Is the bond market competitive? Evidence from the ECB's asset purchase programme

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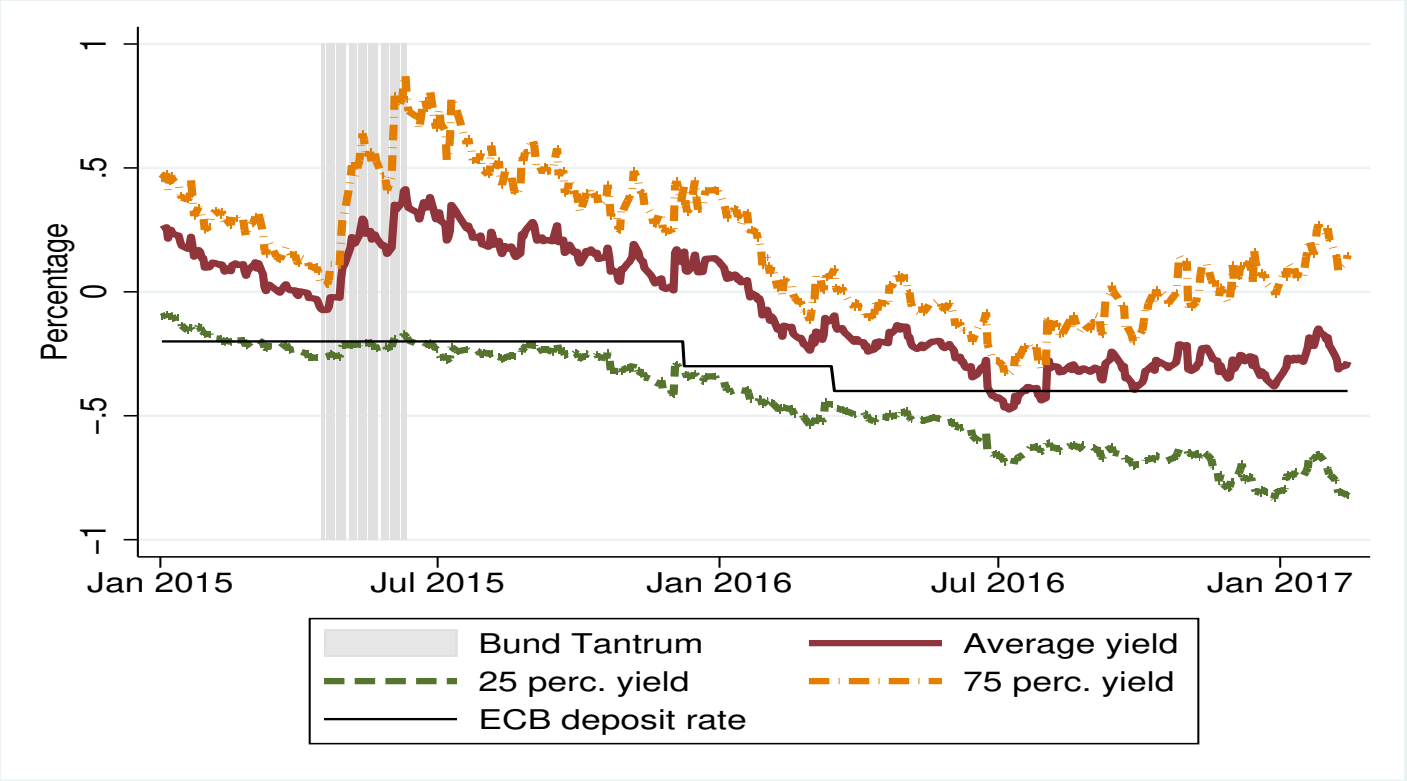
December 2022

The views expressed here are the authors' and do not necessarily reflect those of the ECB or the Eurosystem.

