The Reanchoring Channel of QE

The ECB's Asset Purchase Programme and Long-Term Inflation Expectations

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*The views expressed are those of the authors, and do not necessarily reflect the official position of the ECB or the Eurosystem.

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- In practice, significant announcement effects (Krishnamurthy and Vissing-Jorgensen, 2011; Altavilla, Carboni and Motto, 2015)
- Our focus: Impact on long-term inflation expectations at the ZLB EA
  - Adverse shocks at the ZLB led to some deanchoring in 2013-2014 in EA
  - Initial LSAP announcement in 2015:1 contributed to reanchoring

This paper

- Event-study evidence on ECB's LSAP (APP) announcements on inflation expectations
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- DSGE model with
  - Balance-sheet constrained financial intermediaries
  - Binding effective lower bound
  - Imperfect information about CB's target
- Calibrated to the euro area
  - Quantifies the importance of the reanchoring channel of APP
  - Shock w/o policy action: downturn and deanchoring
  - APP stimulates the economy and leads to reanchoring

Findings

- Reanchoring channel is potent
  - Explains 1/3 of the inflation impact of APP
  - Amplified impact on short-term inflation
  - Mechanism (ZLB and financial accelerator):
    - Higher target implies easier policy
    - Leads to higher expected inflation
    - Implies lower real rates now (ZLB, even though earlier liftoff)
    - Raises asset prices, eases financial constraints in a positive feedback loop

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- Implications
  - Target uncertainty renders policy passivity costly
  - Makes credible policy signals powerful

Reanchoring Channel: Related Literature

- Event-study evidence on QE
  - Broad asset-price impact (Rogers, Scotti and Wright, 2014; Swanson, 2015)
  - Scarce evidence on impact on long-term inflation expectations
    - Market expectations (Krishnamurthy and Vissing-Jorgensen, 2011; Altavilla, Carboni and Motto, 2015): premium component

Reanchoring Channel: Related Literature, cont.

- Information in introducing QE
  - Related to signalling at ZLB (Bhattarai, Eggertsson and Gafarov, 2015)
    - There: QE helps commitment of discretionary CB
    - Here: QE reveals information about policy rule (Gürkaynak, Sack and Swanson, 2005; Gürkaynak, Levin and Swanson, 2010)
  - Complements ‘asset-revaluation’ channels (Gertler and Karadi, 2013; Del Negro, Eggertsson, Ferrero and Kiyotaki, 2010; Chen, Cúrdia and Ferrero, 2012)

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- Amplification at the ZLB
  - QE more powerful at ZLB: monetary policy does not offset its impact (Gertler and Karadi, 2011; Del Negro, Eggertsson, Ferrero and Kiyotaki, 2010)
  - Impact on long-term expectations is also amplified (see also Eggertsson and Pugsley, 2006)

EA event study

- ECB press conferences
  - January 2013 - June 2016
  - Special ECB: IR announcements separate from press conferences
  - Press conferences (36)
  - Robustness: exclude 3 with key FG announcements (June 5, 2014; October 22, 2015; March 10, 2016)

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  - Press conferences (36)
  - Robustness: exclude 3 with key FG announcements (June 5, 2014; October 22, 2015; March 10, 2016)
- Measurement of the monetary policy indicator
  - 5-year German bund yield
  - Market price: average of the best bid and ask quotes, from the last 5
  - Surprise: price change between 10 minutes before, 80 minutes after the start of the press conference
  - Cumulated over each quarter

EA event study, cont

- Inflation expectations
  - 5-year ahead inflation expectations in the SPF
  - Robustness: 5-year inflation swap yields 5-year-ahead

EA event study, cont

- Inflation expectations
  - 5-year ahead inflation expectations in the SPF
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- Methodology: Quarterly regressions EA

$$\Delta y_t = \alpha + \beta \tilde{\Delta} x_{t-1} + \varepsilon_t,$$

Impact on 5-year inflation expectations

	(1) Post 2013	(2) Pre 2013	(3) APP	(4) APP, No FG
	Change in 5-year-ahead inflation expectations			
5-year German yield surprise	-0.599***	0.0932	-0.583**	-0.508***
	(-4.392)	(1.551)	(-3.151)	(-3.960)
Sample	2013q1-2016q2	2001q1-2012q4	2014q2-2016q2	2014q2-2016q2
Observations	15	47	10	10
R-squared	0.523	0.051	0.457	0.539

Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

- Easing yields to reanchoring
- Robustness: ILS

Overview

- Quantitative DSGE model
  - Representative family with Households
    - Consumption habits
    - Monopolistically competitive labor market; staggered wage setting
    - Portfolio adjustment costs HH assets
  - Intermediate good producers with ‘working capital constraint’ Intermediate
  - Capital producers with investment adjustment costs (Q) Capital
  - Monopolistically competitive retailers with staggered price setting Retailers

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- Balance sheet constrained financial intermediaries

- Central bank with uncertain inflation target

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  - Perfect consumption insurance

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  - f bankers, $1 - f$ workers
  - Perfect consumption insurance
- With iid. probability $1 - \sigma$, a banker becomes a worker. (Limits bankers' ability to save themselves out of the financial constraints)
- Each period, $(1 - \sigma)f$ workers randomly become bankers
- New banker receives a start-up fund from the family

Asset Returns

- Return on capital (state-contingent debt)

$$R_{kt+1} = \frac{Z_{t+1} + Q_{t+1}}{Q_t}$$

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- Return on long term gov't bonds

$$R_{bt+1} = \frac{\Xi / P_t + q_{t+1}}{q_t}$$

Financial Intermediaries

- Intermediary Balance Sheet

$$Q_t s_t + q_t b_t = n_t + d_t$$

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- Evolution of net worth

$$n_t = R_{kt} Q_{t-1} s_{t-1} + R_{bt} q_{t-1} b_{t-1} - R_t d_{t-1}$$

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- FI's objective

$$V_t = E_t \sum_{i=1}^{\infty} (1-\sigma)\sigma^{i-1} \Lambda_{t,t+i} n_{t+i} \tag{1}$$

Limits to Arbitrage

- Agency problem: banker can divert
  - the fraction θ of loans and
  - $\Delta\theta$ of gov't bonds, with $0 \leq \Delta \leq 1$.

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- Agency problem: banker can divert
  - the fraction θ of loans and
  - $\Delta\theta$ of gov't bonds, with $0 \leq \Delta \leq 1$.
- Lenders can recover the residual funds and shut the bank down.
- Incentive constraint

$$V_t \geq \theta Q_t s_t + \Delta\theta q_t b_t. \tag{2}$$

Implications

Solution

- 'Risk-adjusted' leverage constraint

$$Q_t s_t + \Delta q_t b_t = \phi_t n_t$$

where ϕ_t is an endogenous leverage ratio.

