The Power of Quantitative Easing: Liquidity Channel vs Interest Rate Channel

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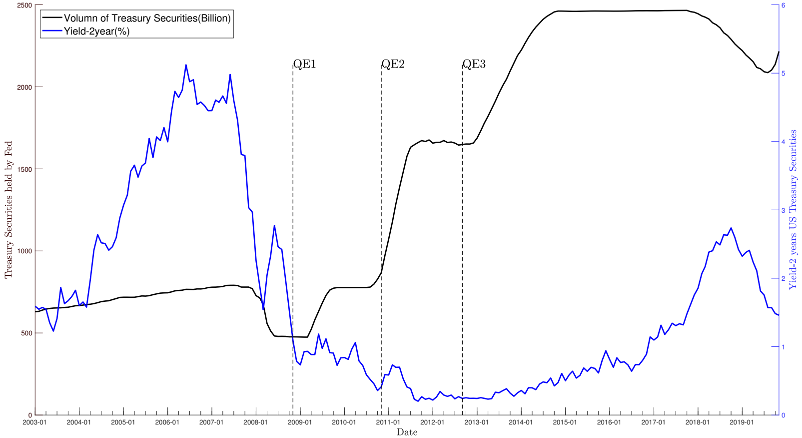
Outline

Quantitative Easing after The Great Recession

- Balance sheet expansion and Term Yield twisting



Why Quantitative Easing works?

- Sign/Information Effect
  - Change Expectation about short-term interest rate $\rightarrow$ Euler Equation/SDF
  - Signal from central bank to market to reveal unobservable economic foundation $\rightarrow$ Anchoring belief
- Portfolio Rebalance Effect (Bernanke 2020AER)
  - Imperfect substitution and Balance Sheet twisting $\rightarrow$ Investment $\uparrow$ (Gertler and Karadi 2011JME) and (Vayanos and Vila 2021ETCA)|

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Liquidity Channel & Interest Rate Channel

- Quantitative Easing after Great Recession Mechanism

QE Policy

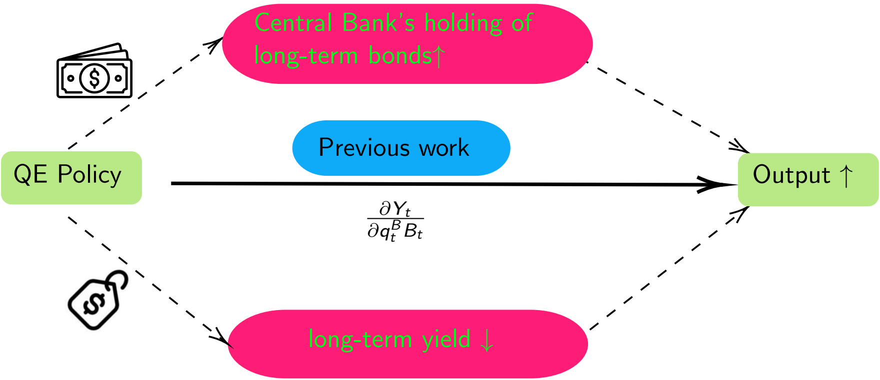
Previous work

$$\text{QE Policy} \xrightarrow[\frac{\partial Y_t}{\partial q_t^B B_t}]{\text{Previous work}} \text{Output} \uparrow$$

Output ↑

Liquidity Channel & Interest Rate Channel

- Quantitative Easing after Great Recession Mechanism



Liquidity Channel & Interest Rate Channel

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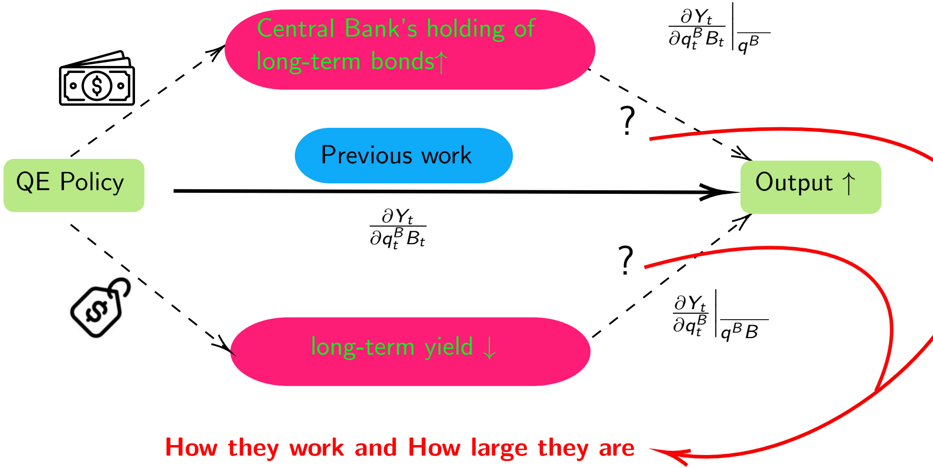


How they work

- Supply Side

How they work

- Supply Side

Output ↑

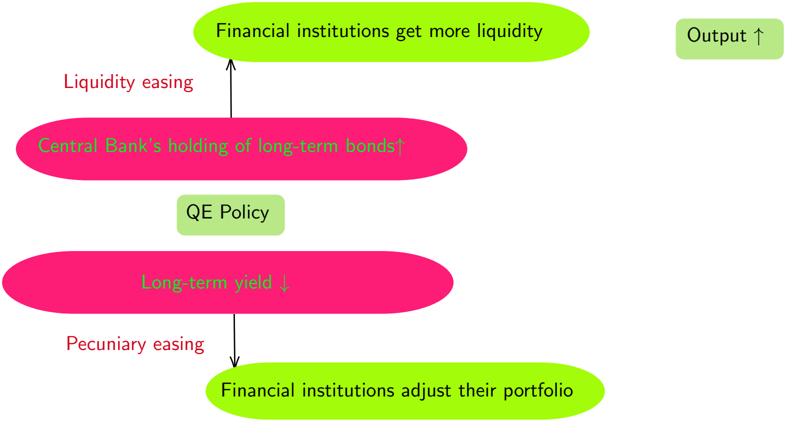
Central Bank's holding of long-term bonds↑