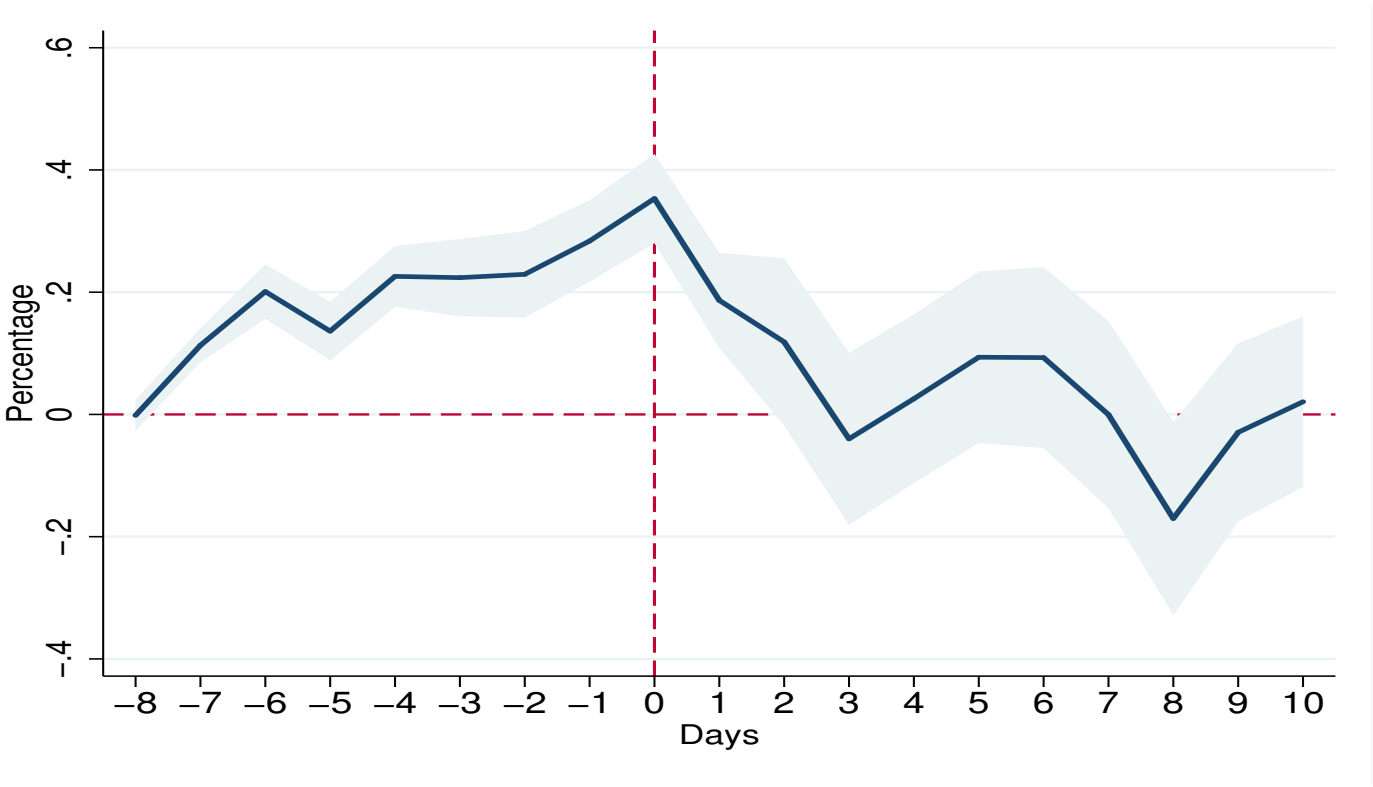
Quantitative Easing and Bond markets

- Implementation of 'unconventional monetary policy' (Quantitative Easing) has led to world wide implementation of **large scale asset purchases** by Central Banks.
  - Raises new question about effectiveness of Monetary policy, but also
  - provides unique opportunity to study microstructure of bond markets
- We focus on the European Central Bank (ECB) Public Sector Purchase Program (PSPP)
  - Do CB get efficient price execution?
  - How to design Large Asset Purchases?
  - Is OTC structure of bond markets competitive?
  - What is role of bond dealers?