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$$Q_t s_t + \Delta q_t b_t = \phi_t n_t$$

where ϕ_t is an endogenous leverage ratio.

- 'Arbitrage' between corporate and sovereign bonds

$$\Delta E_t \beta \tilde{\Omega}_{t+1}(R_{kt+1} - R_{t+1}) = E_t \beta \tilde{\Omega}_{t+1}(R_{bt+1} - R_{t+1}),$$

where $\tilde{\Omega}_{t+1}$ the FI's discount factor.

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- Aggregate net worth

$$N_t = \sigma \left[(R_{kt} - R_t) Q_{t-1} S_{pt-1} + (R_{bt} - R_t) q_{t-1} B_{pt-1} + R_t N_{t-1} \right] + X.$$

Credit Policy

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- Asset purchases
  - Gov't: Reducing the supply of long-term assets
  - Private: Direct credit to the private sector

Credit Policy, cont.

- Composition of Assets between banks and central bank

$$S_t = S_{pt} + S_{gt}$$
$$B_t = B_{pt} + B_{gt}$$

Credit Policy, cont.

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- Private Securities Demand

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\begin{aligned}
Q_t S_t =& \phi_t N_t + Q_t S_{gt} + \Delta q_t (B_{gt} - B_t) \\
E_t \tilde{\Omega}_{t+1}(R_{bt+1} - R_{t+1}) =& \Delta E_t \tilde{\Omega}_{t+1}(R_{kt+1} - R_{t+1})
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- Purchases of gov't bonds have:
  - Weaker effects on private vs. gov't securities demand
  - Stronger effects on excess returns of private vs. gov't sec.

Resource Constraint and Government Policy

- Resource constraint

$$Y_t = C_t + I_t + f\left(\frac{I_t}{I_{t-1}}\right) I_t + G + \Phi_t$$

where Φ_t is the portfolio transactions costs.

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- Gov't budget constraint

$$G = T_t + (R_{kt} - R_t - \tau) S_{gt-1} + (R_{bt} - R_t) B_{gt-1}$$

Central Bank

- LSAP: $\Psi_t = (Q_t S_{gt} + \Delta q_t B_{gt})/4\bar{Y}$
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- Interest rate policy with ZLB: i_t

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\begin{aligned}
i_t &= \max(0, i_t^*) \\
i_t^* &= \rho_i i_{t-1} + (1-\rho_i)\left[\pi_t^* + \kappa_\pi(\pi_t - \pi_t^*) + \kappa_y y_t\right] + \\
&\qquad \kappa_{\Delta\pi}(\pi_t - \pi_{t-1}) + \kappa_{\Delta y}(y_t - y_{t-1}) + \varepsilon_t \\
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- Conventional and unconventional policies are substitutes
  - Effective lower bound on the interest rate
  - LSAP unconstrained

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- Learning rule,

$$\begin{aligned} \pi_{t+1}^{*e} =& \rho_{\pi^{*e}} \pi_t^{e*} - \xi \left\{ s_t - s_t^e \right\} \\ s_t =& i_t - \varsigma \Psi_t - \left[(1-\rho_i)\kappa_\pi + \kappa_{\Delta\pi} \right] \pi_t - \left[(1-\rho_i)\kappa_y + \kappa_{\Delta y} \right] y_t \\ s_t^e =& \tilde{E}_{t-1} \left[s_t \right] \end{aligned}$$

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  - Agents assume LSAP substitutes IRs at the ZLB, $i_t^S = i_t - \varsigma \Psi_t$
- Reanchoring
  - At ZLB $i_t = i_t^e$ w/o LSAP, low inflation leads to deanchoring
  - LSAP: $\Psi_t > \Psi_t^e$ leads to reanchoring

Solution

- Learning equilibrium
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  - CB sets LSAP policy and interest rates s.t. ZLB
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- First-order appr. solution: impulse response analysis
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  - Shocks hit in period 1
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  - Shocks hit in period 1
  - Inflation target stays unchanged (unknown to agents)
  - ZLB binds endogenously (non-linearity)
- Algorithm: solution over the impulse response space
  - Each period: Update expectations about the inflation target
  - Forecast perceived responses (including the length ZLB is expected to bind)
  - Consume, work, save, invest, set prices, wages now
  - IR policy is set according to a constant inflation target
  - Repeat each period until steady state reached

Calibration

- Tightness of credit conditions
  - Average credit spreads
    - Private: 2.45% (LT CCB - Eonia)
    - Sovereign: 2.1% (EA 10-year yield - Eonia)
  - FI leverage: 6
    - Assets over equity of FIs, NFCs in EA SA

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- Learning rule
  - 15bps decline in LT expectations before APP ($\xi = 0.062$)
  - Similar impact of APP and 1.1% monpol shock ($\varsigma = 0.068$) Monpol
  - 9bps increase on APP announcement (consistent with SPF change between 2015Q1-Q3)

Calibration, cont.

- Conventional parameters
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  - As estimated in NAWM (Christoffel et al., 2008) Monpol
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- APP
  - 11% of GDP, maturity: 8, 9% in ten-year equivalents
  - Hump-shaped pattern
  - Calibrated to reach peak in 2 years, exit as bonds mature

Results

- Stylized demand shock Level
  - Persistent shock to savings preference
  - Inflation: -2.4%, Output -7%, 10-year rate -100bps
  - Deanchoring: perceived target -15 bps, expected liftoff: 7 quarters

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- Raising efficiency
  - Maturity extension (from 8 to 11, +10bps inflation effect) Maturity
  - Forward guidance (+5 bps inflation effect) Forward guidance

Other channels

- Duration channel Figure

Other channels

- Duration channel Figure
- "Stealth recapitalization" Recapitalization

Conclusion

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  - Event-study evidence
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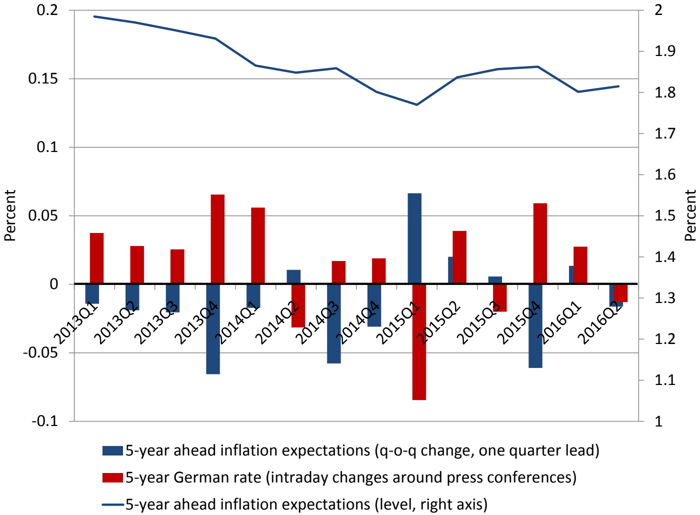
  - Event-study evidence
  - Quantified in a DSGE macromodel
- Policy conclusions
  - Inactivity particularly costly with deanchoring
  - Reanchoring enhances policy effectiveness
  - Duration of targeted assets should be maximized
  - Forward guidance reinforces the effectiveness of APP

Euro Area Inflation Expectations



Source: ECB, Survey of Professional Forecasters.

