

# The Reanchoring Channel of QE

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

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Oct 2016

\*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

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  - ▶ Binding effective lower bound
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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)
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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

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    - ▶ Market expectations (Krishnamurthy and Vissing-Jorgensen, 2011; Altavilla, Carboni and Motto, 2015): premium component
- ▶ 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)

## EA event study

- ▶ ECB press conferences
  - ▶ January 2013 - December 2015
  - ▶ 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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- ▶ 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

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  - ▶ Robustness: 5-year inflation swap yields 5-year-ahead
- ▶ 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*** (-4.392)	0.0932 (1.551)	-0.583** (-3.151)	-0.508*** (-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

# Financial intermediaries

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  - ▶  $f$  bankers,  $1 - f$  workers
  - ▶ Bankers: start-up fund  $X$ , stochastic survival  $\sigma$

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  - ▶  $f$  bankers,  $1 - f$  workers
  - ▶ Bankers: start-up fund  $X$ , stochastic survival  $\sigma$
- ▶ Assets:
  - ▶ State-contingent loans  $(Q_t S_t)$ :  $R_{kt}$
  - ▶ Long-term government bond  $(q_t B_t)$ :  $R_{bt}$

# Financial intermediaries

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  - ▶ Collect deposits from HHs:  $D_t$
  - ▶ Accumulate net worth from retained earnings  $N_t$
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  - ▶ Invest them into loans and government bonds
- ▶ Agency problem: bankers can divert
  - ▶ the fraction  $\theta$  of loans and
  - ▶  $\Delta\theta$  of gov't bonds, with  $0 \leq \Delta \leq 1$ .



# Implications

[Details](#)

- ▶ ‘Risk-adjusted’ aggregate leverage constraint

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

where  $\phi_t$  is an endogenous leverage ratio.

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- ▶ ‘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

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

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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

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

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$$Q_t S_t = \phi_t N_t + Q_t S_{gt} + \Delta q_t (B_{gt} - B_t)$$



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- ▶ Private Securities Demand

$$Q_t S_t = \phi_t N_t + Q_t S_{gt} + \Delta q_t (B_{gt} - B_t)$$

- ▶ 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.

# Central Bank

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- ▶ Interest rate policy with ZLB:  $i_t$

$$i_t = \max(0, i_t^*)$$

$$i_t^* = \rho_i i_{t-1} + (1 - \rho_i) [\pi_t^* + \kappa_\pi (\pi_t - \pi_t^*) + \kappa_y y_t] + \kappa_{\Delta\pi} (\pi_t - \pi_{t-1}) + \kappa_{\Delta y} (y_t - y_{t-1}) + \varepsilon_t$$

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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,

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

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- ▶ Idea
  - ▶ Motivated by constant gain ( $\kappa$ ) learning
  - ▶ Agents assume LSAP substitutes IRs at the ZLB,  
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- ▶ Idea
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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
  - ▶ Agents optimize, learn about CB target
  - ▶ CB sets LSAP policy and interest rates s.t. ZLB
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  - ▶ Optimality conditions loglinearized around a non-stochastic steady state
  - ▶ Shocks hit in period 1
  - ▶ Inflation target stays unchanged (unknown to agents)
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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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  - ▶ FI leverage: 6
    - ▶ Assets over equity of FIs, NFCs in EA SA
- ▶ Learning rule
  - ▶ 15bps decline in LT expectations before APP ( $\kappa = 0.062$ )
  - ▶ Similar impact of APP and 1.1% monopol shock ( $\varsigma = 0.068$ )  
Monopol
  - ▶ 9bps increase on APP announcement (consistent with SPF change between 2015Q1-Q3)

## Calibration, cont.

- ▶ Conventional parameters
  - ▶ Price- and wage stickiness, consumption habits, investment adjustment costs, policy rule **Parameters**
  - ▶ As estimated in NAWM (Christoffel et al., 2008) **Monpol**
  - ▶ High nominal stickiness

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  - ▶ As estimated in NAWM (Christoffel et al., 2008) **Monpol**
  - ▶ High nominal stickiness
- ▶ 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  $-100\text{bps}$
  - ▶ Deanchoring: perceived target  $-15\text{ bps}$ , expected liftoff: 7 quarters