German Sovereign Yields during PSPP



German Bund price anomaly



Average **cumulative bond return** *(*$\log(P_{day}/P_{-9})$*) with day ranging from* -9 *to* $+10$ **around month-end** *from March 2015 to March 2017.*
The vertical dashed line is last day of month.
Shadow area is 95%*-confidence interval.*

- German sovereign bond prices increase steadily before the end-of-month and drop shortly thereafter.

Our explanation

- Linked to the ECB's Public sector purchase program (PSPP) implementation.
- Dealers charge higher prices at the end-of-month anticipating the ECB needs to meet a **self-imposed fixed monthly target**.
- Evidence is consistent with a model of **imperfect competition** faced by the CB bargaining with a few dealers over a finite number of rounds.

Related Bond price anomalies

- US Tsy yields around scheduled auctions (Lou, Zhan, Yang (2013)).

→ Proposed Interpretation:
  - Limited risk-bearing capacity of intermediaries who require price-concession to bear 'inventory' risk (Grossman-Miller (1987)).
  - Dealers short other notes (close substitutes) to hedge in anticipation of the auction.
  - Slow moving capital (Duffie (2010)) of investors who do not arbitrage away the anomaly .
- Euro area evidence around auctions more mixed (Beetsma, Giuliodori, de Jong and Widijanto (2016,JFI)):
  - No effect around German Bund auctions.
  - Some effect around Italian auctions especially during financial crisis.

→ Interpretation: hedging demand of dealers who face risk about issuance amount and payoff (Sigaux (2020)).

Related Literature: Theories of price impact

- Asymmetric Information
  (Kyle (1985,Econ.) and Glosten and Milgrom (1985,JFE))
- Imperfect risk-sharing may lead to persistent price impact:
  - Investor inattention 'Slow moving capital'(Duffie (2010))
  - Investor constraints, such as fixed investment mandates 'Inelastic Markets' (Gabaix and Koijen (2021))
- Instead, our explanation is based on **imperfect competition** between dealers whose bargaining power increases at month-end, partly due to the APP design and possibly to regulatory constraints.

Related literature

- Impact of QE on bond markets
  - Euro area: Eser and Schwaab (2016,JFE), Ghysels, Idier, Manganelli and Vergote (2017, JEEA), Corradin and Maddaloni (2020,JFE), Koijen, Koulischer, Nguyen and Yogo (2021,JFE)
  - US: Krishnamurthy and Vissing-Jorgensen (2011), Gagnon et al. (2011, IJCB), D'Amico and al. (2012,EJ)
- Monetary policy implementation:
  - FED's QE auctions Treasury Bond purchases (Song and Zhu (2018,JFE))
  - FED's MBS purchases (An and Song (2021))

Related literature

- Regulatory Capital Constraints impact dealer intermediation capacity by raising balance sheet costs
  - He, Nagel and Song (2021,JFE) document "inconvenience" of US Treasury during Covid-19
  - Bond illiquidity increases around end-of-quarters (Breckenfelder and Ivashina (2021))
- Sequential search model
  - Consumer literature (Weitzman (1979,Econ.), Stahl (1989,AER), Janssen & al. (2005,IJIO)

    Two-stage search-matching game between a continuum of buyers and a finite number of sellers
  - Applied to OTC markets and 'benchmarks' by Duffie, Dworszack, and Zhu (2017,JF)
  - This paper: Multiple trading rounds to account for key features of the PSP

Road map

1. **PSPP implementation and motivating evidence**
2. Theory: search-based model with imperfect competition among dealers
3. Empirical analysis
4. Discussion and policy implications