QE Policy

Long-term yield ↓

How they work

- Supply Side



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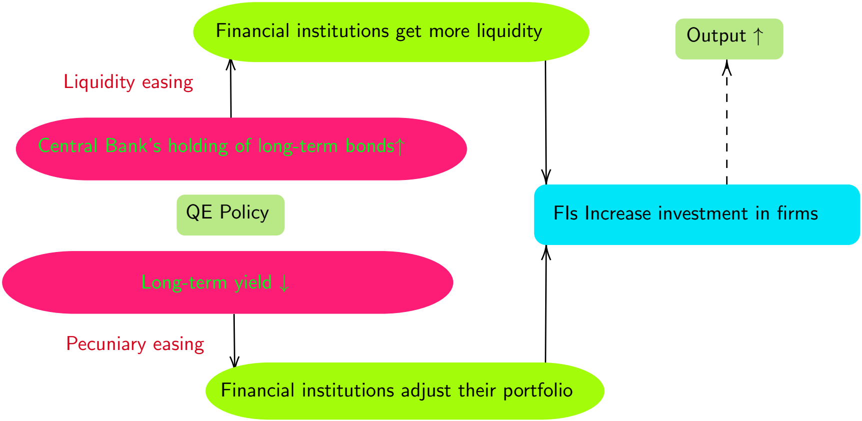

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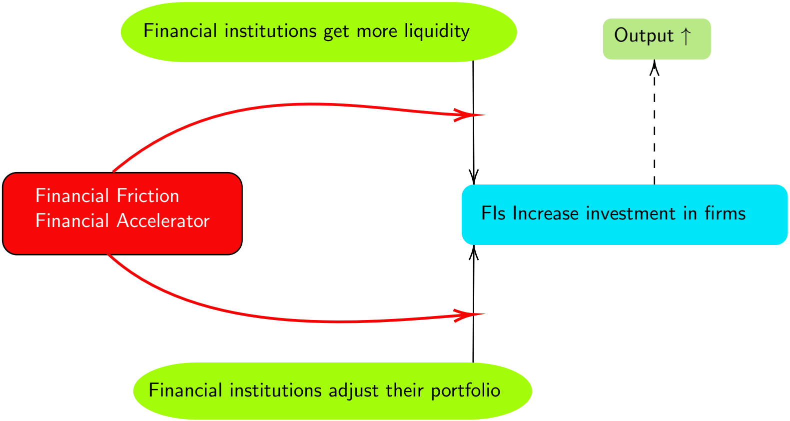


How they work

- Demand Side

How they work

- Demand Side

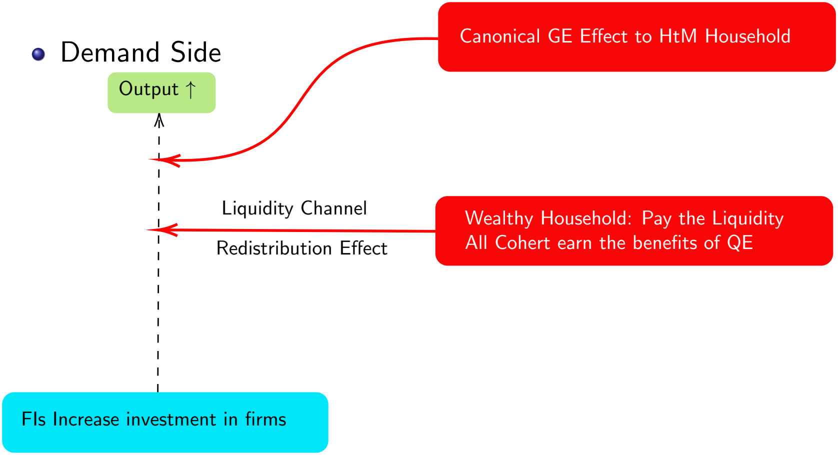
Output ↑

Canonical GE Effect to HtM Household

FIs Increase investment in firms

How they work

- Demand Side



How they work

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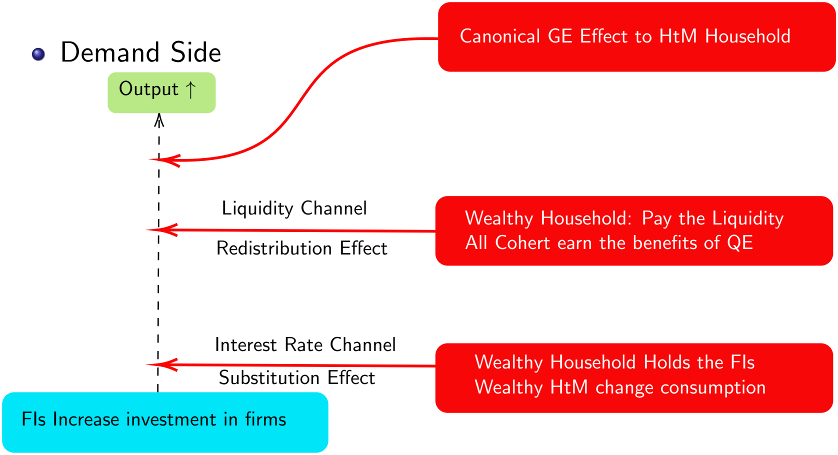


How they work

- Decompose the stimulation power of QE to output into two channels

How they work

- Decompose the stimulation power of QE to output into two channels
- Propose 4 main mechanisms through which these two channels work

