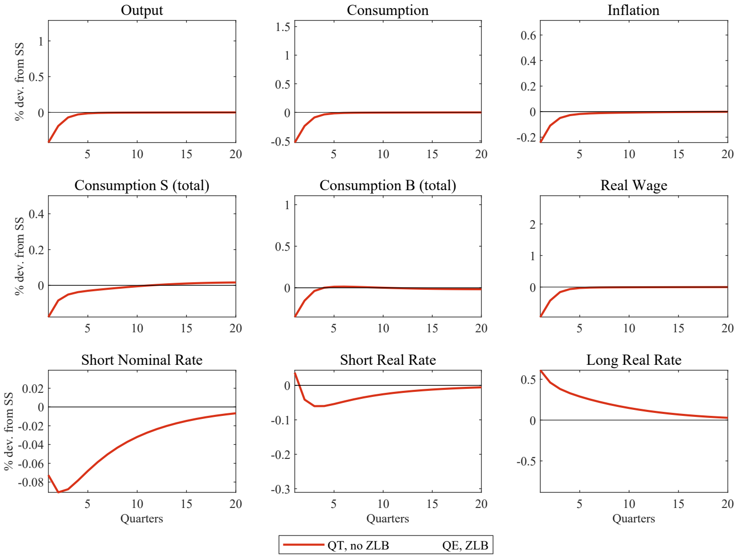
Counterfactual exercise

Compare **QE and QT of <u>similar</u> size** across different states of the economy and **"quantify"** the **asymmetry** coming from the ZLB

Two independent cases:

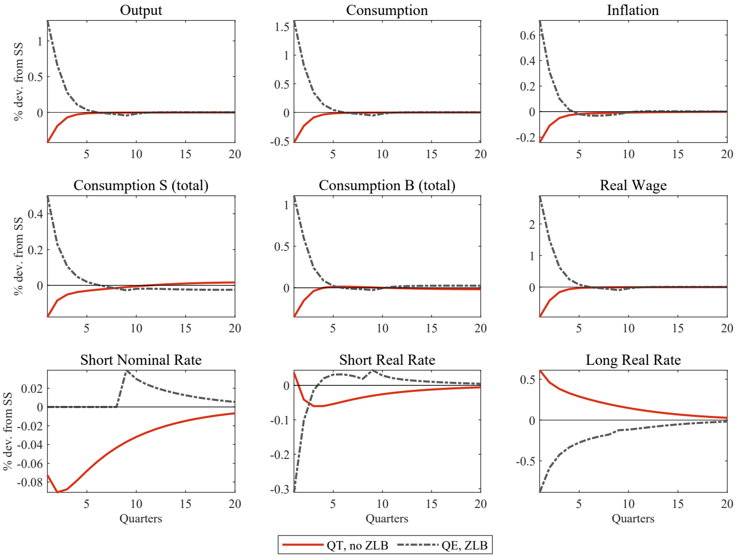
1. QE at the ZLB $\rightarrow$ capturing US-QE1 program
2. QT off the ZLB $\rightarrow$ US-QT1 scenario

State-dependent asset market operations



▸ More ▸ HH components

State-dependent asset market operations



▸ More ▸ HH components

Net impact of QE (at ZLB) vs. QT (off ZLB)

	Output		**Inflation**		**Consumption**	
	QE	QT	QE	QT	QE	QT
RANK	1.05	-0.44	0.70	-0.32	1.32	-0.56
TANK-BS	1.29	-0.42	0.71	-0.24	1.61	-0.53

Multipliers on impact (baseline, in %)

Net impact of QE (at ZLB) vs. QT (off ZLB)

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Multipliers on impact (baseline, in %)

$\hookrightarrow$ Asymmetry at **aggregate** level (*within* model): |QE impact| > |QT impact|

- Macro effects of QE are stronger: 2x (RANK) and 3x (TANK-BS)
- Important role of ZLB (state dependency)

Net impact of QE (at ZLB) vs. QT (off ZLB)

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↪ **Distribution** matters (*across* models): $|\Delta\text{QE impact}| > |\Delta\text{QT impact}|$

- No ZLB: relative contribution of S ↓ but high-MPC B's labor income ↑
- With ZLB: B's labor income ↑↑ (via direct and indirect effects)

▸ More ▸ irfs QT ▸ irfs QE ▸ Robust

Concluding Remarks

Policy implications

- QE as **powerful** monetary policy tool **at the ZLB** ("*temporary* substitute")
  - Constrained households accelerate the stabilization of the economy
- Away from ZLB, asset market operations relatively less influential
  - Different state of the world and "complementarity" with policy rate
  - RANK may provide an adequate approximation of aggregate QE/QT effects
- At least **two scenarios**:
  1. Strong PB channel: large macroeconomic costs or policy rate cut?
  2. Weak PB channel and/or forceful other channels: degree of strength?