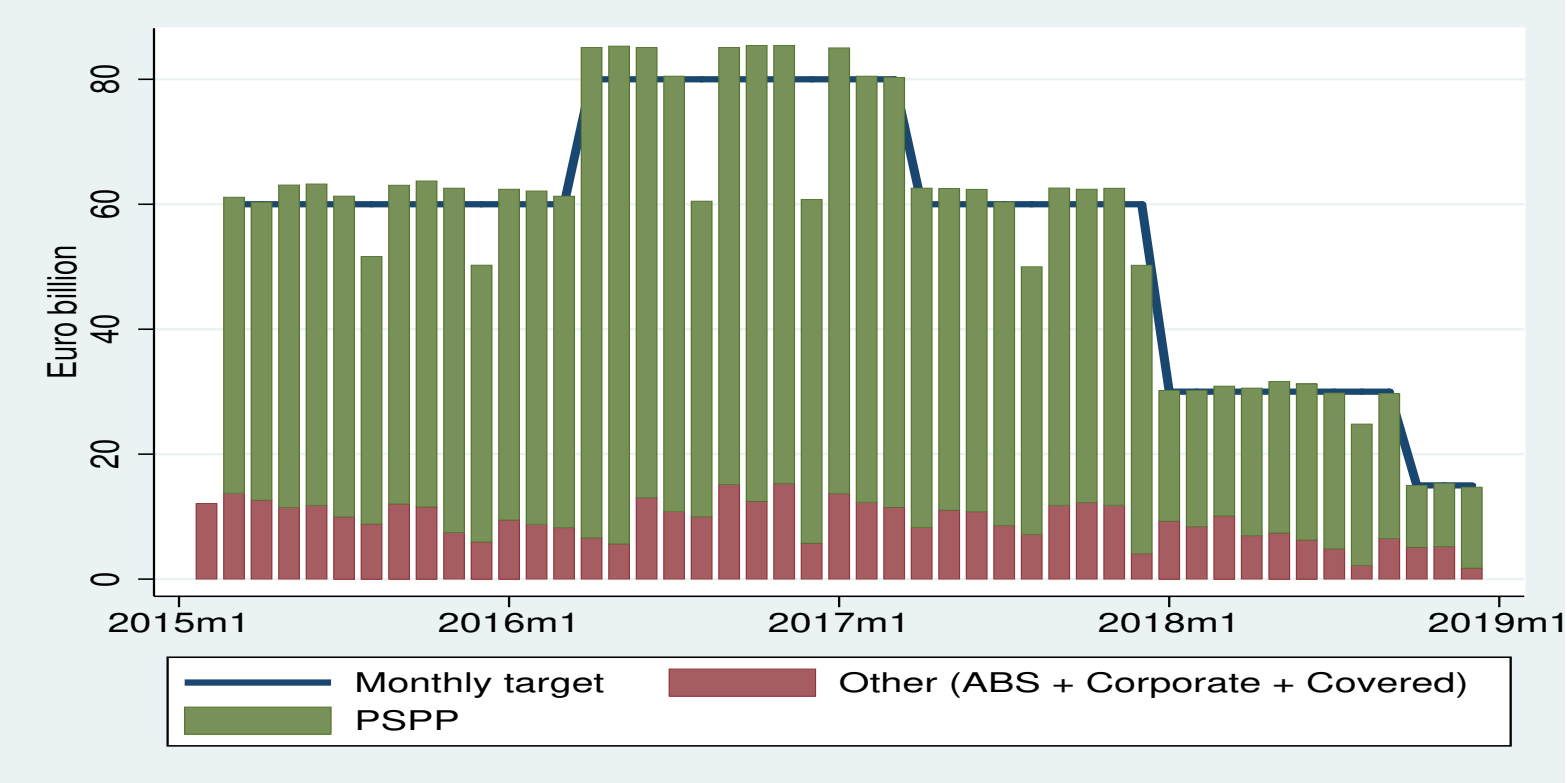
PSPP implementation (I)

- On January 22th 2015, the ECB announced an expanded asset purchase program (APP)
  - APP monthly purchase targets determine how much can be bought within a month
  - The program started with €60 billion per month
- PSPP under APP
  - PSPP targets euro area sovereign bonds
  - PSPP is the main program: almost 82% of total net purchases
  - The ECB capital key guides net purchases under the PSPP on a monthly basis
    - Germany has the highest share of ECB capital: 26%
    - Monthly purchases of German securities: $\approx 60 \times 0.82 \times 0.26 =$ €13 billion.

    $\rightarrow$ Eurosystem owned 24% of all outstanding German sovereign bonds by 2017.