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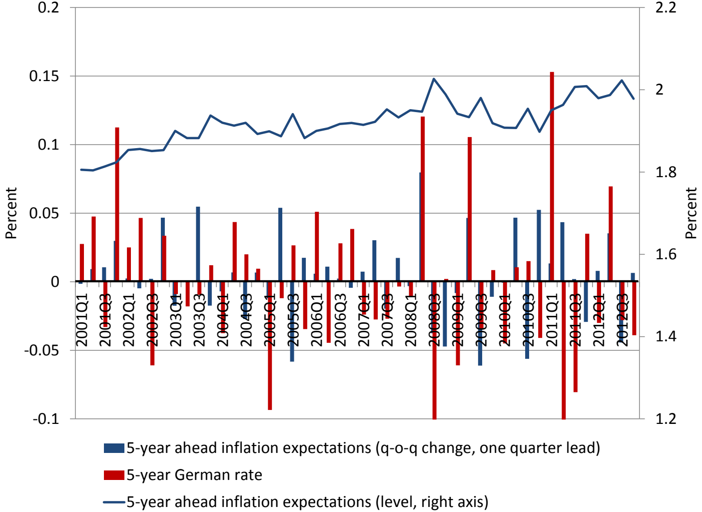

Source: ECB, Survey of Professional Forecasters.

Impact on 5x5 inflation-linked swap rates

	(1)	(2)	(3)	(4)
	Post 2013	Pre 2013	APP	APP, No FG
	Change in 5x5 inflation-linked swap yields			
5-year German yield surprise	-1.222**	0.571***	-1.533**	-1.189**
	(-2.754)	(4.303)	(-2.592)	(-2.571)
Sample	2013q1-2016q2	2004q1-2012q4	2014q2-2016q2	2014q2-2016q2
Observations	15	34	10	10
R-squared	0.315	0.176	0.426	0.399

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- Easing yields to reanchoring

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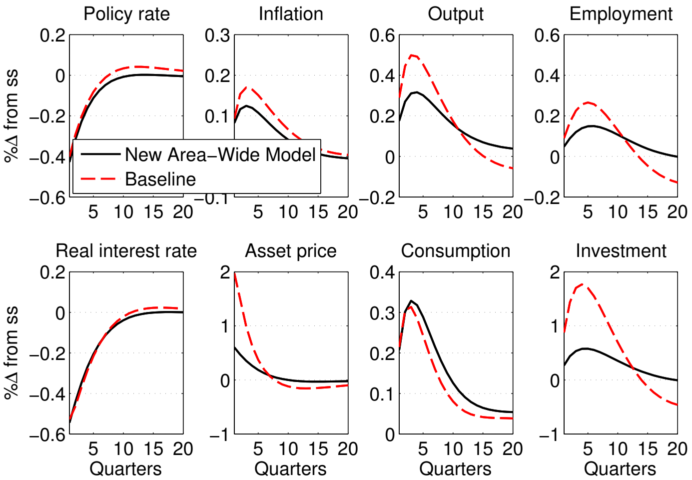
Impact of an interest rate innovation



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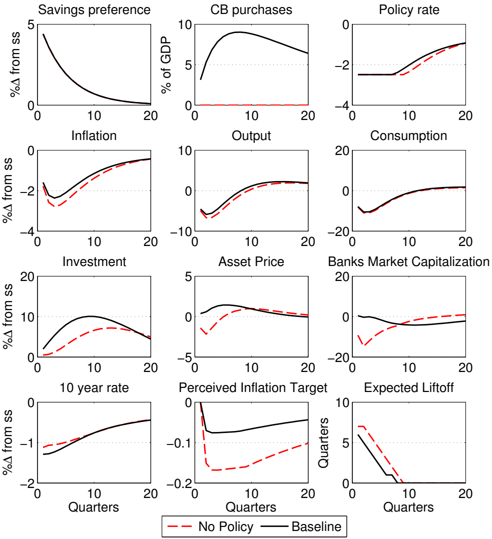
Demand shock and APP



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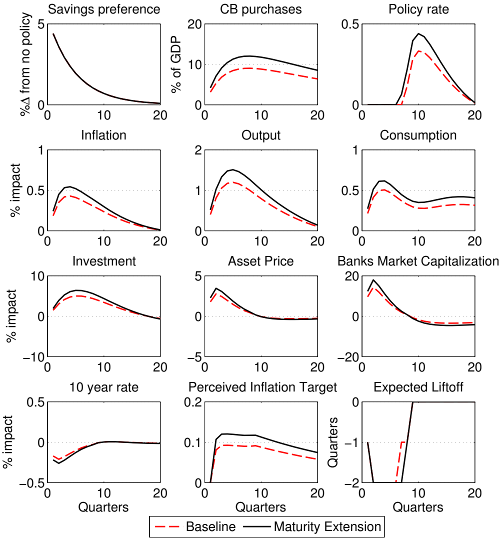
APP and maturity extension



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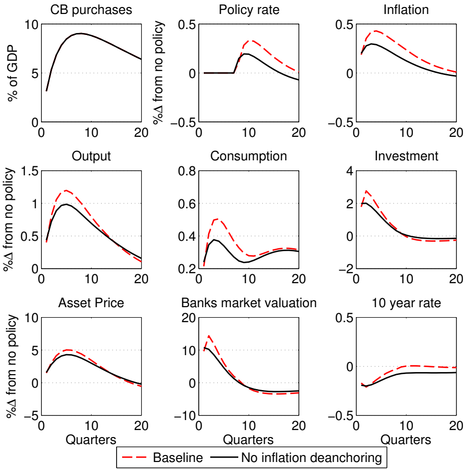
APP with and without reanchoring channel