Conclusion

Key take-aways

- Built a tractable borrower-saver model to study macroeconomic implications of doing QE and unwinding it
- Highlighted the role of an occasionally binding ZLB in determining an asymmetry between QE and QT (state dependency)
- When economy is close to or at ZLB, central bank should prioritize raising the nominal interest rate before unwinding QE
- Asymmetry is more pronounced with household heterogeneity *on top*

⇒ QT in practice: state of economy, timing, pace, and channels matter

Thank you for your attention

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– Appendix –

Households

Period utility function for $j = \{B, S\}$

$$U\left(c_t^j, N_t^j\right) = \theta_t \left(\frac{(c_t^j)^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}} - \zeta^j \frac{(N_t^j)^{1+\varphi}}{1+\varphi} \right)$$

Savers (S): Maximize lifetime utility subject to real budget constraint

$$c_t^S + b_t^S + b_t^{S,L} = \; r_{t-1}\, b_{t-1}^S + r_t^L\, b_{t-1}^{S,L} + w_t\, N_t^S + \frac{1-\tau^D}{1-\lambda} d_t - t_t - \Psi_t^S - \frac{tr}{1-\lambda}$$

Borrowers (B): Less patient than savers (value future less): $\beta^S > \beta^B$

- Difference in discount factors induces lending from S to B in equilibrium
- Budget and borrowing constraint, with exogenous borrowing limit $\overline{D} \geq 0$

$$c_t^B + b_t^B + b_t^{B,L} \leq \; r_{t-1}\, b_{t-1}^B + r_t^L\, b_{t-1}^{B,L} + w_t\, N_t^B + \frac{\tau^D}{\lambda} d_t - t_t - \Psi_t^B + \frac{tr}{\lambda}$$

$$-b_t^B - b_t^{B,L} \leq \; \overline{D}$$

Households: Optimality conditions

For $j = \{B, S\}$

$$w_t = \zeta^j \left(N_t^j\right)^{\varphi} \left(c_t^j\right)^{\frac{1}{\sigma}}$$

$$1 = \beta^j R_t \mathbb{E}_t \left[\frac{\theta_{t+1}}{\theta_t} \left(\frac{c_{t+1}^j}{c_t^j} \right)^{-\frac{1}{\sigma}} \frac{1}{\Pi_{t+1}} \right] - \frac{\nu\, \delta}{b_t^{j,L}} \left(\delta \frac{b_t^j}{b_t^{j,L}} - 1 \right) + \mathbb{I}^j \psi_t^B$$

$$1 = \beta^j \mathbb{E}_t \left[\frac{\theta_{t+1}}{\theta_t} \left(\frac{c_{t+1}^j}{c_t^j} \right)^{-\frac{1}{\sigma}} \frac{R_{t+1}^L}{\Pi_{t+1}} \right] + \frac{\nu\, \delta\, b_t^j}{\left(b_t^{j,L}\right)^2} \left(\delta \frac{b_t^j}{b_t^{j,L}} - 1 \right) + \mathbb{I}^j \psi_t^B$$

$$0 = \mathbb{I}^j \psi_t^B \left(b_t^B + b_t^{B,L} + \overline{D} \right)$$

where $\mathbb{I}^j$ is an indicator function with values $\mathbb{I}^S = 0$ and $\mathbb{I}^B = 1$, and $\psi_t^B \geq 0$ is the Lagrangian multiplier on the borrowing constraint.

Back

Long-term bonds

- Perpetuities with exponentially declining coupon (Woodford, 2001)
- Bond issued at t pays $k+1$ periods later a nominal coupon χ^k $(k \geq 0)$
- Nominal value of a bond...
  - issued at t: V_t
  - issued k periods ago: $\chi^k V_t$
- Nominal value of long-term bond holdings of $j = \{B, S\}$: $B_t^{j,L} = V_t \tilde{B}_t^{j,L}$
- (Ex-post) nominal return on long-term bonds (Harrison, 2017):

$$R_t^L = \frac{1 + \chi V_t}{V_{t-1}}$$

Back

Portfolio adjustment cost

Costly changes in asset allocation between short-term and long-term bonds (Chen et al., 2012; Harrison, 2017)

$$\Psi_t^j = \frac{\nu}{2} \left(\delta^j \frac{b_t^j}{b_t^{j,L}} - 1 \right)^2$$

with $\delta^j = \frac{b^{j,L}}{b^j}$

- Creates role for QE/QT as a policy instrument
- **Portfolio balance channel**: QE/QT $\Rightarrow$ Δ relative asset supply $\Rightarrow$ Δ relative asset prices and returns $\Rightarrow$ rebalance
  - Evidence (UK): Christensen and Rudebusch (2012); Joyce, Lasaosa, Stevens, and Tong (2011)
- Rationale: imperfect substitutability between assets along yield curve (Andrés, López-Salido, & Nelson, 2004; Vayanos & Vila, 2009, 2021)

Back

Firms

Final goods producer (perfectly competitive)

- Aggregates differentiated intermediate goods (CES production function)

Intermediate goods producers (monopolistically competitive)

- Use technology $y_t(i) = z_t N_t(i)$ to produce varieties i
- Set prices s.t. quadratic adjustment cost (Rotemberg)
- Marginal cost pricing $\Rightarrow$zero-profit steady state
- Phillips curve:

$$\phi_p \left(\Pi_t - 1\right) \Pi_t = \beta \mathbb{E}_t \left[\frac{\theta_{t+1}}{\theta_t} \left(\frac{c^S_{t+1}}{c^S_t} \right)^{-\frac{1}{\sigma}} \phi_p \left(\Pi_{t+1} - 1\right) \Pi_{t+1} \frac{y_{t+1}}{y_t} \right] + \epsilon \, mc_t + \left(1 + \tau^S\right)(1 - \epsilon)$$