PSPP implementation (II)

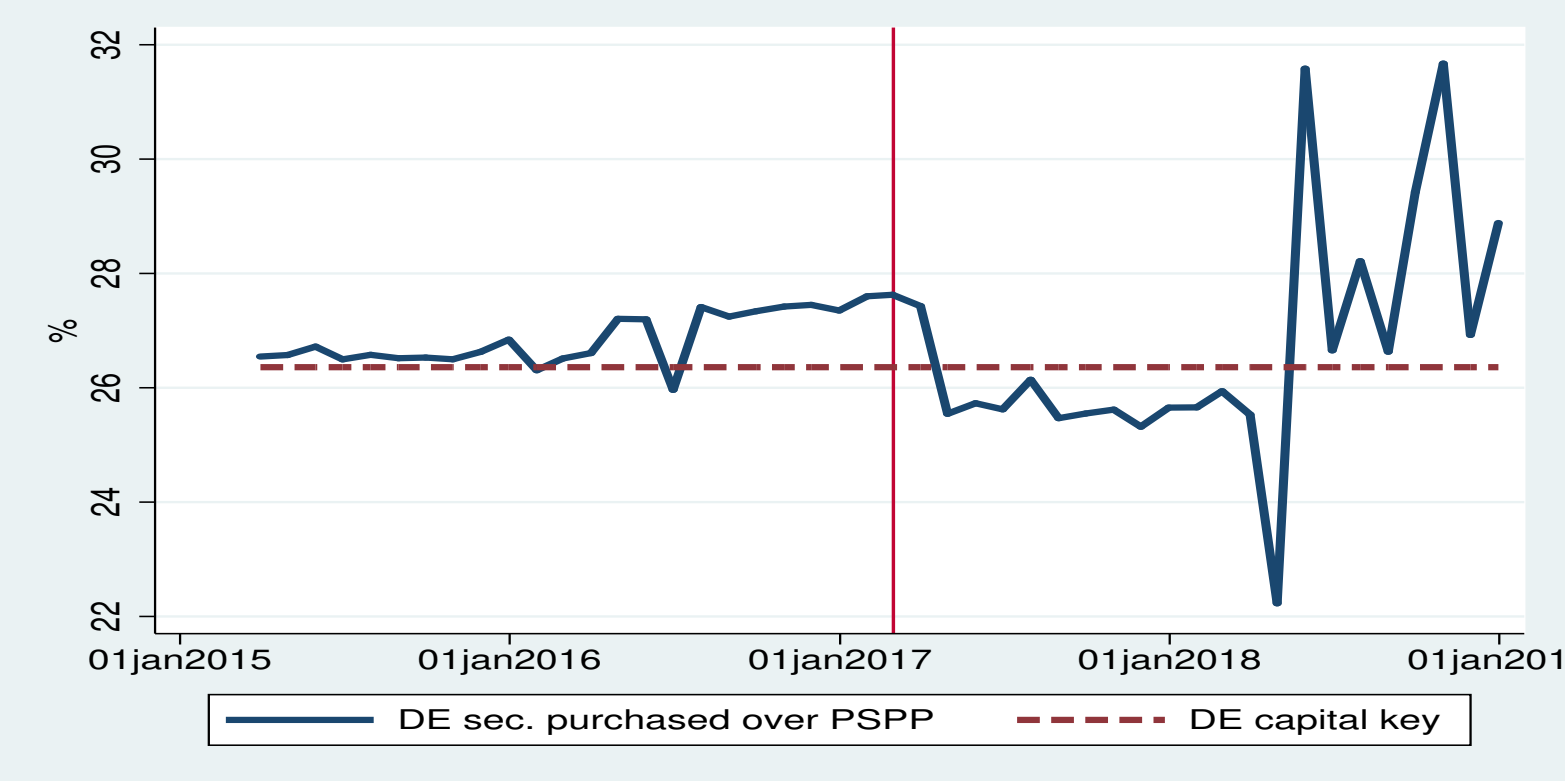
- Well-defined monthly APP targets
- Purchase activity 'front-loaded' before summer and end-of-year



Monthly aggregate volume purchased under the PSPP.

Source: ECB

PSPP implementation (III)



Monthly share of German securities purchased under PSPP.