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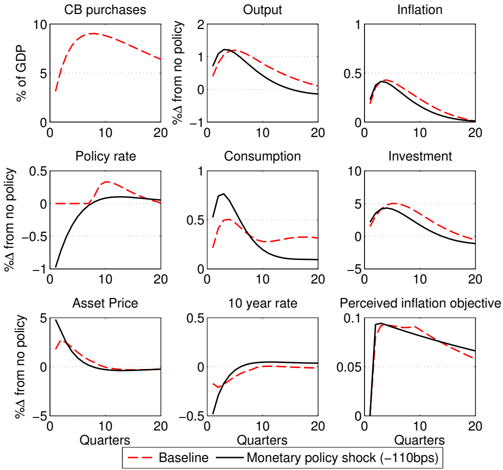
APP and monetary policy shock



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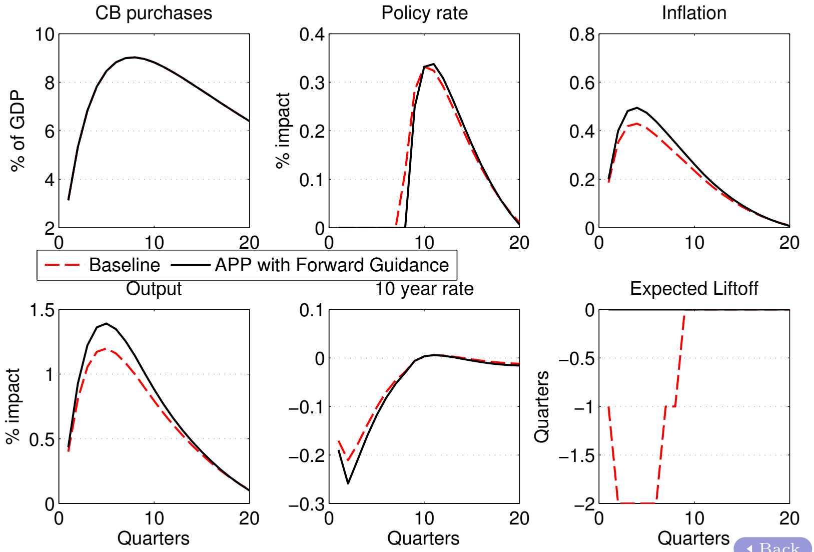
APP and forward guidance



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Households

- Maximize utility

$$E_t \sum_{i=0}^{\infty} \beta^i \left[\ln(C_{t+i} - hC_{t+i-1}) - \frac{\chi}{1+\varphi} L_{t+i}^{1+\varphi} \right]$$

- subject to

$$C_t + D_{ht+1} = W_t L_t + \Pi_t + T_t + R_t D_t$$

- where
  - D_{ht} : short term debt (deposits and government debt)
  - Π_t : payouts to the household from firm ownership net the transfers it gives to the bankers

Wage setting

- Labor supply is a composite of heterogeneous labor services

$$N_t = \left[\int_0^1 N_{ft}^{\frac{\varepsilon^W - 1}{\varepsilon^W}} df \right]^{\frac{\varepsilon^W}{\varepsilon^W - 1}} \tag{3}$$

where N_{ft} is the supply of labor service f.

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- From cost minimization by firms:

$$N_{ft} = \left(\frac{W_{ft}}{W_t} \right)^{-\varepsilon^W} N_t \tag{4}$$

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- Staggered wage setting a la Calvo
  - Wages can be adjusted with probability $1 - \gamma_W$
  - Indexation with probability γ_W $(\Pi_t^\dagger)$

Wage Setting

- Optimal Wage Setting

$$\sum_{i=0}^{\infty} \gamma^i \beta^i \Lambda_{t+i} \left[\frac{W_t^* \Pi_{t,t+i}^{\dagger}}{P_{t+i}} - \mu_W N_{ft+i}^{\varphi} \right] N_{ft+i} = 0 \qquad (5)$$

with $\mu_W = \frac{1}{1-1/\varepsilon_W}$.

Wage Setting

- Optimal Wage Setting

$$\sum_{i=0}^{\infty} \gamma^i \beta^i \Lambda_{t+i} \left[\frac{W_t^* \Pi_{t,t+i}^{\dagger}}{P_{t+i}} - \mu_W N_{ft+i}^{\varphi} \right] N_{ft+i} = 0 \qquad (5)$$

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with $\mu_W = \frac{1}{1-1/\varepsilon_W}$.

- From the law of large numbers,

$$W_t = \left[(1-\gamma_W)(W_t^*)^{1-\varepsilon_W} + \gamma_W (\Pi_{t-1}^{\gamma_{W}i} \Pi_t^{*1-\gamma_{W}i} P_{t-1})^{1-\varepsilon_W} \right]^{\frac{1}{1-\varepsilon_W}} \qquad (6)$$

Household Asset Holdings

- Households can directly hold private securities and long-term gov't bonds subject to transactions costs
  - Private: holding costs: $\frac{1}{2}\kappa(S_{ht} - \overline{S}_h)^2$ for $S_{ht} \geq \overline{S}_h$.
  - Gov't bonds: holding cost: $\frac{1}{2}\kappa(B_{ht} - \overline{B}_h)^2$ for $B_{ht} \geq \overline{B}_h$

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- Household asset demands:

$$S_{ht} = \overline{S}_h + \frac{E_t \Lambda_{t,t+1}(R_{kt+1} - R_{t+1})}{\kappa}$$
$$B_{ht} = \overline{B}_h + \frac{E_t \Lambda_{t,t+1}(R_{bt+1} - R_{t+1})}{\kappa}$$

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- Elasticity κ
    - the excess returns go to zero as $\kappa \to 0$,
    - the quantities go to their frictionless values as $\kappa \to \infty$.

Credit policy with HH asset demand

- Composition of Assets

$$S_t = S_{pt} + S_{ht} + S_{gt}$$

$$B_t = B_{pt} + B_{ht} + B_{gt}$$

Credit policy with HH asset demand

- Composition of Assets

$$S_t = S_{pt} + S_{ht} + S_{gt}$$

$$B_t = B_{pt} + B_{ht} + B_{gt}$$

- Private Asset Demands

$$Q_t(S_t - \overline{S}_h) = \phi_t N_t + Q_t S_{gt} + \Delta q_t \left[B_{gt} - (B_t - \overline{B}_h)\right] + (Q_t + \Delta^2 q_t)\frac{E_t \Lambda_{t,t+1}(R_{kt+1} - R_{t+1})}{\kappa}$$

Credit policy with HH asset demand, cont.

- Relative effects of securities versus gov't bond purchases similar to before.
- Larger effects of purchases with fixed demand.
- Responses of household asset demands can moderate effects.
- Overall, need limits to arbitrage for bank and household asset demands.