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- ▶ APP **Impact**
  - ▶ Peak effects: inflation  $40\text{bps}$ , output:  $1.1\%$
  - ▶ Important channel: reanchoring (1/3 of inflation effect) **Reanchoring**
  - ▶ Alternative calibration: inflation  $25\text{bps}$ , output  $50\text{bps}$ , reanchoring 1/2 of inflation effect
  - ▶ Equivalent to a  $-1.1\%$  monopol shock **Monopol**

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- ▶ Raising efficiency
  - ▶ Maturity extension (from 8 to 11,  $+10\text{bps}$  inflation effect) **Maturity**
  - ▶ Forward guidance ( $+5\text{bps}$  inflation effect) **Forward guidance**

Overview  
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Literature  
○

Event study  
○○○

Model  
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Solution  
○

Results  
○○○●

Conclusion  
○

Figures  
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References

## Other channels

- ▶ Duration channel [Figure](#)

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- ▶ Duration channel [Figure](#)
- ▶ “Stealth recapitalization” [Recapitalization](#)

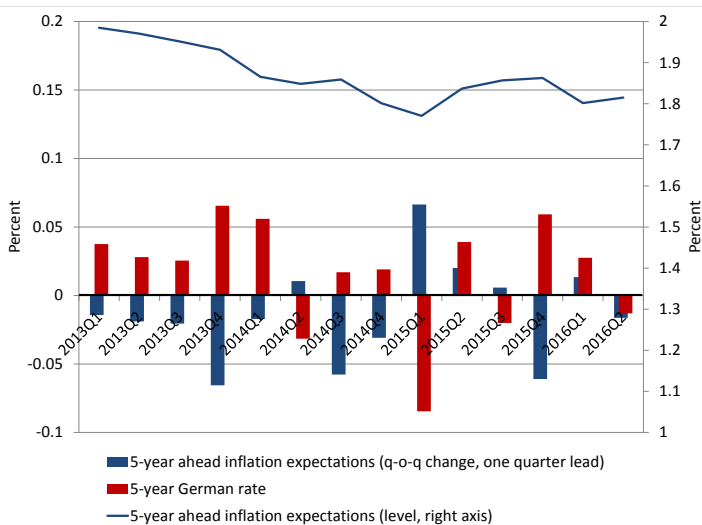
# Conclusion

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  - ▶ Event-study evidence
  - ▶ Quantified in a DSGE macromodel

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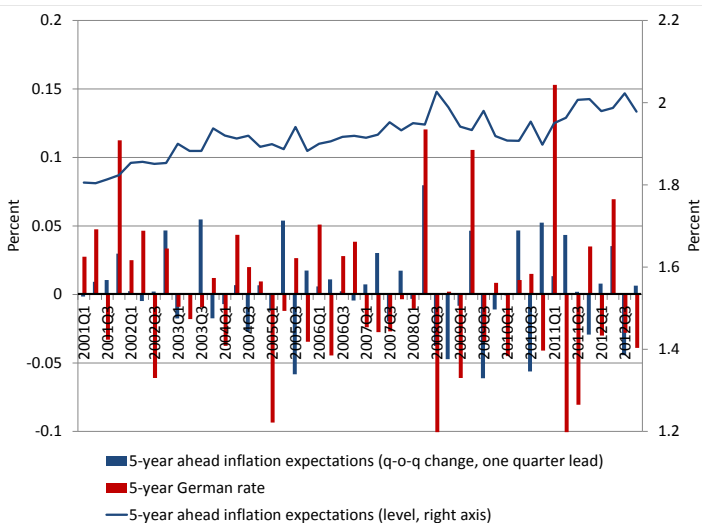
- ▶ Inflation-expectation reanchoring: key channel
  - ▶ Event-study evidence
  - ▶ Quantified in a DSGE macromodel
- ▶ Policy conclusions
  - ▶ Inactivity particularly costly with deanchoring
  - ▶ Reanchoring enhances policy effectiveness
  - ▶ Duration of targeted assets should be maximized
  - ▶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

# Euro Area Inflation Expectations



Source: ECB, Survey of Professional Forecasters.