Source: ECB

PSPP: How purchases are executed

- PSPP purchases are executed by the National Central Bank (NCB) and the ECB for each sovereign
- Bond Eligibility Criteria:
  - Central gvt bonds only;
    extended to local and regional gvt on Dec 5 2015
  - Bond maturity > 2 years;
    extended to > 1 year on Jan 19 2017
  - $< 33\%$ of an issue (issuer) after 2015
  - Yield $>$ ECB deposit facility rate;
    relaxed after Jan 19, 2017
  - Blackout period for new issuances
- PSPP purchases are mainly executed by bilateral trades with counterparties:
  - Trading via major electronic platforms and voice
  - CB asks several (typically 5) counterparties for quotes
  - At least three counterparties' responses required
  - The lowest price wins

PSPP: Timing of trades within month

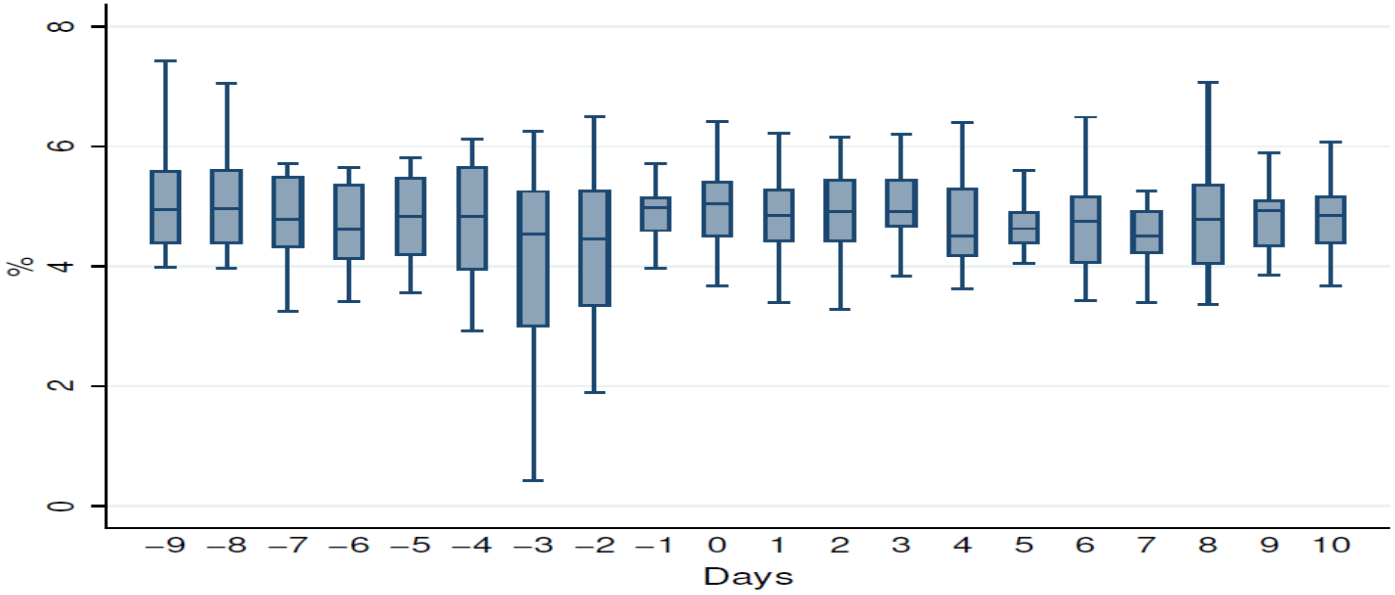
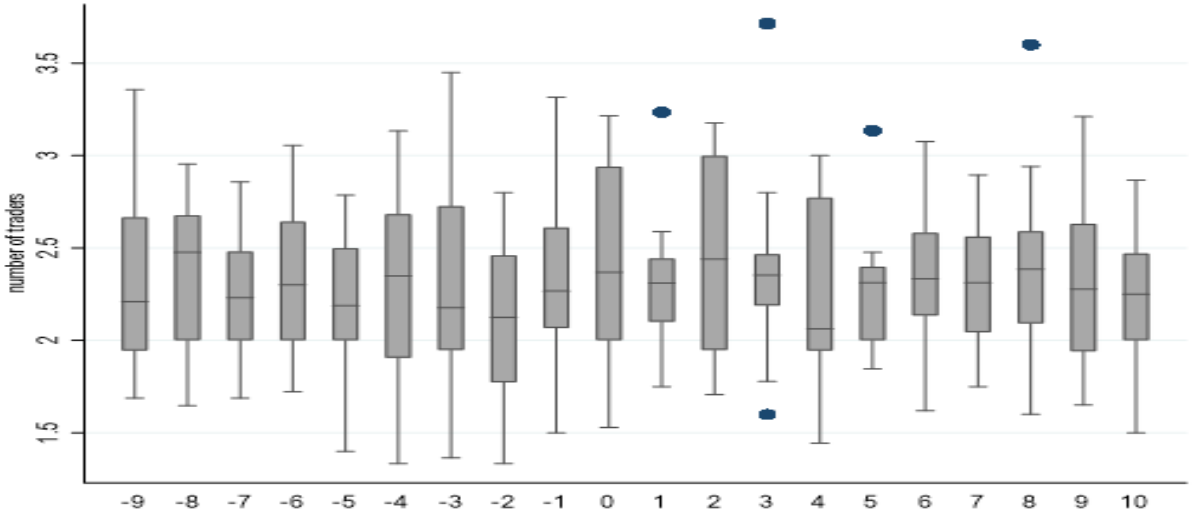