Households

- Representative family
  - f bankers, $1 - f$ workers
  - Perfect consumption insurance

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- Each period, $(1 - \sigma)f$ workers randomly become bankers

Households

- Representative family
  - f bankers, $1 - f$ workers
  - Perfect consumption insurance
- With iid. probability $1 - \sigma$, a banker becomes a worker. (Limits bankers' ability to save themselves out of the financial constraints)
- Each period, $(1 - \sigma)f$ workers randomly become bankers
- New banker receives a start-up fund from the family

Assets

- Return on state-contingent debt (capital)

$$R_{kt+1} = \frac{Z_{t+1} + Q_{t+1}}{Q_t}$$

Assets

- Return on state-contingent debt (capital)

$$R_{kt+1} = \frac{Z_{t+1} + Q_{t+1}}{Q_t}$$

- Return on long term gov't bonds

$$R_{bt+1} = \frac{\Xi/P_t + q_{t+1}}{q_t}$$

Financial Intermediaries

- Intermediary Balance Sheet

$$Q_t s_t + q_t b_t = n_t + d_t$$

Financial Intermediaries

- Intermediary Balance Sheet

$$Q_t s_t + q_t b_t = n_t + d_t$$

- Evolution of net worth

$$n_t = R_{kt} Q_{t-1} s_{t-1} + R_{bt} q_{t-1} b_{t-1} - R_t d_{t-1}$$

Financial Intermediaries

- Intermediary Balance Sheet

$$Q_t s_t + q_t b_t = n_t + d_t$$

- Evolution of net worth

$$n_t = R_{kt} Q_{t-1} s_{t-1} + R_{bt} q_{t-1} b_{t-1} - R_t d_{t-1}$$

- FI's objective

$$V_t = E_t \sum_{i=1}^{\infty} (1-\sigma) \sigma^{i-1} \Lambda_{t,t+i} n_{t+i} \tag{7}$$

Limits to Arbitrage

- Agency problem: banker can divert
  - the fraction θ of loans and
  - $\Delta\theta$ of gov't bonds, with $0 \leq \Delta \leq 1$.

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  - $\Delta\theta$ of gov't bonds, with $0 \leq \Delta \leq 1$.
- Lenders can recover the residual funds and shut the bank down.

Limits to Arbitrage

- Agency problem: banker can divert
  - the fraction θ of loans and
  - $\Delta\theta$ of gov't bonds, with $0 \leq \Delta \leq 1$.
- Lenders can recover the residual funds and shut the bank down.
- Incentive constraint

$$V_t \geq \theta Q_t s_t + \Delta\theta q_t b_t. \tag{8}$$

Implications Solution

- ‘Risk-adjusted’ leverage constraint

$$Q_t s_t + \Delta q_t b_t = \phi_t n_t$$

where ϕ_t is an endogenous leverage ratio.

Implications Solution

- ‘Risk-adjusted’ leverage constraint

$$Q_t s_t + \Delta q_t b_t = \phi_t n_t$$

where ϕ_t is an endogenous leverage ratio.

- ‘Arbitrage’ between corporate and sovereign bonds

$$\Delta E_t \beta \tilde{\Omega}_{t+1}(R_{kt+1} - R_{t+1}) = E_t \beta \tilde{\Omega}_{t+1}(R_{bt+1} - R_{t+1}),$$

where $\tilde{\Omega}_{t+1}$ the FI’s discount factor.

Aggregation

- Aggregate leverage

$$Q_t S_{pt} + \Delta q_t B_{pt} \leq \phi_t N_t$$

Aggregation

- Aggregate leverage

$$Q_t S_{pt} + \Delta q_t B_{pt} \leq \phi_t N_t$$

- Aggregate net worth

$$N_t = \sigma \left[(R_{kt} - R_t) Q_{t-1} S_{pt-1} + (R_{bt} - R_t) q_{t-1} B_{pt-1} + R_t N_{t-1} \right] + X$$

Resource Constraint and Government Policy

- Resource constraint

$$Y_t = C_t + I_t + f\left(\frac{I_t}{I_{t-1}}\right) I_t + G + \Phi_t$$

where Φ_t is the portfolio transactions costs.

Resource Constraint and Government Policy

- Resource constraint

$$Y_t = C_t + I_t + f\left(\frac{I_t}{I_{t-1}}\right) I_t + G + \Phi_t$$

where Φ_t is the portfolio transactions costs.

- Central bank balance sheet

$$Q_t S_{gt} + q_t B_{gt} = D_{gt}$$

Resource Constraint and Government Policy

- Resource constraint

$$Y_t = C_t + I_t + f\left(\frac{I_t}{I_{t-1}}\right) I_t + G + \Phi_t$$

where Φ_t is the portfolio transactions costs.

- Central bank balance sheet

$$Q_t S_{gt} + q_t B_{gt} = D_{gt}$$

- Gov't budget constraint

$$G = T_t + (R_{kt} - R_t - \tau) S_{gt-1} + (R_{bt} - R_t) B_{gt-1}$$

Financial Intermediaries' Problem

- End-of-period value function V_t

$$V_{t-1}(s_{t-1}, b_{t-1}, n_{t-1}) = E_{t-1}\Lambda_{t-1,t}\{(1-\sigma)n_t + \sigma W_t(n_t)\}$$

Financial Intermediaries' Problem

- End-of-period value function V_t

$$V_{t-1}(s_{t-1}, b_{t-1}, n_{t-1}) = E_{t-1}\Lambda_{t-1,t}\{(1-\sigma)n_t + \sigma W_t(n_t)\}$$

- Beginning-of-period value function W_t

$$W_t(n_t) = \max_{s_t, b_t} V_t(s_t, b_t, n_t)$$

subject to $[\lambda_t]$

$$V_t(s_t, b_t, n_t) \geq \theta Q_t s_t + \Delta\theta q_t b_t$$

Solution

- Conjecture: linear end-of-period value function

$$V_t = \mu_{st} Q_t s_t + \mu_{bt} q_t b_t + \nu_t n_t$$

Solution

- Conjecture: linear end-of-period value function

$$V_t = \mu_{st} Q_t s_t + \mu_{bt} q_t b_t + \nu_t n_t$$

- Beginning-of-period Lagrange function

$$(1+\lambda_t)(\mu_{st} Q_t s_t + \mu_b q_t b_t + \nu_t n_t) - \lambda_t(\theta Q_t s_t + \Delta\theta q_t b_t)$$

Solution, cont.