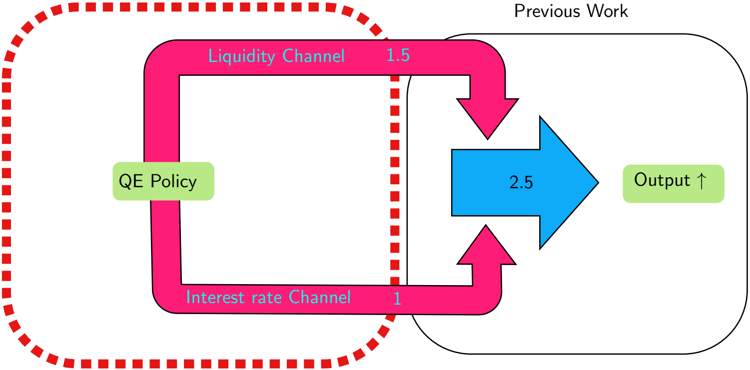
Table: QE Decomposition

QE effect	Liquidity channel	Interest rate channel
Supply side	liquidity easing	pecuniary easing
Demand side	redistribution effect	substitution effect

- Heterogeneous household, financial friction and financial accelerator asymmetrically affect liquidity and interest rate channel

How large they are

- Three Agents DSGE: Quantitatively the stimulation power on output of liquidity channel is 1.5 times larger than that of interest rate channel $\frac{\partial Y_t}{\partial q_t^B B_t}$ Slutskey



IV-VAR

- Canonical IV to monetary policy - FOMC announcement
  - ΔP_t^F, change of the price of future contract during announcement
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- A New Instrument variable: Treasury securities issuing announcement
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  - Treasury securities issuing announcement$\rightarrow$ Information about the change in volume of liquidity $\rightarrow$ liquidity channel

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- A New Bayesian IV–VAR algorithm

Literature review

- Term structure change triggered by QE: Bauer and Rudebusch (2014), Kuttner (2018)
    - Kuttner (2018): imperfect sustainability,improvements in financial balance sheet and signal about future short-term rate
- Conventional monetary policy-HANK: McKay, Nakamura, and Steinsson (2016), Kaplan, Moll, and Violante (2018), Auclert (2019), Bayer et al. (2019), Bilbiie (2020)
- Unconventional monetary policy-Financial friction: Carlstrom, Fuerst, and Paustian (2017), Sims and Wu (2021), and Karadi, Peter and Anton Nakov (2021).
- Unconventional monetary policy-HANK&Financial friction:Cui and Sterk (2021) and Sims, Wu, and Zhang (2022).
- IV-VAR, frequentist method: Stock and Watson (2012), Mertens and Ravn (2013) and Gertler and Karadi (2015).
- Bayesian-IV-VAR: Arias, Rubio-Ramírez, and Waggoner (2021) and Giacomini, Kitagawa, and Read (2021).

Liquidity & Interest Rate channel: Implication from Model

Proposition 1

When the price and depreciation rate is fixed, the contemporaneous effect of unconventional monetary policy on output can be decomposed to liquidity and interest rate channel such that Literature

$$\left.\frac{\partial \widehat{Y}_t}{\partial\left(\widehat{q}_t^B + \widehat{B}_t^m\right)}\right|_{\widehat{q}_t^B = q^B} = -\frac{\frac{1}{h^n} - 1 + \frac{\lambda^b}{\phi} + \varphi_1^m \frac{\varphi_1^h}{Th^n}}{C^n \frac{\psi}{\sigma} + \frac{(1-\tau)WL}{h^n} + \varphi_1^m \varphi_4^h} q^B B^m = -\varphi_L q^B B^m$$

$$\left.\frac{\partial \widehat{Y}_t}{\partial \widehat{q}_t^B}\right|_{\widehat{q}_t^B + \widehat{B}_t^m = q^B + B^m} = \frac{\rho}{C^n \frac{\psi}{\sigma} + \frac{(1-\tau)WL}{h^n} + \varphi_1^m \varphi_4^h} q^B B^m = \varphi_R q^B B^m$$

Liquidity & Interest Rate channel: Implication from Model

Redistribution Effect

$$\left.\frac{\partial \widehat{Y}_t}{\partial\left(\widehat{q}_t^B+\widehat{B}_t^m\right)}\right|_{\widehat{q}_t^B=q^B}=-\frac{\frac{1}{h^n}-1+\frac{\lambda^b}{\phi}+\varphi_1^m\frac{\varphi_1^h}{Th^n}}{C^n\frac{\psi}{\sigma}+\frac{(1-\tau)WL}{h^n}+\varphi_1^m\varphi_4^h}q^B B^m=-\varphi_L q^B B^m$$

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Asymmetric effect

Liquidity & Interest Rate channel: Implication from Model

Canonical GE Effect

$$\left.\frac{\partial \widehat{Y}_t}{\partial\left(\widehat{q}_t^B+\widehat{B}_t^m\right)}\right|_{\widehat{q}_t^B=q^B}=-\frac{\frac{1}{h^n}-1+\frac{\lambda^b}{\phi}+\varphi_1^m\frac{\varphi_1^h}{Th^n}}{C^n\frac{\psi}{\sigma}+\frac{(1-\tau)WL}{h^n}+\varphi_1^m\varphi_4^h}q^B B^m=-\varphi_L q^B B^m$$