▸ Back

Fiscal and monetary policy

Government budget constraint

$$b_t + b_t^L = r_{t-1}\, b_{t-1} + r_t^L\, b_{t-1}^L + \Omega_t + g_t - t_t$$

- Supply of long-term bonds and govt spending: AR(1) process
- Lump-sum taxes: $\frac{t_t}{t} = \left(\frac{t_{t-1}}{t}\right)^{\rho^{\tau,t}} \left(\frac{b_t + b_t^L}{b + b^L}\right)^{\rho^{\tau,b}} \left(\frac{g_t}{g}\right)^{\rho^{\tau,g}}$
- Net purchases of long-term bonds by central bank: $\Omega_t = b_t^{CB,L} - r_t^L\, b_{t-1}^{CB,L}$

Monetary policy instruments

(i) Asset purchases via fraction of total market value of long bonds (∼AR(1)):

$$b_t^{CB,L} = q_t\, b_t^L$$

(ii) Conventional interest rate setting according to Taylor rule

Back

Aggregation and market clearing

- Aggregate consumption and aggregate:

$$c_t = \lambda c_t^H + (1-\lambda) c_t^S$$
$$N_t = \lambda N_t^H + (1-\lambda) N_t^S$$

- Bond markets clearing:

$$b_t = \lambda b_t^B + (1-\lambda) b_t^S$$
$$b_t^L = \underbrace{\lambda b_t^{B,L} + (1-\lambda)\, b_t^{S,L}}_{b_t^{H,L}} + b_t^{CB,L}$$

- Resource constraint:

$$y_t = c_t + g_t + \frac{\phi_p}{2}\left(\Pi_t - 1\right)^2 y_t$$

Back

Model summary (1)

Labor supply	$w_t = \zeta^j (N_t^j)^{\varphi} (c_t^j)^{1/\sigma}, \quad j = \{B, S\}$
Euler short bonds, S	$1 = \beta^S \, \mathbb{E}_t \left[\frac{\theta_{t+1}}{\theta_t} \left(\frac{c_{t+1}^S}{c_t^S} \right)^{-\frac{1}{\sigma}} \frac{R_t}{\Pi_{t+1}} \right] - \frac{\nu \, \delta^S}{b_t^{S,L}} \left(\delta^S \, \frac{b_t^S}{b_t^{S,L}} - 1 \right)$
Euler long bonds, S	$1 = \beta^S \, \mathbb{E}_t \left[\frac{\theta_{t+1}}{\theta_t} \left(\frac{c_{t+1}^S}{c_t^S} \right)^{-\frac{1}{\sigma}} \frac{R_{t+1}^L}{\Pi_{t+1}} \right] + \frac{\nu \, \delta^S \, b_t^S}{\left(b_t^{S,L} \right)^2} \left(\delta^S \, \frac{b_t^S}{b_t^{S,L}} - 1 \right)$
Budget constraint, S	$c_t^S + b_t^S + b_t^{S,L} = r_{t-1} \, b_{t-1}^S + r_t^L \, b_{t-1}^{S,L}$ $+ w_t \, N_t^S + \frac{1-\tau^D}{1-\lambda} d_t - t_t - \Psi_t^S - \frac{tr}{1-\lambda}$
Euler short bonds, B	$1 = \beta^B \, \mathbb{E}_t \left[\frac{\theta_{t+1}}{\theta_t} \left(\frac{c_{t+1}^B}{c_t^B} \right)^{-\frac{1}{\sigma}} \frac{R_t}{\Pi_{t+1}} \right] - \frac{\nu \, \delta^B}{b_t^{B,L}} \left(\delta^B \, \frac{b_t^B}{b_t^{B,L}} - 1 \right) + \psi_t^B$
Euler long bonds, B	$1 = \beta^B \, \mathbb{E}_t \left[\frac{\theta_{t+1}}{\theta_t} \left(\frac{c_{t+1}^B}{c_t^B} \right)^{-\frac{1}{\sigma}} \frac{R_{t+1}^L}{\Pi_{t+1}} \right] + \frac{\nu \, \delta^B \, b_t^B}{\left(b_t^{B,L} \right)^2} \left(\delta^B \, \frac{b_t^B}{b_t^{B,L}} - 1 \right) + \psi_t^B$
Budget constraint, B	$c_t^B + b_t^B + b_t^{B,L} = r_{t-1} \, b_{t-1}^B + r_t^L \, b_{t-1}^{B,L}$ $+ w_t \, N_t^B + \frac{\tau^D}{\lambda} d_t - t_t - \Psi_t^B + \frac{tr}{\lambda}$
Borrowing constraint	$-b_t^B - b_t^{B,L} \leq \overline{D}$
Portfolio adj. cost	$\Psi_t^j = \frac{\nu}{2} \left(\delta^j \, \frac{b_t^j}{b_t^{j,L}} - 1 \right)^2, \, j = \{B, S\}$

▸ Back

Model summary (2)