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## Impact on 5x5 inflation-linked swap rates

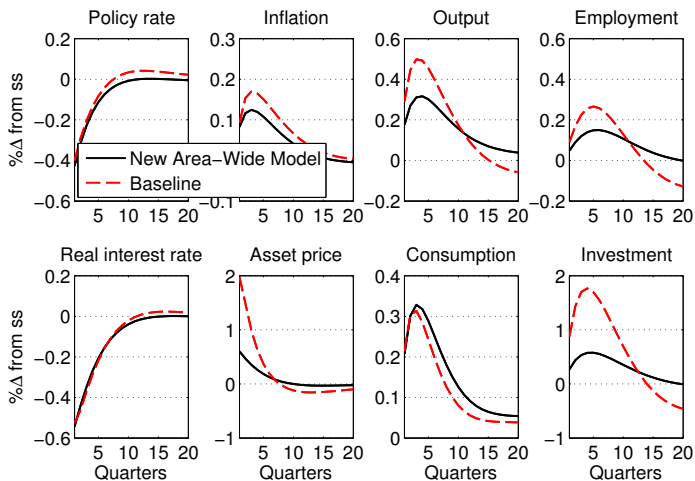
	(1) Post 2013	(2) Pre 2013	(3) APP	(4) APP, No FG
	Change in 5x5 inflation-linked swap yields			
5-year German yield surprise	-1.222** (-2.754)	0.571*** (4.303)	-1.533** (-2.592)	-1.189** (-2.571)
Sample	2013q1-2016q2	2004q1-2012q4	2014q2-2016q2	2014q2-2016q2
Observations	15	34	10	10
R-squared	0.315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

Robust t-statistics in parentheses

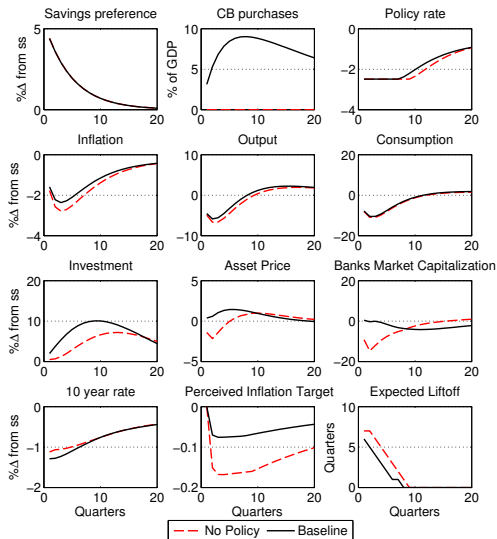
\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