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Asymmetric effect

Liquidity & Interest Rate channel: Implication from Model

Liquidity easing

$$\left.\frac{\partial \widehat{Y}_t}{\partial\left(\widehat{q}_t^B+\widehat{B}_t^m\right)}\right|_{\widehat{q}_t^B=q^B}=-\frac{\frac{1}{h^n}-1+\frac{\lambda^b}{\phi}+\varphi_1^m\frac{\varphi_1^h}{Th^n}}{C^n\frac{\psi}{\sigma}+\frac{(1-\tau)WL}{h^n}+\varphi_1^m\varphi_4^h}q^B B^m=-\varphi_L q^B B^m$$

$$\left.\frac{\partial \widehat{Y}_t}{\partial \widehat{q}_t^B}\right|_{\widehat{q}_t^B+\widehat{B}_t^m=q^B+B^m}=\frac{\rho}{C^n\frac{\psi}{\sigma}+\frac{(1-\tau)WL}{h^n}+\varphi_1^m\varphi_4^h}q^B B^m=\varphi_R q^B B^m$$

Asymmetric effect

Liquidity & Interest Rate channel: Implication from Model

Pecuniary easing

$$\left.\frac{\partial \widehat{Y}_t}{\partial\left(\widehat{q}_t^B+\widehat{B}_t^m\right)}\right|_{\widehat{q}_t^B=q^B}=-\frac{\frac{1}{h^n}-1+\frac{\lambda^b}{\phi}+\varphi_1^m\frac{\varphi_1^h}{Th^n}}{C^n\frac{\psi}{\sigma}+\frac{(1-\tau)WL}{h^n}+\varphi_1^m\varphi_4^h}q^B B^m=-\varphi_L q^B B^m$$

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Asymmetric effect

Liquidity & Interest Rate channel: Implication from Model

Aggregate-demand complementarity(Bilbiie et al. 2022)

$$\left.\frac{\partial \widehat{Y}_t}{\partial\left(\widehat{q}_t^B+\widehat{B}_t^m\right)}\right|_{\widehat{q}_t^B=q^B}=-\frac{\frac{1}{h^n}-1+\frac{\lambda^b}{\phi}+\varphi_1^m\frac{\varphi_1^h}{Th^n}}{C^n\frac{\psi}{\sigma}+\frac{(1-\tau)WL}{h^n}+\varphi_1^m\varphi_4^h}q^B B^m=-\varphi_L q^B B^m$$

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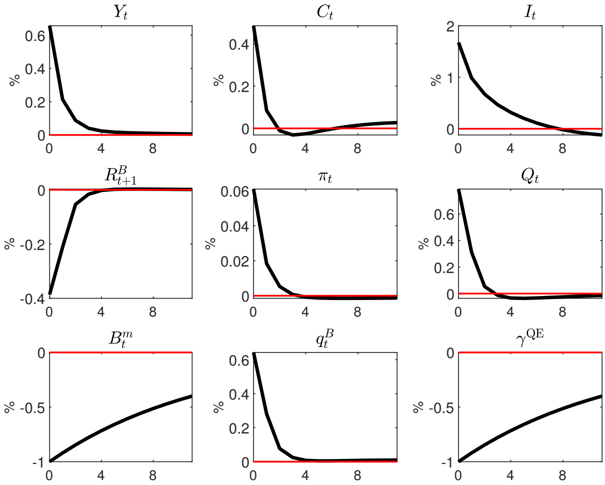
Asymmetric effect

Calibration

Parameter	Value	Description
β	0.98	Discount factor
τ	0.25	Labor income tax
ρ	0.995	Geometric decay rate of long-term bonds
θ^m	0.85	Exist rate of mutual funds
λ^b	0.83	Relative financial friction slackness
λ^ν	0.36	Absolute financial friction
h^{HtM}	0.313	Share of hand-to-mouth household
h^{nHtM}	0.687	Share of non hand-to-mouth household
h^{wHtM}	0.192	Share of wealthy hand-to-mouth household
h^{pHtM}	0.121	Share of poor hand-to-mouth household
p^{EU}	0.044	Possibility go from nHtM to HtM
p^{UE}	0.097	Possibility go from HtM to nHtM
$h^{\mathrm{wHtM}\|\mathrm{HtM}}$	0.613	Share of wealthy hand-to-mouth conditional on HtM
$h^{\mathrm{pHtM}\|\mathrm{HtM}}$	0.387	Share of poor hand-to-mouth conditional on HtM
X	0.55	Total illiquid asset withdrawing

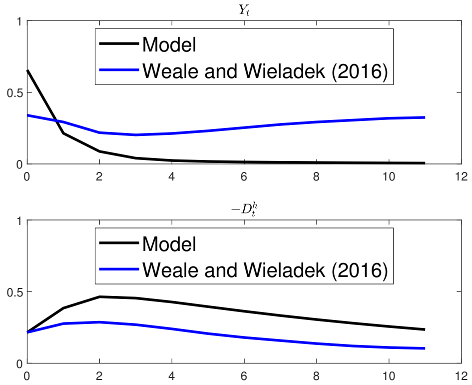
IRF: QE shock

- 1% increase in long-term bonds hold by central bank

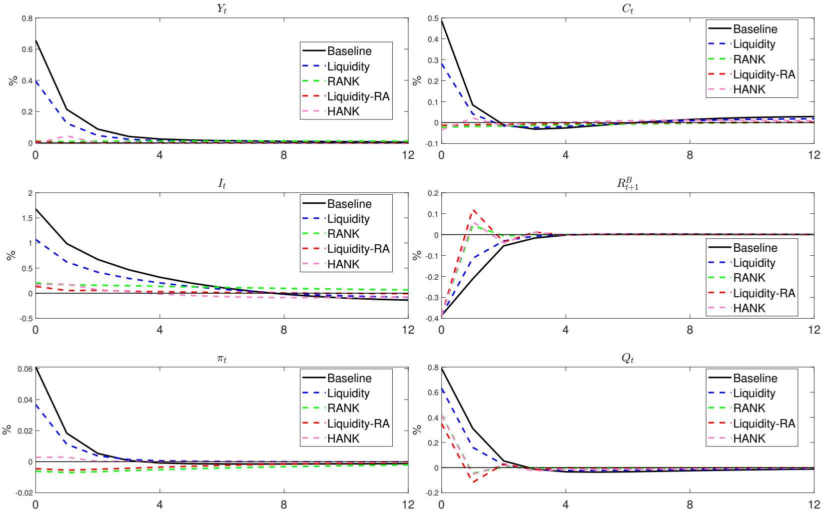


Link Model to Reality

- In line with previous empirical analysis.
  - With the same drop in shadow rate, 0.64% jump in output vs 0.59% at the peak Wu and Xia (2016)
  - With the same jump in the value of long-term bonds hold by central bank