Labor demand	$w_t = mc_t \frac{y_t}{N_t}$
Production function	$y_t = z_t N_t$
Profits, aggregate	$d_t = \left[1 - mc_t - \frac{\phi_p}{2} (\Pi_t - 1)^2\right] y_t$
Phillips curve	$\phi_p (\Pi_t - 1) \Pi_t = \epsilon\, mc_t + \left(1 + \tau^S\right)(1 - \epsilon) + \beta\, \mathbb{E}_t \left[\frac{\theta_{t+1}}{\theta_t} \left(\frac{c^S_{t+1}}{c^S_t}\right)^{-\frac{1}{\sigma}} \phi_p (\Pi_{t+1} - 1) \Pi_{t+1} \frac{y_{t+1}}{y_t}\right]$
Government budget constraint	$b_t + b^L_t = r_{t-1} b_{t-1} + r^L_t b^L_{t-1} + \Omega_t + g_t - t_t$
Real short-term interest rate	$r_t = \frac{R_t}{\mathbb{E}_t \Pi_{t+1}}$
Nominal long-term bond return	$R^L_t = \frac{1 + \chi V_t}{V_{t-1}}$
Real long-term bond return	$r^L_t = \frac{R^L_t}{\Pi_t}$
Net bond purchases, *CB*	$\Omega_t = b^{CB,L}_t - r^L_t b^{CB,L}_{t-1}$
Value bond purchases, *CB*	$b^{CB,L}_t = q_t b^L_t$

Back

Model summary (3)

Taylor rule	$\log\left(\frac{R_t}{R}\right) = \rho_r \log\left(\frac{R_{t-1}}{R}\right) + (1-\rho_r)\left[\phi_\pi \log\left(\frac{\Pi_t}{\Pi}\right)\right] + \epsilon_t^m$
QE shock rule	$\log\left(\frac{q_t}{q}\right) = \rho_q \log\left(\frac{q_{t-1}}{q}\right) + \epsilon_t^q$
Fiscal rule	$\frac{t_t}{t} = \left(\frac{t_{t-1}}{t}\right)^{\rho^{\tau,t}} \left(\frac{b_t+b_t^L}{b+b^L}\right)^{\rho^{\tau,b}} \left(\frac{g_t}{g}\right)^{\rho^{\tau,g}}$
Aggregate consumption	$c_t = \lambda c_t^H + (1-\lambda)c_t^S$
Aggregate labor	$N_t = \lambda N_t^H + (1-\lambda)N_t^S$
Short-term bonds market clearing	$b_t = \lambda b_t^B + (1-\lambda)b_t^S$
Long-term bonds market clearing	$b_t^L = \left(\lambda b_t^{B,L} + (1-\lambda)\, b_t^{S,L}\right) + b_t^{CB,L}$
Resource constraint	$y_t = c_t + g_t + \frac{\phi_p}{2}\left(\Pi_t - 1\right)^2 y_t$
Other shock rules	$\log\left(\frac{x_t}{x}\right) = \rho_x \log\left(\frac{x_{t-1}}{x}\right) + \epsilon_t^x, \quad x = \{g, b^L, z, \theta\}$

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Parameter	Description	Value
λ	Proportion of borrowers	0.35
σ	Intertemporal elasticity of substitution	1
$1/\varphi$	Frisch elasticity of labor supply	1
β^S	Discount factor, saver	0.99 | 0.999
β^B	Discount factor, borrower	0.95
$\bar{D}$	Borrowing limit	0.5
ϵ	Elasticity of substitution between goods	6
ϕ_p	Rotemberg price adjustment cost	42.68
ϕ_π	Taylor rule coefficient on inflation	1.5
χ	Long-term bond coupon decay rate	0.975
ν	Portfolio share adjustment cost	0.1
b^L/b	Steady-state ratio of long-term to short-term bonds	0.3
q	Steady-state CB long-term bond holdings	0.25
g/y	Steady-state government-spending-to-GDP ratio	0.2
$(b+b^L)/y$	Steady-state total-debt-to-GDP ratio	0.6
$\rho^{\tau,t}$	Tax smoothing in fiscal rule	0.7
$\rho^{\tau,b}$	Tax response to total debt	0.33
$\rho^{\tau,g}$	Tax response to government spending	0.1
ρ_q	QE smoothing	0.9

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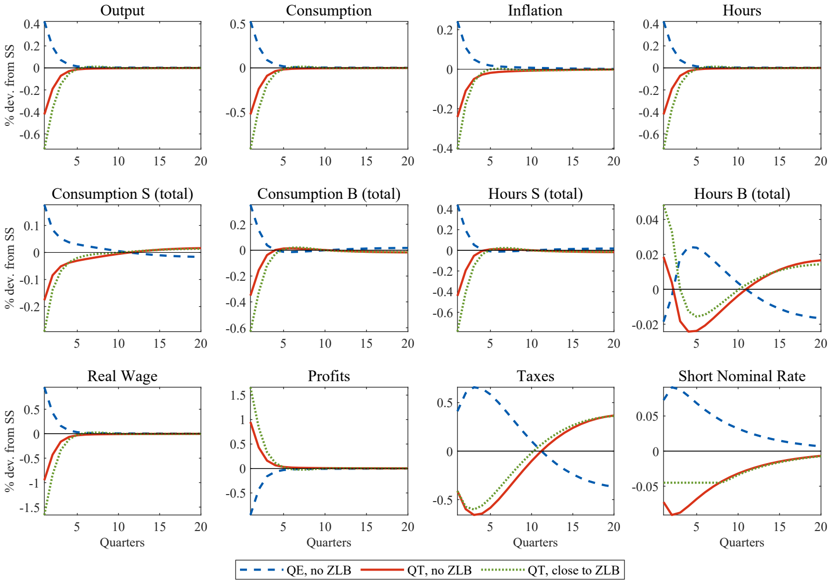
QE/QT shock and QT shock near the ZLB (1/2)