- FONC: s_t

$$\mu_{st} = \frac{\lambda_t}{1+\lambda_t}\theta$$

- FONC: b_t

$$\begin{aligned} \mu_{bt} &= \Delta \frac{\lambda_t}{1+\lambda_t}\theta \\ &= \Delta \mu_{st} \end{aligned}$$

- FONC: λ_t

$$(\mu_{st} Q_t s_t + \mu_{bt} q_t b_t + \nu_t n_t) - (\theta Q_t s_t + \Delta \theta q_t b_t) = 0$$

Solution, cont.

- Endogenous 'risk-adjusted' leverage constraint:

$$Q_t s_t + \Delta q_t b_t = \phi_t n_t$$

where ϕ_t is the leverage ratio:

$$\phi_t = \frac{\nu_t}{\theta - \mu_{st}}$$

Solution, cont.

- Endogenous 'risk-adjusted' leverage constraint:

$$Q_t s_t + \Delta q_t b_t = \phi_t n_t$$

where ϕ_t is the leverage ratio:

$$\phi_t = \frac{\nu_t}{\theta - \mu_{st}}$$

- Beginning-of-period value function

$$\begin{aligned} W_t(n_t) =& \mu_{st} \left(Q_t s_t^* + \Delta q_t b_t^* \right) + \nu_t n_t \\ =& (\mu_{st}\phi_t + \nu_t) n_t \\ =& \theta \phi_t n_t \end{aligned}$$

Solution, cont.

- End-of-period value function

$$\mu_{st-1}Q_{t-1}s_{t-1} + \mu_{bt-1}q_{t-1}b_{t-1} + \nu_{t-1}n_{t-1} = E_{t-1}\Lambda_{t-1,t}\{(1-\sigma)n_t + \sigma W_t(n_t)\},$$

subject to

$$n_t = (R_{kt} - R_t)Q_{t-1}s_{t-1} + (R_{bt} - R_t)q_{t-1}b_{t-1} + R_t n_{t-1}$$

Solution, cont.

- End-of-period value function

$$\mu_{st-1}Q_{t-1}s_{t-1} + \mu_{bt-1}q_{t-1}b_{t-1} + \nu_{t-1}n_{t-1} = E_{t-1}\Lambda_{t-1,t}\{(1-\sigma)n_t + \sigma W_t(n_t)\},$$

subject to

$$n_t = (R_{kt} - R_t)Q_{t-1}s_{t-1} + (R_{bt} - R_t)q_{t-1}b_{t-1} + R_t n_{t-1}$$

- After substitution

$$\mu_{st-1}Q_{t-1}s_{t-1} + \mu_{bt-1}q_{t-1}b_{t-1} + \nu_{t-1}n_{t-1} = E_{t-1}\Lambda_{t-1,t}\{[(1-\sigma) + \sigma\theta\phi_t] (R_{kt} - R_t)Q_{t-1}s_{t-1} + (R_{bt} - R_t)q_{t-1}b_{t-1} + R_t n_{t-1}\},$$

Solution, cont.

- Partial marginal values

$$\begin{aligned}\mu_{st} =& E_t\tilde{\Omega}_{t+1}(R_{kt+1} - R_{t+1})\\ \mu_{bt} =& E_t\tilde{\Omega}_{t+1}(R_{bt+1} - R_{t+1}) = \Delta\mu_{st}\\ \nu_t =& E_t\tilde{\Omega}_{t+1}R_{t+1}\\ \tilde{\Omega}_t =& \Lambda_{t,t+1}\left[1 - \sigma + \sigma\theta\phi_t\right]\end{aligned}$$

where $\tilde{\Omega}_t > 1$ is the FI's discount factor.

Solution, cont.

- Partial marginal values

$$\begin{aligned}
\mu_{st} =& E_t \tilde{\Omega}_{t+1}(R_{kt+1} - R_{t+1}) \\
\mu_{bt} =& E_t \tilde{\Omega}_{t+1}(R_{bt+1} - R_{t+1}) = \Delta \mu_{st} \\
\nu_t =& E_t \tilde{\Omega}_{t+1} R_{t+1} \\
\tilde{\Omega}_t =& \Lambda_{t,t+1} \left[1 - \sigma + \sigma \theta \phi_t\right]
\end{aligned}$$

where $\tilde{\Omega}_t > 1$ is the FI's discount factor.

- End-of-period value function is indeed linear.

Capital producers

- Profit Maximization

$$\max E_t \sum_{\tau=t}^{\infty} \beta^t \Lambda_{t,\tau} \left\{ (Q_\tau - 1) I_\tau - f\left(\frac{I_\tau + I}{I_{\tau-1}}\right)(I_\tau) \right\} \tag{9}$$

where $f(1) = f'(1) = 0$ and $f''(1) > 0$.

Capital producers

- Profit Maximization

$$\max E_t \sum_{\tau=t}^{\infty} \beta^t \Lambda_{t,\tau} \left\{ (Q_\tau - 1) I_\tau - f\left(\frac{I_\tau + I}{I_{\tau-1}} \right) (I_\tau) \right\} \quad (9)$$

where $f(1) = f'(1) = 0$ and $f''(1) > 0$.

- "Q" relation for investment:

$$Q_t = 1 + f(\cdot) + \frac{I_t}{I_{t-1}} f'(\cdot) - E_t \beta \Lambda_{t,t+1} \left(\frac{I_{t+1}}{I_t} \right)^2 f'(\cdot) \quad (10)$$

Intermediate Goods Producer

- Production

$$Y_t = A_t(K_t)^{\alpha} L_t^{1-\alpha} \tag{11}$$

Intermediate Goods Producer

- Production

$$Y_t = A_t(K_t)^{\alpha} L_t^{1-\alpha} \tag{11}$$

- Evolution of firm capital

$$K_{t+1} = [I_t + (1-\delta)K_t]$$

Intermediate Goods Producer

- Production
$$Y_t = A_t(K_t)^\alpha L_t^{1-\alpha} \tag{11}$$
- Evolution of firm capital
$$K_{t+1} = [I_t + (1-\delta)K_t]$$
- Share issue
$$S_t = K_{t+1}$$

Intermediate Goods Producers, cont.

- FONC labor:

$$P_{mt}(1-\alpha)\frac{Y_t}{L_t} = W_t, \tag{12}$$

  P_{mt} be the price of intermediate goods output

- Capital rental

$$Z_t = P_{mt}\alpha\frac{Y_{t+1}}{K_{t+1}} - \delta,$$

  the replacement price of used capital is fixed at unity.

Retailers and price setting

- Final output as a composite of retail output

$$Y_t = \left[\int_0^1 {Y_{ft}}^{\frac{\varepsilon-1}{\varepsilon}} df\right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{13}$$

where Y_{ft} is output by retailer f.