Liquidity & Interest Rate Channel: Quantitative Result



IV to Liquidity: Treasury securities issuing announcement

TREASURY NEWS

Department of the Treasury • Bureau of the Fiscal Service

Embargoed Until 11:00 A.M.
February 16, 2017

CONTACT: Treasury Securities Services
202-504-3550

TREASURY OFFERING ANNOUNCEMENT [1]

Term and Type of Security	2-Year Note
Offering Amount	$26,000,000,000
Currently Outstanding	$0
CUSIP Number	912828W30
Auction Date	February 21, 2017
Original Issue Date	February 28, 2017
Issue Date	February 28, 2017
Maturity Date	February 28, 2019
Dated Date	February 28, 2017
Series	AX-2019
Yield	Determined at Auction
Interest Rate	Determined at Auction
Interest Payment Dates[4]	August 31 and February 28
Accrued Interest from 02/28/2017 to 02/28/2017	None
Premium or Discount	Determined at Auction
Minimum Amount Required for STRIPS	$100
Corpus CUSIP Number	9128206Q5
Additional TINT(s) Due Date(s) and	None
CUSIP Number(s)	None
Maximum Award	$9,100,000,000
Maximum Recognized Bid at a Single Yield	$9,100,000,000
NLP Reporting Threshold	$9,100,000,000
NLP Exclusion Amount	$0
Minimum Bid Amount and Multiples	$100
Competitive Bid Yield Increments [2]	0.001%
Maximum Noncompetitive Award	$5,000,000
Eligible for Holding in TreasuryDirect®	Yes
Estimated Amount of Maturing Coupon Securities Held by the Public	$81,108,000,000
Maturing Date	February 28, 2017
SOMA Holdings Maturing	$13,175,000,000
SOMA Amounts Included in Offering Amount	No
FIMA Amounts Included in Offering Amount [3]	Yes
Noncompetitive Closing Time	12:00 Noon ET

Methodology

- Reduce form DGP

$$Y_t = \sum_{j=1}^{p} A_j Y_{t-j} + B\varepsilon_t = \sum_{j=1}^{p} A_j Y_{t-j} + u_t$$

- IV m_t to specific shock we are interested

$$E\left[m_t {\varepsilon'}_{1t}\right] = \Phi \tag{3}$$

$$E\left[m_t {\varepsilon'}_{2t}\right] = 0 \tag{4}$$

Methodology

- Previous work: Fully identify Φ with restriction on β_1

$$\Phi\beta_1' = \Sigma_{mu'} \tag{5}$$

- Fully identify β_1 with restriction on Φ Detail_S11

$$\Phi\Phi' = \Sigma_{mu_1'}\left(\Sigma_{mu_1'}^{\prime -1} s_{11} s_{11}'\right)^{-1} \tag{6}$$

- New inequality restriction

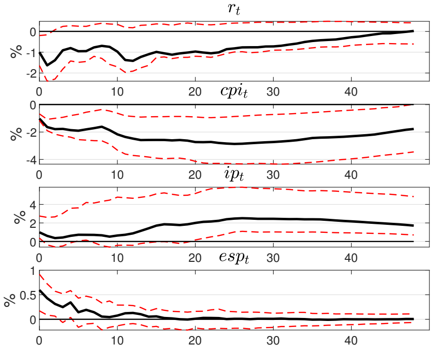
$$F\left(\Phi_{tr}, Q; \rho\right) \equiv \mathrm{diag}\left\{(\Phi_{tr}Q) \circ (\Phi_{tr}Q)\begin{bmatrix} 1 & -\frac{1}{1-\kappa_2} \\ -\frac{1}{1-\kappa_1} & 1 \end{bmatrix}\right\} > 0 \tag{7}$$

Liquidity vs Interest rate - Empirical

- market yield on 2-Year U.S. Treasury Securities r_t
- consumer price index cpi_t
- industrial production y_t
- excess bonds premium esp_t from Gilchrist, Simon and Egon Zakrajšek (2012)

Liquidity vs Interest rate - Empirical

Impulse Response to QE via liquidity channel



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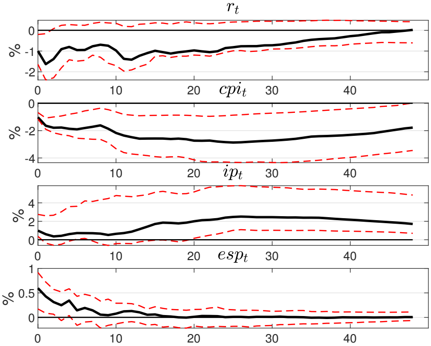
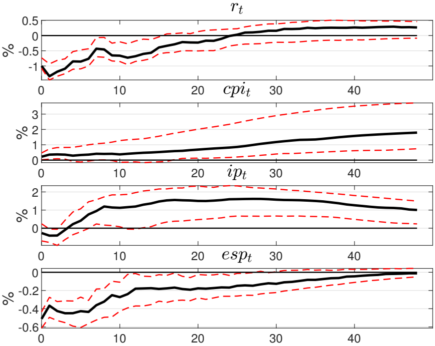


Impulse Response to QE via Interest rate channel



Conclusion

- the effectiveness of quantitative easing can be decomposed into liquidity channel and interest rate channel
  - stimulate the economy via different mechanisms
  - asymmetrically affected by Household heterogeneity and Financial friction
- liquidity channel is 1.5 times larger than the interest rate channel quantitatively
- novel instrument variable and identification algorithm
- liquidity channel is 1.46 times larger than the interest rate channel empirically