Figure 10. Central bank purchases within window. The figure provides a box-whisker plot of the ratio of the amount of bonds purchased in a day t over the total amount of bonds purchased in the same window. The figure draws a box raging from the first to the third quartile with a line at the median. The "whiskers" going from the box to the adjacent values are the highest and lowest values that are not farther from the median than 1.5 times the interquartile range. t ranges from -9 to 10 (including $t = 0$) and $t = 0$ being the last day of the month.

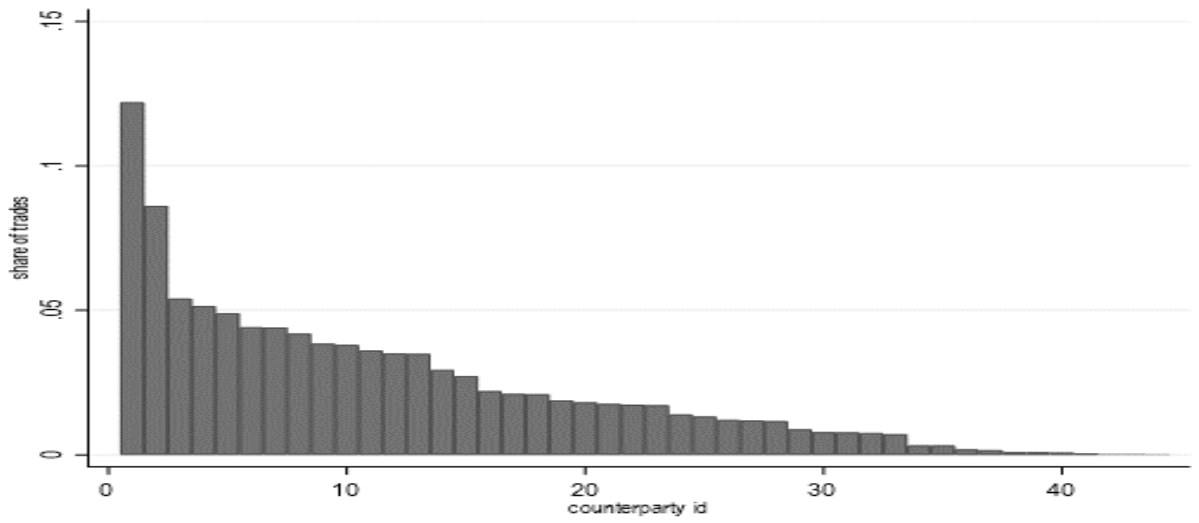
PSPP: Trades within day

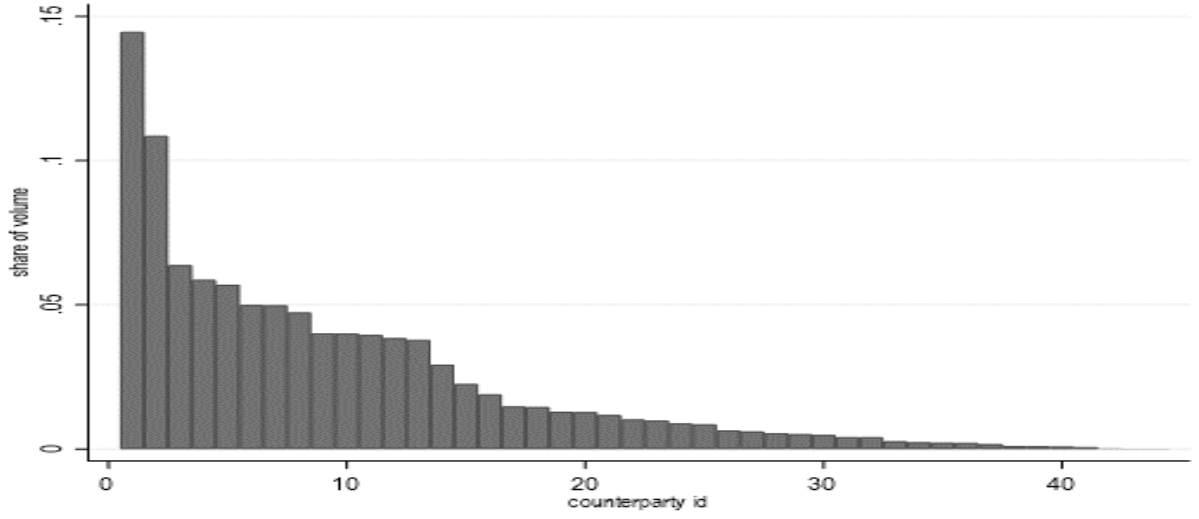
- Number of trades per day = 42.3 on average
  (p25=33, p50= 40, p75=50)
- Trade size = 16 million Euros on average:
  (p25=6, p50=11, p75=26)
- Number of trades per dealer across days of the month:



→ On average day CB trades with 20 dealers, executes about 40 trades of 16 million euros, on 15 different Isins.

PSPP: Trade Distribution across Dealers





Data

- We look at Germany: the safest and most liquid bond market in the euro area
- Sample: March 2015 to March 2017