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- Final output as a composite of retail output

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where Y_{ft} is output by retailer f.

- From cost minimization by users of final output:

$$Y_{ft} = \left(\frac{P_{ft}}{P_t} \right)^{-\varepsilon} Y_t \tag{14}$$

Retailers and price setting

- Final output as a composite of retail output

$$Y_t = \left[\int_0^1 Y_{ft}^{\frac{\varepsilon-1}{\varepsilon}} df \right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{13}$$

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- Staggered price setting a la Calvo
  - Price can be adjusted with probability $1 - \gamma$
  - Indexation with probability γ
    - Partially $(1 - \gamma_P)$ to target Π_t^*,
    - Partially (γ_P) to past inflation Π_{t-1}
    - $\Pi_t^\dagger = \Pi_t^{*1-\gamma_P} \Pi_{t-1}^{\gamma_P}$

Price Setting

- Price Setting Problem

$$\max \sum_{i=0}^{\infty} \gamma^i \beta^i \Lambda_{t,t+i} \left[\frac{P_t^* \Pi_{t,t+i}^{\dagger}}{P_{t+i}} - P_{mt+i} \right] Y_{ft+i} \tag{15}$$

Price Setting

- Price Setting Problem

$$\max \sum_{i=0}^{\infty} \gamma^i \beta^i \Lambda_{t,t+i} \left[\frac{P_t^* \Pi_{t,t+i}^{\dagger}}{P_{t+i}} - P_{mt+i} \right] Y_{ft+i} \tag{15}$$

- Optimal Price Setting

$$\sum_{i=0}^{\infty} \gamma^i \beta^i \Lambda_{t,t+i} \left[\frac{P_t^* \Pi_{t,t+i}^{\dagger}}{P_{t+i}} - \mu P_{mt+i} \right] Y_{ft+i} = 0 \tag{16}$$

with $\mu = \frac{1}{1-1/\varepsilon}$.

Price Setting

- Price Setting Problem

$$\max \sum_{i=0}^{\infty} \gamma^i \beta^i \Lambda_{t,t+i} \left[\frac{P_t^* \Pi_{t,t+i}^{\dagger}}{P_{t+i}} - P_{mt+i} \right] Y_{ft+i} \tag{15}$$

- Optimal Price Setting

$$\sum_{i=0}^{\infty} \gamma^i \beta^i \Lambda_{t,t+i} \left[\frac{P_t^* \Pi_{t,t+i}^{\dagger}}{P_{t+i}} - \mu P_{mt+i} \right] Y_{ft+i} = 0 \tag{16}$$

with $\mu = \frac{1}{1-1/\varepsilon}$.

- From the law of large numbers,

$$P_t = \left[(1-\gamma)(P_t^*)^{1-\varepsilon} + \gamma (\Pi_{t-1}^{\gamma_P} \Pi_t^{*1-\gamma_P} P_{t-1})^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}} \tag{17}$$

Parameters

Households		
β	0.994	Discount rate
h	0.567	Habit parameter
χ	20.758	Relative utility weight of labor
B/Y	0.700	Steady state Treasury supply
$\bar{K}^h/K$	0.000	Proportion of direct capital holdings of the HHs
$\bar{B}^h/B$	0.750	Proportion of long term Treasury holdings of the HHs
κ	1.000	Portfolio adjustment cost
φ	2.000	Inverse Frisch elasticity of labor supply
ϵ_W	4.333	Elasticity of labor substitution
γ_W	0.765	Probability of keeping the wage constant
$\gamma_{W,-1}$	0.635	Wage indexation parameter
$\rho_{\pi^* p}$	0.990	Persistence of a shock to the perceived inflation objective
κ	0.0622	Kalman-gain
ς	0.0683	Relative weight of APP surprise
Financial Intermediaries		
θ	0.315	Fraction of capital that can be diverted
Δ	0.840	Proportional advantage in seizure rate of government debt
ω	0.0047	Proportional transfer to the entering bankers
σ	0.925	Survival rate of the bankers
Intermediate good firms		
α	0.360	Capital share
δ	0.025	Depreciation rate

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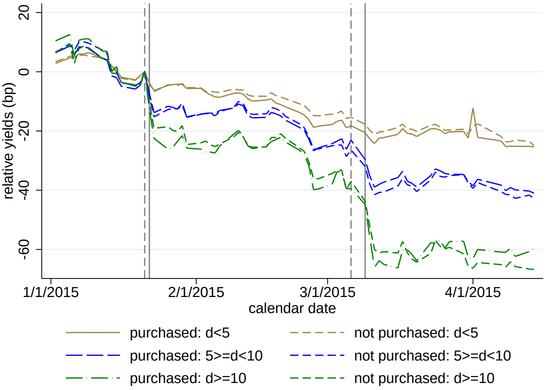
Parameters, cont.

Capital Producing Firms		
η_i	5.169	Inverse elasticity of net investment to the price of capital
Retail Firms		
ϵ	3.857	Elasticity of substitution
γ_P	0.920	Probability of keeping the price constant
$\gamma_{P,-1}$	0.417	Price indexation parameter
Government		
$\frac{G}{Y}$	0.200	Steady state proportion of government expenditures
ρ_i	0.865	Interest rate smoothing parameter
κ_π	1.904	Inflation coefficient in the policy rule
$\kappa_{d\pi}$	0.185	Inflation growth coefficient in the policy rule
κ_{dy}	0.147	Output growth coefficient in the policy rule
$\rho_{i,zlb}$	0.500	Interest rate smoothing leaving the lower bound
γ_ψ	0.290	Share of private assets in the purchase program
Shocks		
ψ	0.018	Initial asset purchase shock
$\rho_{1,\psi}$	1.700	First AR coefficient of the purchase shock
$\rho_{2,\psi}$	-0.710	Second AR coefficient of the purchase shock
e_β	0.044	Initial savings preference shock (β)
ρ_β	0.815	Persistence of the savings preference shock (β)

Bond yields around announcement and implementation

- Both announcement and implementation of the PSPP have sizable impact on yields
- High duration bonds are impacted significantly more
- Not only purchased bonds show lower yields (no scarcity channel)



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Impact of purchases on bond yields

- No significant effect of individual trades on daily yield changes (excludes first two weeks)
- Three different setups: (i) simple panel, (ii) event study around the first purchase, (iii) black-out period
- No differential impact of trading intensity (several measures)
- Stringent controls: time FE, bond FE.