QE-effect Decomposition: Transmission mechanism

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- Financial friction
  - Low: Extra liquidity $\rightarrow$ Less debt but not more investment $\rightarrow$ QE policy plays no role in stimulating output
  - High: Scarcity of liquidity dominates; One more unit of liquidity in net worth $\rightarrow$ ϕ unit of more investment
- Heterogeneous household
  - GE effect: more output $\rightarrow$ more wage income $\rightarrow$ more consumption even fixed real interest rate
  - Non-HtM household pays the liquidity $\rightarrow$ Wealth Redistribution from non-HtM to HtM
  - Substitution: Iliquid asset investment&withdrawing

Back

QE-effect Decomposition: Slutsky equation

- ✗ $dY(q_t^B, B_t) = \frac{\partial Y}{\partial q^B} dq_t^B + \frac{\partial Y}{\partial B} dB_t$

i.e. Financial institutions get 7.5 dollars of liquidity from central bank ($\Delta q_t B_t = 1.5 \times 5$ where $\Delta B_t = 5$,$\Delta q_t = 0.5$ and $q_{t-1} = 1$). 1×5 dollars comes from selling the bonds and 0.5×5 dollars comes from price inflation.

- ✔ $dY(q_t^B, q_t^B B_t) = \frac{\partial Y}{\partial q^B} dq_t^B + \frac{\partial Y}{\partial q^B B} d(q_t^B B_t)$

i.e. Financial institutions get 7.5 dollars of liquidity from central bank. What is the response of output if they sell 1×7.5 dollars of bonds to central bank or sell 0 dollars (but bonds price gets a 0.5 dollars inflation).

Back

Liquidity Channel & Interest Rate Channel

- Debortoli and Galí (2022): Average consumption $\frac{(1-\tau)WL}{h^n}$ vs Cross-sectional consumption dispersion $C^n \frac{\psi}{\sigma}$
- Redistribution credit effect $\frac{1}{h^n} - 1$
- Portfolio adjustment effect $\frac{\lambda^b}{\phi}$
- Pecuniary effect ρ
- Bilbiie, Känzig, and Surico (2022): multiplier φ_1^m of multiplier effect φ_4^h

Back

Liquidity Channel & Interest Rate Channel

Proposition 2

The complementary component of stimulation effect at supply side can be further decomposed as

$$\varphi_1^m = \underbrace{\left(N^h \frac{1-\theta^m+\theta^m\eta}{\theta^m}\lambda\frac{R^k}{R^k-R}\frac{1}{KQ+\Pi^f}-1+\frac{1}{\phi}\right)\frac{\varphi_I}{\delta}(1-\beta\Lambda)}_{\text{redistribution return}}\ \underbrace{-\left(1-\frac{1}{\phi}\right)Q}_{\text{redistribution wealth}}$$

Back

FOCs of mutual funds

$$\Omega_{t,t+1} = \Lambda_{t,t+1}\omega_{t+1}$$

$$\omega_t = 1 - \theta^m + \theta^m \eta_t$$

$$\eta_t = \frac{\zeta_t}{1 - \lambda_t}$$

$$W_t = \eta_t n_t$$

$$V_t = \mu_t^s Q_t s_t + \mu_t^b q_t^B b_t + \zeta_t n_t$$

$$\zeta_t = E_t\left[\beta \Omega_{t,t+1} R_t\right]$$

$$\mu_t^s = E_t \beta \Omega_{t,t+1}\left(R_{t+1}^k - R_t\right)$$

$$\mu_t^b = E_t \beta \Omega_{t,t+1}\left(R_{t+1}^B - R_t\right)$$

Back

IV-Methodology

Write the $\mathbf{B}$ into partition

$$\mathbf{B} = \begin{bmatrix} \mathbf{s}_{11} & \mathbf{s}_{12} \\ \mathbf{s}_{21} & \mathbf{s}_{22} \end{bmatrix}$$

$$\mathbf{\Sigma}_{uu'} = \begin{bmatrix} \boldsymbol{\sigma}_{11} & \boldsymbol{\sigma}_{12} \\ \boldsymbol{\sigma}_{21} & \boldsymbol{\sigma}_{22} \end{bmatrix}$$

where $\mathbf{s}_{11}$ is the k-by-k matrix. Then I can use the relationship

$$\mathbf{s}_{11}\mathbf{s}_{11}' = \boldsymbol{\sigma}_{11} - \mathbf{s}_{12}\mathbf{s}_{12}' \tag{8}$$

$$\mathbf{s}_{12}\mathbf{s}_{12}' = \left(\boldsymbol{\sigma}_{21} - \mathbf{s}_{21}\mathbf{s}_{11}^{-1}\boldsymbol{\sigma}_{11}\right)' \mathbf{Q}^{-1} \left(\boldsymbol{\sigma}_{21} - \mathbf{s}_{21}\mathbf{s}_{11}^{-1}\boldsymbol{\sigma}_{11}\right)$$

$$\mathbf{Q} = \mathbf{s}_{21}\mathbf{s}_{11}^{-1}\boldsymbol{\sigma}_{11}\left(\mathbf{s}_{21}\mathbf{s}_{11}^{-1}\right)' - \left(\boldsymbol{\sigma}_{21}\left(\mathbf{s}_{21}\mathbf{s}_{11}^{-1}\right)' + \mathbf{s}_{21}\mathbf{s}_{11}^{-1}\boldsymbol{\sigma}_{21}'\right) + \boldsymbol{\sigma}_{22}$$