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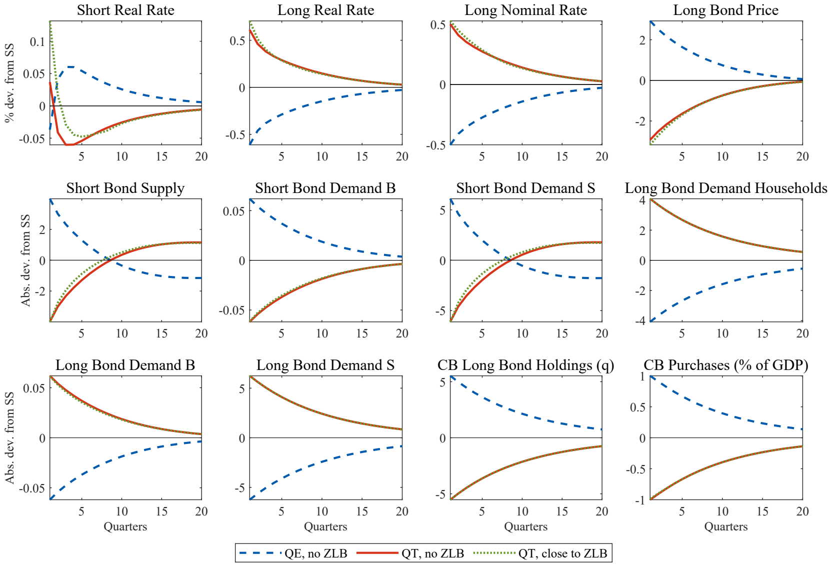
QE/QT shock and QT shock near the ZLB (2/2)



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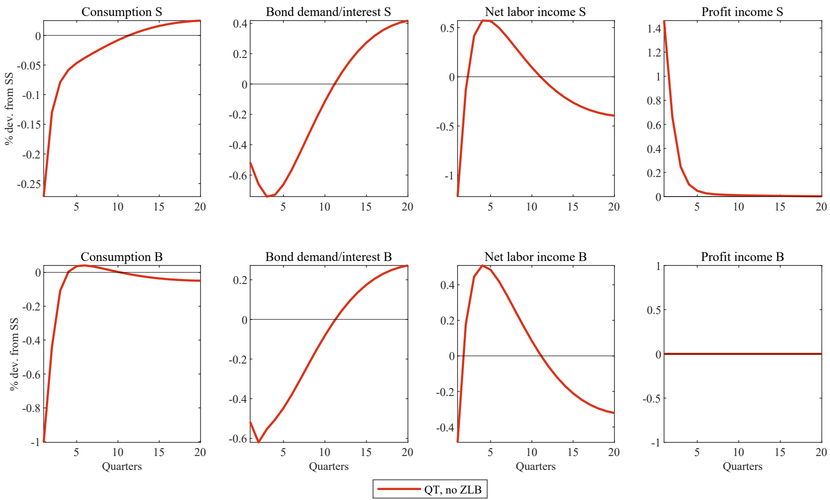
HHs' budget components: QE/QT shock and QT shock near the ZLB



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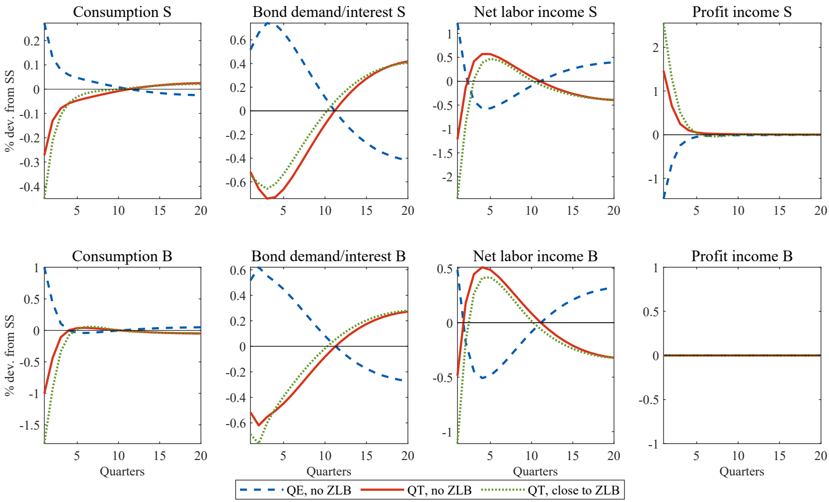
HHs' budget components: QE/QT shock and QT shock near the ZLB



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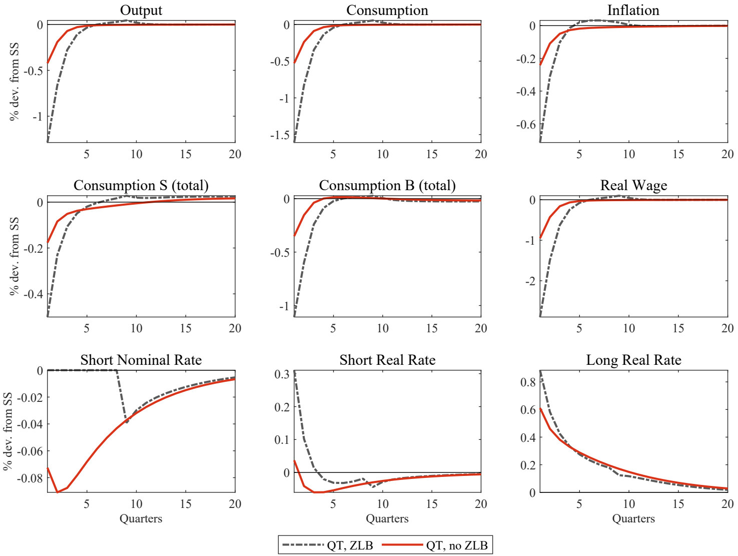
QT peg vs Taylor rule