- ▶ Easing yields to reanchoring

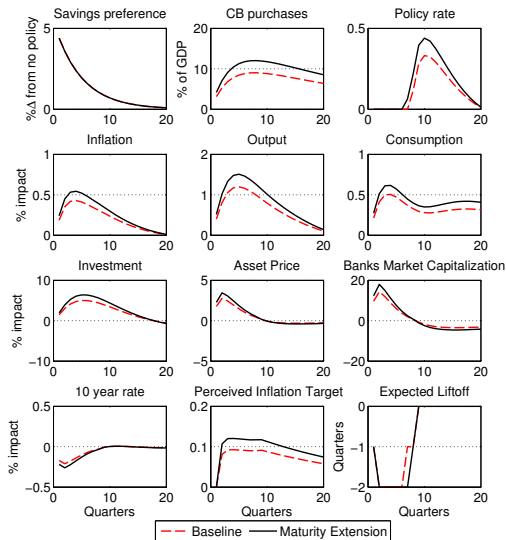
# Impact of an interest rate innovation



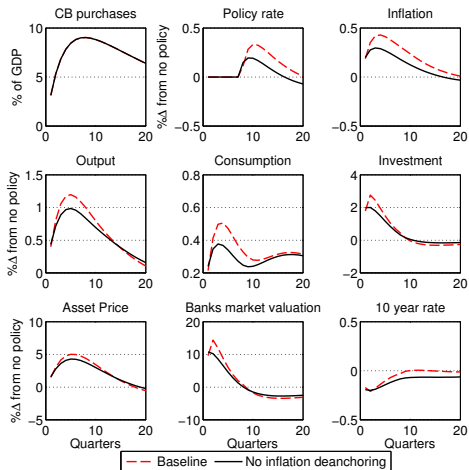
# Demand shock and APP



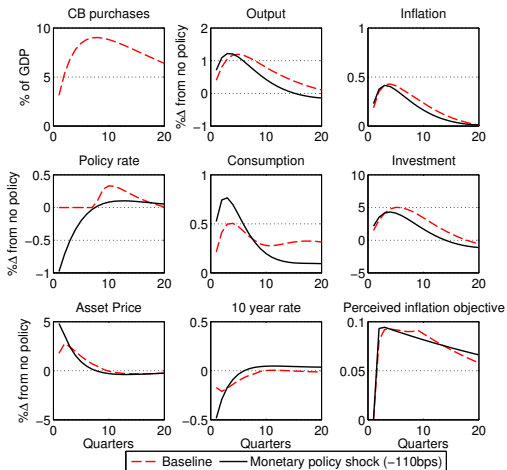
# APP and maturity extension



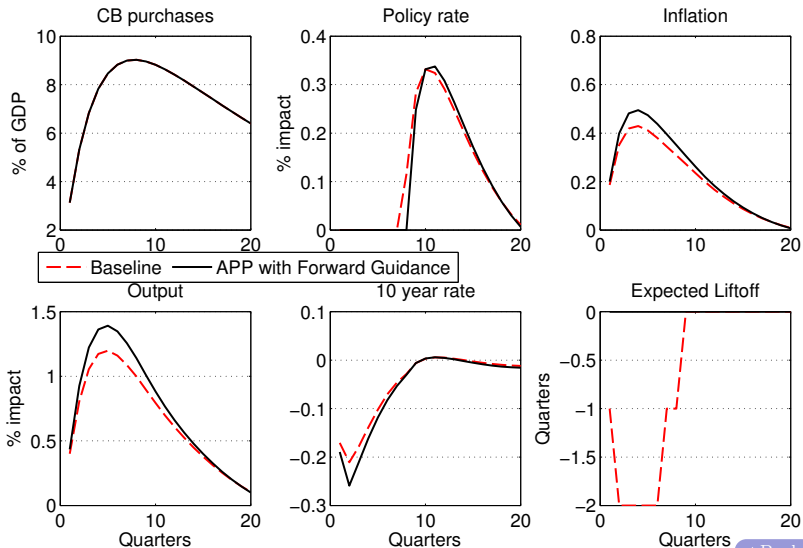
# APP with and without reanchoring channel



# APP and monetary policy shock



# 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)
  - ▶  $\Pi_t$  : 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

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

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

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

# Wage Setting

## ► Optimal Wage Setting

$$\sum_{i=0}^{\infty} \gamma^i \beta^i \Lambda_{t+i} \left[ \frac{W_t^* \Pi_{t,t+i}^\dagger}{P_{t+i}} - \mu_W N_{ft+i}^\varphi \right] N_{ft+i} = 0 \quad (3)$$

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



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

- ▶ From the law of large numbers,

$$W_t = \left[ (1 - \gamma_W)(W_t^*)^{1-\varepsilon_W} + \gamma_W (\Pi_{t-1}^{\gamma_W} \Pi_t^{*1-\gamma_W} P_{t-1})^{1-\varepsilon_W} \right]^{\frac{1}{1-\varepsilon_W}} \quad (4)$$

## Household Asset Holdings

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

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- ▶ Household asset demands:

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

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

# 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

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

## 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
- ▶ New banker receives a start-up fund from the family

# Assets

- ▶ Return on state-contingent debt (capital)

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

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

- ▶ 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

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

- ▶ FI's objective

$$V_t = E_t \sum_{i=1}^{\infty} (1 - \sigma) \sigma^{i-1} \Lambda_{t,t+i} n_{t+i} \quad (5)$$

## Limits to Arbitrage

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

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- ▶ Lenders can recover the residual funds and shut the bank down.
  
- ▶ Incentive constraint

$$V_t \geq \theta Q_t s_t + \Delta \theta q_t b_t. \quad (6)$$

# Implications

[Solution](#)

- ▶ ‘Risk-adjusted’ leverage constraint

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

where  $\phi_t$  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  $\phi_t$  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

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



## 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  $\Phi_t$  is the portfolio transactions costs.

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

- ▶ 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  $V_t$

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

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- ▶ 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

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

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

- ▶ Beginning-of-period Lagrange function

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

## 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:  $\lambda_t$

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



## Solution, cont.

- ▶ Endogenous ‘risk-adjusted’ leverage constraint:

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

where  $\phi_t$  is the leverage ratio:

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

## Solution, cont.

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where  $\phi_t$  is the leverage ratio:

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

- ▶ Beginning-of-period value function

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

## 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

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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