Back

Household

- Three types of household: poor hand-to-mouth, wealthy hand-to-mouth and non hand-to-mouth
- Household $i \in \{\mathrm{pHtM}, \mathrm{wHtM}, \mathrm{nHtM}\}$ solves the problem

$$
\begin{aligned}
V(b^i_{t-1}, a^i_{t-1}, \varepsilon^i) &= \max_{c_t, b_t, X^i_t} U(c^i_t, l^i_t) + \beta \mathbb{E} V(b^i_t, a^i_t, \varepsilon^i) \\
\text{s.t. } c^i_t + b^i_t &= X^i_t + b^i_{t-1} R_{t-1} + (1-\tau_l) w_t l_t \varepsilon^i_t + \Theta^i_t 1_{\varepsilon^i_t = 0} + T_t \\
a^i_t &\geq 0 \\
R^a_t a^i_{t-1} - X^i_t &= a^i_t
\end{aligned}
$$

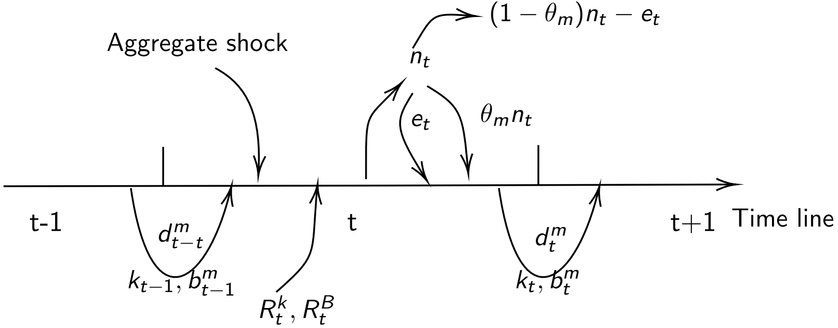
where a_t is illiquid asset. b^i_t is liquid asset. Θ^i_t is unemployment insurance. T_t is lump-sum tax transfer.

Household

- Iliquid asset: fixed withdrawing $X_t^{wHtM} = X^{\mathrm{wHtM}}$ and $X_t^{nHtM} = X^{nHtM}$
  - Iliquid asset a_t is fully determined by illiquid asset return R_t^a
- Constrained household: poor hand-to-mouth $pHtM$ and wealthy hand-to-mouth wHtM
  - Euler equation does not hold anymore $c_t^{pHtM} = \Theta_t^{\mathrm{HtM}} + T_t$ and $c_t^{\mathrm{wHtM}} = X^{\mathrm{wHtM}} + \Theta_t^{\mathrm{HtM}} + T_t$
- Unconstrained household: precautionary saving

$$U_c\left(c_t^{\mathrm{nHtM}}\right) = \mathbb{E}\beta R_t\left\{p^{\mathrm{nHtM}} U_c\left(c_{t+1}^{\mathrm{nHtM}}\right) + p^{\mathrm{pHtM}} U_c\left(c_{t+1}^{\mathrm{pHtM}}\right) + p^{\mathrm{wHtM}} U_c\left(c_{t+1}^{\mathrm{wHtM}}\right)\right\}$$

Mutual funds



Mutual funds

- Ex-post value of mutual fund at time t (Value of mutual fund conditional on survived at time t)

$$W\left(n_t | s_t^*, b_{,t}^{m*}\right) = \max_{s_{j,t}, b_{j,t}^m} V\left(s_t, b_t^m, n_t\right) \tag{9}$$

$$\text{s.t. } V\left(s_t, b_t^m, n_t\right) \geq \lambda^v Q_t s_t + \lambda^b \lambda^v q_t^B b_t^m \tag{10}$$

- Ex-ante value of mutual fund at time $t+1$

$$V\left(s_t, b_t^m, n_t\right) = E_t \beta \Lambda_{t,t+1}\left[\left(1-\theta^m\right) n_{t+1} + \theta^m W\left(n_{t+1} | s_{t+1}^*, b_{t+1}^{m*}\right)\right]$$

- Balance sheet $Q_t s_t + q_t^B b_t^m = n_t + d_t^m$
- Budget constraint
$n_t = R_t^k Q_{t-1} s_{t-1} - Q_t s_t + \frac{\left(1+\rho q_t^B\right)}{\Pi_t} b_{t-1}^m - q_t^B b_t^m - R_{t-1} d_{t-1}^m$

Mutual funds

- Law of motion of the net worth

$$n_t = \left(R_t^k - R_{t-1}\right) Q_{t-1} s_{t-1} + \left(R_t^B - R_{t-1}\right) q_{t-1}^B b_{t-1}^m + R_{t-1} n_{t-1}$$

$$N_t = \theta^m \left[\left(R_t^k - R_{t-1}\right) Q_{t-1} S_{t-1} + \left(R_t^B - R_{t-1}\right) q_{t-1}^B B_{t-1}^m + R_{t-1} N_{t-1}\right] \\ + \varphi \phi_t N_{t-1}$$

where$N_t = \int n_{j,t} dj$ and $R_t^B = \frac{1+\rho^B q_t^B}{q_{t-1}^B}$

Mutual funds

Non-arbitrage condition

$$\lambda^b E_t \beta \Omega_{t,t+1} \left(R^k_{t+1} - R_t \right) = E_t \beta \Omega_{t,t+1} \left(R^B_{t+1} - R_t \right)$$

If no financial friction, $R^k_{t+1} = R_t = R^B_{t+1}$.
One unit of liquidity $\rightarrow$ decrease one unit of debt;instead of increasing one unit of physical investment

Mutual funds

Endogenous leverage ratio

$$\phi_t \leq \overline{\phi}_t = \frac{E_t\left[\beta\Omega_{t,t+1}R_t\right]}{\lambda^v - E_t\left[\beta\Omega_{t,t+1}\left(R^k_{t+1} - R_t\right)\right]}$$