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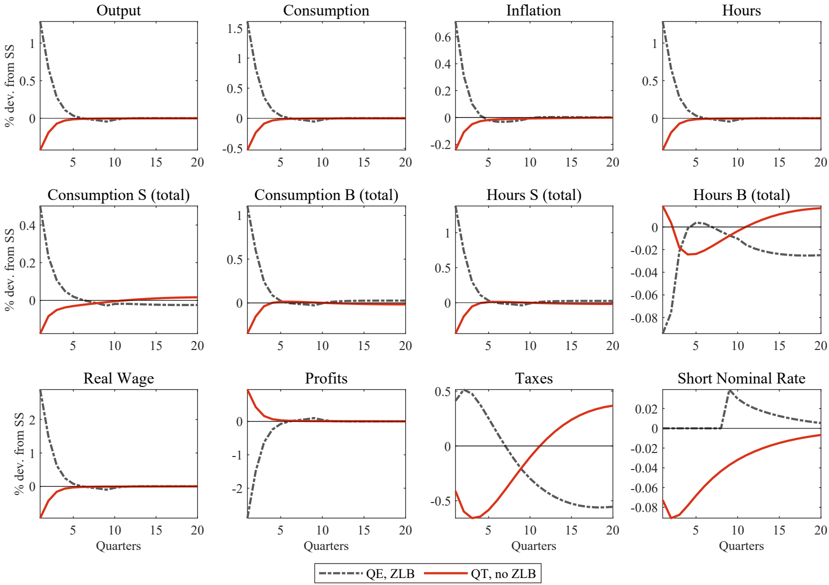
QE shock ZLB and QT shock off the ZLB (1/2)



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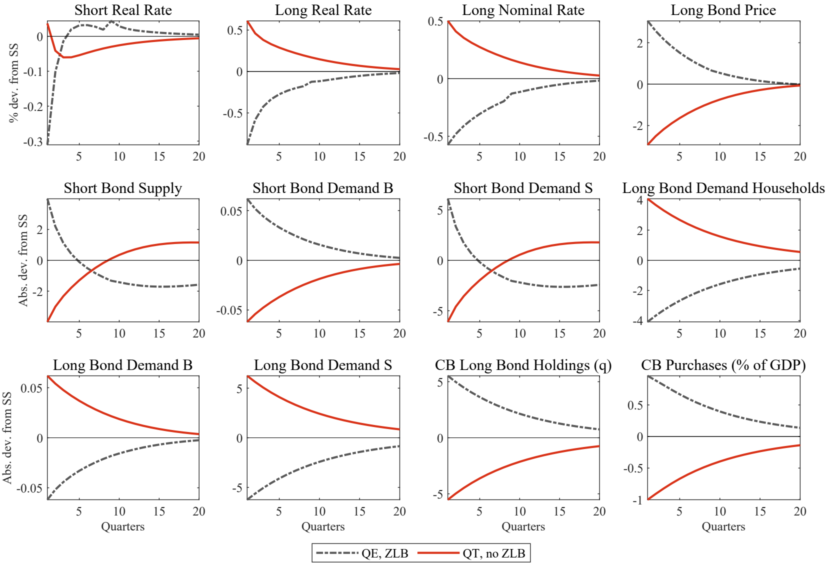
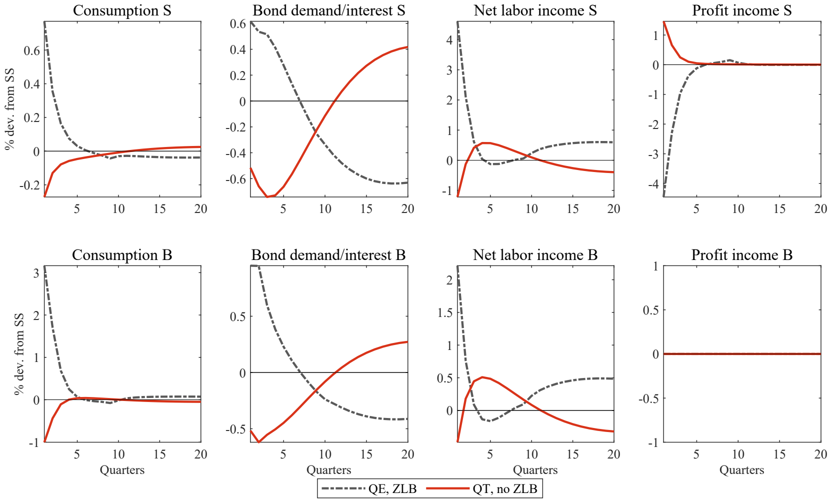
QE shock at ZLB and QT shock off the ZLB (2/2)



HHs' budget components: QE shock at ZLB and QT shock off the ZLB



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Multipliers: on impact and cumulated

	Output		Inflation		Consumption	
	QE	QT	QE	QT	QE	QT
RANK (impact)	1.05	-0.44	0.70	-0.32	1.32	-0.56
TANK-BS (impact)	1.29	-0.42	0.71	-0.24	1.61	-0.53
RANK (cumulative)	2.18	-0.86	1.32	-0.67	2.72	-1.08
TANK-BS (cumulative)	2.32	-0.71	1.14	-0.43	2.90	-0.89