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

## Solution, cont.

- ▶ Partial marginal values

$$\mu_{st} = E_t \tilde{\Omega}_{t+1} (R_{kt+1} - R_{t+1})$$

$$\mu_{bt} = E_t \tilde{\Omega}_{t+1} (R_{bt+1} - R_{t+1}) = \Delta \mu_{st}$$

$$\nu_t = E_t \tilde{\Omega}_{t+1} R_{t+1}$$

$$\tilde{\Omega}_t = \Lambda_{t,t+1} [1 - \sigma + \sigma \theta \phi_t]$$

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

## Solution, cont.

- ▶ Partial marginal values

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$$\mu_{bt} = E_t \tilde{\Omega}_{t+1} (R_{bt+1} - R_{t+1}) = \Delta \mu_{st}$$

$$\nu_t = E_t \tilde{\Omega}_{t+1} R_{t+1}$$

$$\tilde{\Omega}_t = \Lambda_{t,t+1} [1 - \sigma + \sigma \theta \phi_t]$$

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

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

## Capital producers

► Profit Maximization

$$\max E_t \sum_{\tau=t}^{\infty} \beta^t \Lambda_{t,\tau} \left\{ (Q_{\tau} - 1)I_{\tau} - f\left(\frac{I_{\tau} + I}{I_{\tau-1}}\right) (I_{\tau}) \right\} \quad (7)$$

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

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

- ▶ “ $Q$ ” relation for investment:

$$Q_t = 1 + f(\cdot) + \frac{I_t}{I_{t-1}} f'(\cdot) - E_t \beta \Lambda_{t,t+1} \left( \frac{I_{t+1}}{I_t} \right)^2 f'(\cdot) \quad (8)$$



# Intermediate Goods Producer

► Production

$$Y_t = A_t(K_t)^\alpha L_t^{1-\alpha} \quad (9)$$

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

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- ▶ 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:

$$P_{mt}(1 - \alpha)\frac{Y_t}{L_t} = W_t, \quad (10)$$

$P_{mt}$  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

$$Y_t = \left[ \int_0^1 Y_{ft}^{\frac{\varepsilon-1}{\varepsilon}} df \right]^{\frac{\varepsilon}{\varepsilon-1}} \quad (11)$$

where  $Y_{ft}$  is output by retailer  $f$ .

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- ▶ From cost minimization by users of final output:

$$Y_{ft} = \left( \frac{P_{ft}}{P_t} \right)^{-\varepsilon} Y_t \quad (12)$$

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

# Price Setting

## ► Price Setting Problem

$$\max \sum_{i=0}^{\infty} \gamma^i \beta^i \Lambda_{t,t+i} \left[ \frac{P_t^* \Pi_{t,t+i}^\dagger}{P_{t+i}} - P_{mt+i} \right] Y_{ft+i} \quad (13)$$



## Price Setting

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$$\max \sum_{i=0}^{\infty} \gamma^i \beta^i \Lambda_{t,t+i} \left[ \frac{P_t^* \Pi_{t,t+i}^\dagger}{P_{t+i}} - P_{mt+i} \right] Y_{ft+i} \quad (13)$$

- ▶ Optimal Price Setting

$$\sum_{i=0}^{\infty} \gamma^i \beta^i \Lambda_{t,t+i} \left[ \frac{P_t^* \Pi_{t,t+i}^\dagger}{P_{t+i}} - \mu P_{mt+i} \right] Y_{ft+i} = 0 \quad (14)$$

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

## Price Setting

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$$\max \sum_{i=0}^{\infty} \gamma^i \beta^i \Lambda_{t,t+i} \left[ \frac{P_t^* \Pi_{t,t+i}^\dagger}{P_{t+i}} - P_{mt+i} \right] Y_{ft+i} \quad (13)$$

- ▶ Optimal Price Setting

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

- ▶ From the law of large numbers,

$$P_t = \left[ (1 - \gamma)(P_t^*)^{1-\varepsilon} + \gamma(\Pi_{t-1}^{\gamma_P} \Pi_t^{*1-\gamma_P} P_{t-1})^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}} \quad (15)$$