	Trading effect				First purchase effect		Blackout period effect
	purchase dummy		relative purchases				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
purchase effect	-0.021	0.059	0.019	-0.368	-0.045	0.047	0.862
	(0.041)	(0.087)	(0.038)	(0.327)	(0.088)	(0.200)	(1.310)
purchase intensity (perc.25–50)						0.016	
						(0.255)	
purchase intensity (perc.50–75)						-0.278	
						(0.265)	
purchase intensity (perc.75–100)						-0.094	
						(0.265)	
purchase effect × April		0.317		0.446			
		(0.257)		(0.339)			
purchase effect × May		0.067		0.666*			
		(0.110)		(0.362)			
purchase effect × June		0.029		0.680*			
		(0.119)		(0.349)			
purchase effect × July		-0.481***		0.266			
		(0.114)		(0.342)			
purchase effect × Aug		0.105		0.363			
		(0.095)		(0.332)			
purchase effect × Sep		-0.278**		0.332			
		(0.139)		(0.349)			
purchase effect × Oct		-0.216**		0.368			
		(0.097)		(0.334)			
purchase effect × Nov		-0.285***		0.269			
		(0.099)		(0.335)			
purchase effect × Dec		0.236**		0.166			
		(0.108)		(0.418)			
Observations	913,091	913,091	913,044	913,044	774,051	774,051	434
R-squared	0.0236	0.0236	0.0236	0.0236	0.0251	0.0251	0.6261
-	-	-	-	-	-	-	-
Bond FE	YES	YES	YES	YES	YES	YES	YES
daily Time FE	YES	YES	YES	YES	YES	YES	YES
-	-	-	-	-	-	-	-
Cluster Bond	YES	YES	YES	YES	YES	YES	YES

*** p<0.01, ** p<0.05, * p<0.1

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The impact of the PSPP on euro area banks

- QE as a form of bank capital relief: the larger the sovereign bonds holdings, the larger the benefits
- Event study: reaction of each bank's stock price to PSPP announcement. Focus on quoted banks with info on govt bond holdings (as of end-2014). SNL data, 150 banks.
- 2-day changes: January 21-23; March 4-6
- Need to control for:
  - Broader effects on discounted future profits through improvement in macroeconomic conditions
    - Proxy: increase in country's stock price index
  - Impact of flattened yield curve on interest rate margins
    - Proxy 1: change in 10-yrs govt yield
    - Proxy 2: dummy=1 if bank located in EA
- Support of bank capital relief in Jan 2015.

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Equity price reactions between January 21 and 23, 2015 (SNL sample)

	(1)	(2)	(3)
constant	2.55***	2.09***	1.74***
	(4.38)	(3.81)	(3.21)
Δyield	15.67***	9.12***	8.76***
	(4.61)	(2.83)	(2.76)
ΔSM	0.39***	0.80***	0.77***
	(2.88)	(3.96)	(4.54)
EA bank (d)		-2.23***	-2.56***
		(-3.65)	(-4.69)
exposure			0.06***
			(2.73)
Adj. R^2	0.09	0.19	0.26
No. Obs.	150	150	120

(White robust t-statistics)

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Signal of lower future policy rates

- Impact on average expectation from SPF
  - 2015Q1-2015Q3: MRO rate forecasts declined from 11 to 6bps for 2016 and from 43 to 31bps for 2017
- What do low interest rates mean? (Andrade et al., 2015)
  - Policy will be more accommodative
  - Outlook worse than thought: Trap will last longer
- Which one prevailed?
  - Estimate individual pre-crisis interest rate rule; panel regression over 1999Q1-2007Q4
  - Compare observed individual policy rate forecast with forecasts consistent with individual policy rule
  - On average APP associated with expected future accommodation

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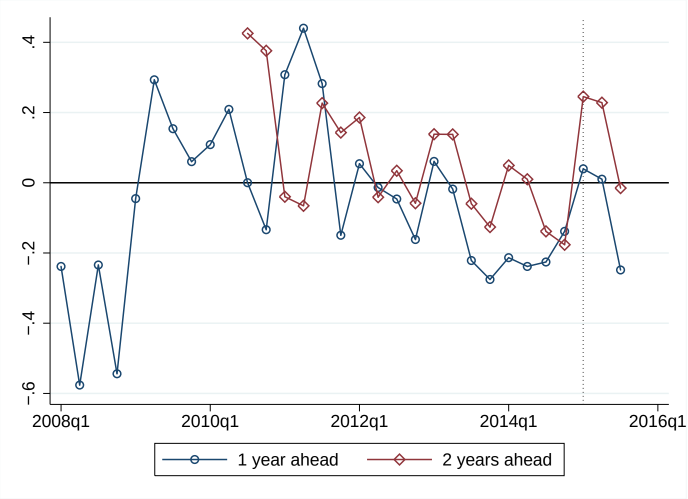
Expected deviations from normal times policy



Source: ECB SPF and Own calculations

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Risk of reduced effectiveness of the APP

- Increased issuance of long-term bonds by national governments would raise investors' exposure to duration risk, offsetting the impact of APP.
- Following announcement of PSPP, average maturity of newly issued eligible bonds relative to maturing bonds rose by approx 2 yrs.
- Combined effect on duration risk is a reduction, over 2015Q1-Q4:
  - Govt issuance increased supply of 10-yrs equivalent debt by 1.9 percent of GDP.
  - PSPP reduced it by 4.5 percent of GDP.

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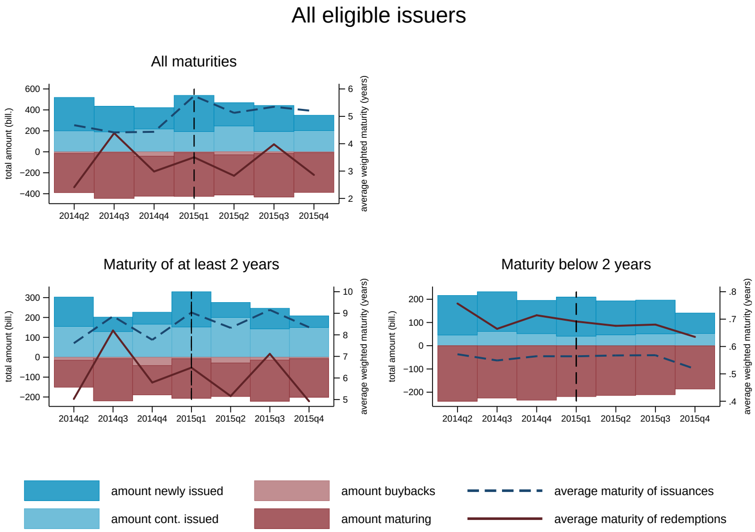
Limits to the effectiveness



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