Multipliers on impact and cumulated over four periods (in %)

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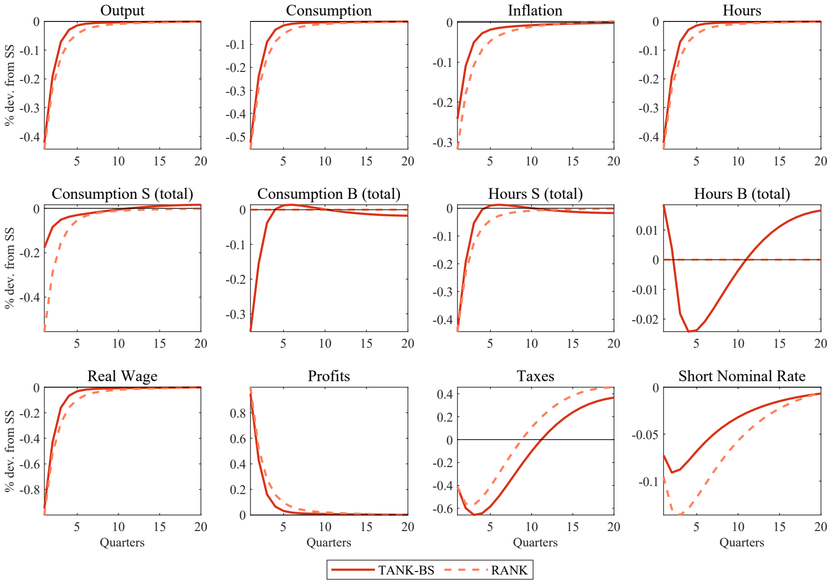
QT shock off the ZLB: RANK vs. TANK-BS (1/2)



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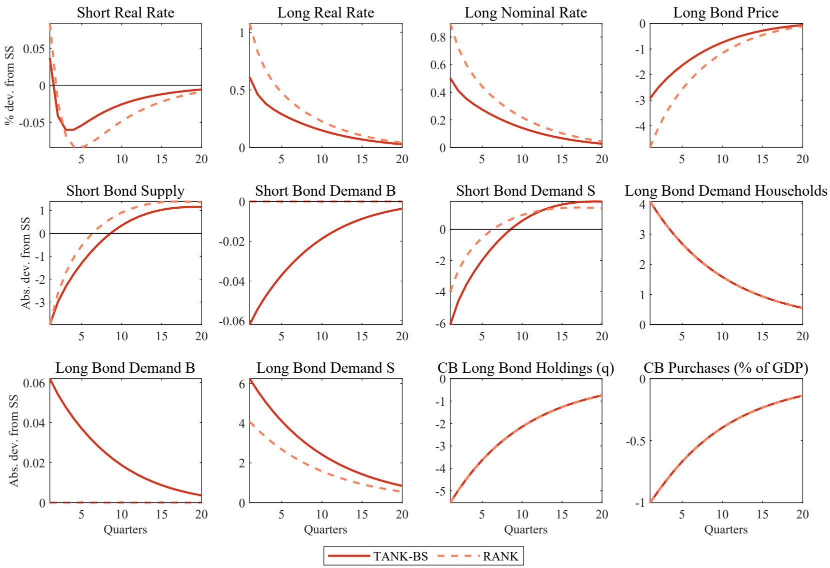
QT shock off the ZLB: RANK vs. TANK-BS (2/2)



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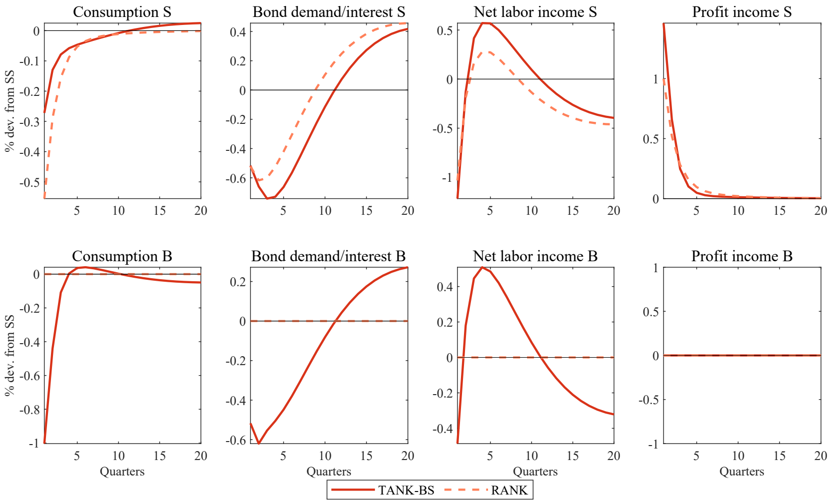
HHs' budget components: QT shock off the ZLB