# Parameters

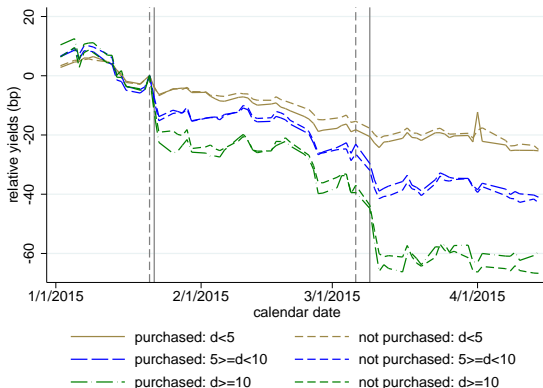
Households		
$\beta$	0.994	Discount rate
$h$	0.567	Habit parameter
$\chi$	20.758	Relative utility weight of labor
$B/Y$	0.700	Steady state Treasury supply
$\bar{K}^h/K$	0.000	Proportion of direct capital holdings of the HHs
$\bar{B}^h/B$	0.750	Proportion of long term Treasury holdings of the HHs
$\kappa$	1.000	Portfolio adjustment cost
$\varphi$	2.000	Inverse Frisch elasticity of labor supply
$\epsilon_W$	4.333	Elasticity of labor substitution
$\gamma_W$	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
$\kappa$	0.0622	Kalman-gain
$\varsigma$	0.0683	Relative weight of APP surprise
Financial Intermediaries		
$\theta$	0.315	Fraction of capital that can be diverted
$\Delta$	0.840	Proportional advantage in seizure rate of government debt
$\omega$	0.0047	Proportional transfer to the entering bankers
$\sigma$	0.925	Survival rate of the bankers
Intermediate good firms		
$\alpha$	0.360	Capital share
$\delta$	0.025	Depreciation rate

## Parameters, cont.

Capital Producing Firms		
$\eta_i$	5.169	Inverse elasticity of net investment to the price of capital
Retail Firms		
$\epsilon$	3.857	Elasticity of substitution
$\gamma_P$	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
$\rho_i$	0.865	Interest rate smoothing parameter
$\kappa_\pi$	1.904	Inflation coefficient in the policy rule
$\kappa_{d\pi}$	0.185	Inflation growth coefficient in the policy rule
$\kappa_{dy}$	0.147	Output growth coefficient in the policy rule
$\rho_{i,zlb}$	0.500	Interest rate smoothing leaving the lower bound
$\gamma_\psi$	0.290	Share of private assets in the purchase program
Shocks		
$\psi$	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
$e_\beta$	0.044	Initial savings preference shock ( $\beta$ )
$\rho_\beta$	0.815	Persistence of the savings preference shock ( $\beta$ )

# 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)



# 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		(5)	(6)	(7)
	(1)	(2)	(3)	(4)			
purchase effect	-0.021 (0.041)	0.059 (0.087)	0.019 (0.038)	0.019 (0.327)	-0.368 (0.088)	0.047 (0.200)	0.862 (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 (0.257)		0.446 (0.330)			
purchase effect × May		0.067 (0.110)		0.660* (0.362)			
purchase effect × June		0.029 (0.119)		0.680* (0.349)			
purchase effect × July		-0.481*** (0.114)		0.266 (0.342)			
purchase effect × Aug		0.105 (0.095)		0.363 (0.332)			
purchase effect × Sep		-0.278** (0.139)		0.332 (0.349)			
purchase effect × Oct		-0.216** (0.097)		0.368 (0.334)			
purchase effect × Nov		-0.285*** (0.099)		0.269 (0.335)			
purchase effect × Dec		0.236** (0.108)		0.166 (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

## 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.

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

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

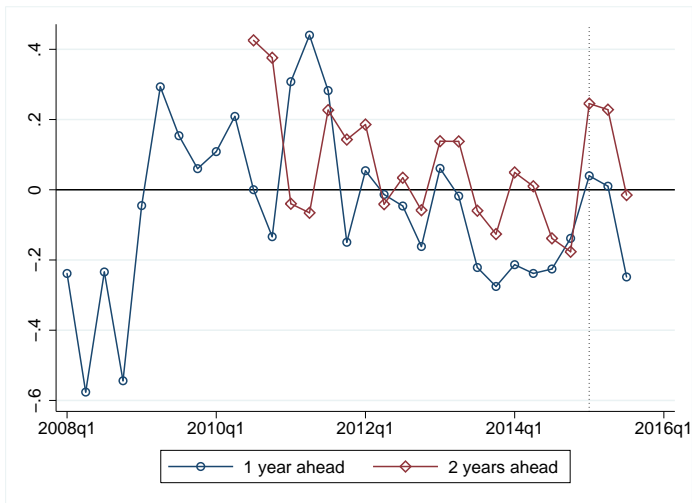
(White robust  $t$ -statistics)



## 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

## Expected deviations from normal times policy



Source: ECB SPF and Own calculations

## 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-yr equivalent debt by 1.9 percent of GDP.
  - ▶ PSPP reduced it by 4.5 percent of GDP.

# Limits to the effectiveness

## All eligible issuers