A larger $E_t\left[\beta\Omega_{t,t+1}R_t\right] \rightarrow$ increased funding cost $\rightarrow$ smaller $\overline{\phi}_t$
A larger $E_t\left[\beta\Omega_{t,t+1}\left(R^k_{t+1} - R_t\right)\right] \rightarrow$ mutual funds are more valuable $\rightarrow$ larger $\overline{\phi}_t$ FOCs

Production sector

- Intermediate good producer closes the equity market

$$R_t^k = \frac{\left[\frac{\Pi_t^f + \tau_y m}{\xi_t K_{t-1}} + Q_t\right]\xi_t}{Q_{t-1}}$$

- Capital producer pins down capital price
- Retailer sets the price with monopolic power
- Final goods producer: CES aggregation

Central Bank and Government

- Budget constraint

$$T_t = T_t^s - \frac{(1+\rho q_t^B)}{\Pi_t} B_{t-1}^g + q_t^B B_t^g \tag{11}$$

$$T_t^s + D_t^h - R_{t-1} D_{t-1}^h + D_t^m - R_{t-1} D_{t-1}^m = \frac{(1+\rho q_t^B)}{\Pi_t} B_{t-1}^{cb} - q_t^B B_t^{cb} \tag{12}$$

where

$$B_t^g = B_t^{cb} + B_t^m = 0 \tag{13}$$

$$B_t^m = \int b_{i,t}^m di \tag{14}$$

$$D_t^h + h^{\mathrm{nHtM}} b_t^{\mathrm{nHtM}} = 0 \tag{15}$$

$$D_t^m = \int d_{i,t}^m di \tag{16}$$

Central Bank and Government

- Conventional monetary policy

$$\mathcal{R}_t = \max\left\{\mathcal{R}_{t-1}^{\theta_r}\mathbb{E}_t\left[\left(\frac{\Pi_{t+1}}{\Pi}\right)^{\theta_\pi}\left(\frac{Y_t}{Y}\right)^{\theta_y}\right]^{1-\theta_r}\gamma_t^{MP}, 1\right\} \tag{17}$$

- Unconventional monetary policy

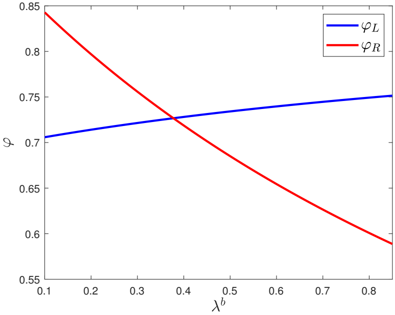
$$\frac{B_t^m}{\overline{B^m}} = \frac{B_{t-1}^m}{\overline{B^m}}^{\theta_r^{QE}}\left[\left(\frac{\Pi_{t+1}}{\Pi}\right)^{\theta_\pi^{QE}}\left(\frac{Y_t}{Y}\right)^{\theta_y^{QE}}\right]^{1-\theta_r^{QE}}\gamma_t^{QE} \tag{18}$$

- The money used to implement QE policy is fully funded by household

$$q_t^B B_t^m = D_t^h + \overline{T}_{\mathrm{cb}}$$

Asymmetric effect: Supply Side

Low Financial Friction $\rightarrow$
High Financial Friction



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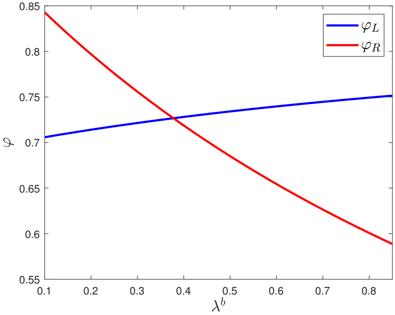
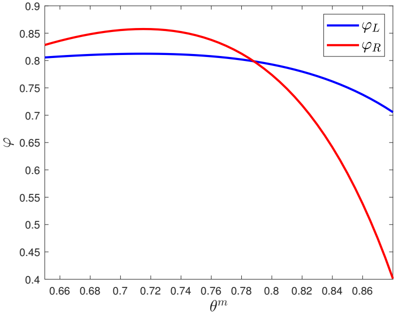
Asymmetric effect: Supply Side

Low Financial Friction $\rightarrow$ High Financial Friction

Higher Financial Accelerator $\rightarrow$ Low Financial Accelerator





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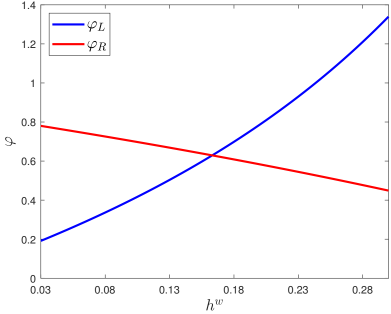
Asymmetric effect: Demand Side

Redistribution: Low Inequality $\rightarrow$ High Inequality



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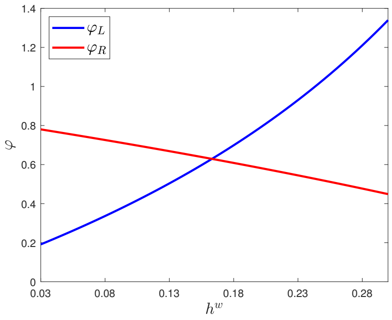
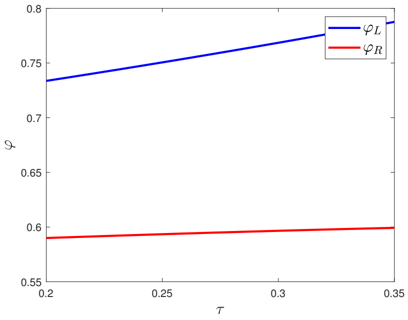
Asymmetric effect: Demand Side

Redistribution: Low Inequality → High Inequality



Income Effect: Low Inequality → High Inequality



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