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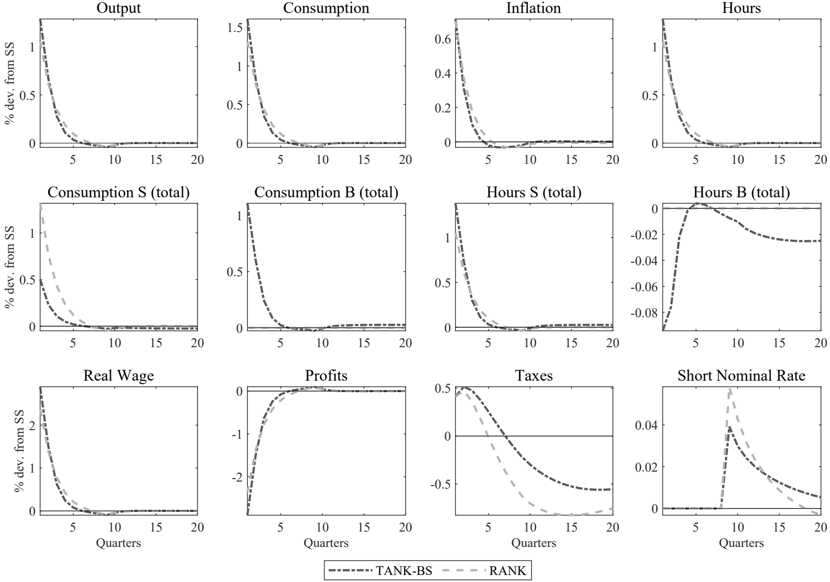
QE shock at the ZLB: RANK vs. TANK-BS (1/2)



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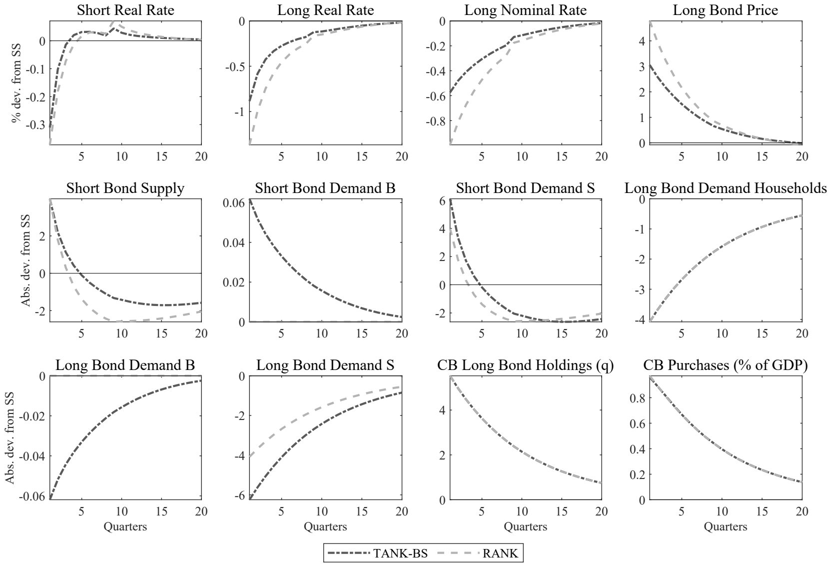
QE shock at the ZLB: RANK vs. TANK-BS (2/2)



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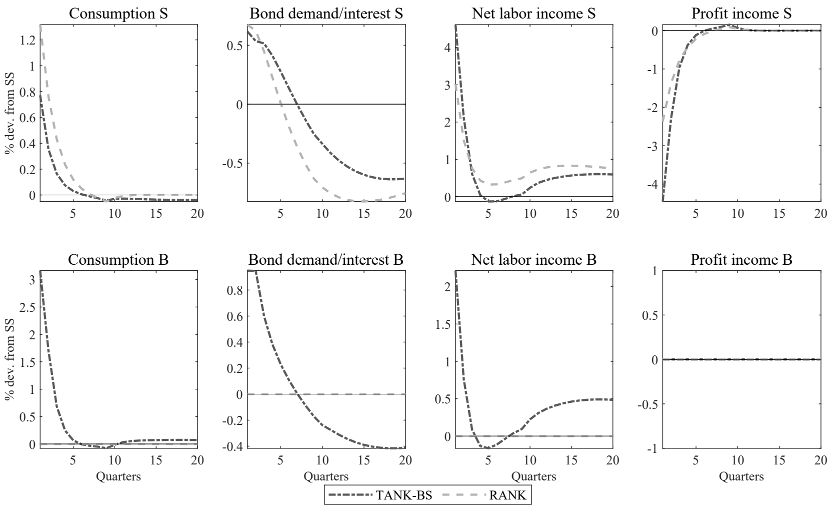
HHs' budget components: QE shock at the ZLB: RANK vs. TANK-BS



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Robustness: Multipliers on impact of a QE or QT shock

	Output		Inflation		Consumption	
	QE	QT	QE	QT	QE	QT
TANK-BS						
Baseline (τ^D=0, ν=0.05)	1.29	-0.42	0.71	-0.24	1.61	-0.53
$\tau^D = 0.2$	0.81	-0.31	0.52	-0.20	1.02	-0.38
$\tau^D = 0.35$	0.63	-0.26	0.43	-0.18	0.79	-0.32
$\nu = 0.04$	1.05	-0.34	0.58	-0.19	1.31	-0.43
$\nu = 0.06$	1.51	-0.50	0.84	-0.29	1.89	-0.63
RANK						
Baseline (τ^D=0, ν=0.05)	1.05	-0.44	0.70	-0.32	1.32	-0.56
$\tau^D = 0.2$	0.88	-0.39	0.62	-0.29	1.10	-0.49
$\tau^D = 0.35$	0.78	-0.36	0.57	-0.28	0.98	-0.45
$\nu = 0.04$	0.90	-0.36	0.60	-0.26	1.12	-0.45
$\nu = 0.06$	1.20	-0.53	0.79	-0.37	1.50	-0.66

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