- Data sources:
  - Sovereign bond prices from Bloomberg and TraX (also monthly traded volumes)
  - ECB and NCB purchase amounts, executed prices and counterparties' identity at bond-day level
  - Bond characteristics (outstanding amount, etc.) from ECB Centralized Security Database
  - Repo rates from Brokertec platform

Data: Summary statistics

	Obs.	Mean	St. dev
Panel A - Outstanding universe			
Time-to-maturity (years)	90,725	6.45	4.30
Coupon rate (%)	90,725	1.27	1.47
Outstanding amount (euro millions)	90,725	3,630	6,530
Yield (%)	90,725	0.10	0.46
Share fixed rate coupon (%)	90,725	92.78	3.18
Share central gover. (%)	90,725	83.79	2.59
Special repo rate (%)	15,243	-0.48	0.24
Panel B - ECB & NCB			
Dum. Purchase	90,725	0.07	0.26
Time-to-maturity (years)	6,989	11.17	7.42
Coupon rate (%)	6,989	2.61	1.88
Outstanding amount (euro millions)	6,989	14,800	7,120
Dum. Fixed rate coupon	6,989	0.96	0.20
Dum. Central govern.	6,989	0.91	0.28
Special repo rate (%)	5,829	-0.46	0.26
Monthly cum. central gov. / Outstanding (%)	1,478	0.96	1.46
Monthly cum. central gov. / Trax volume (%)	1,430	8.61	18.25
Num. counterparties	6,989	1.29	0.58

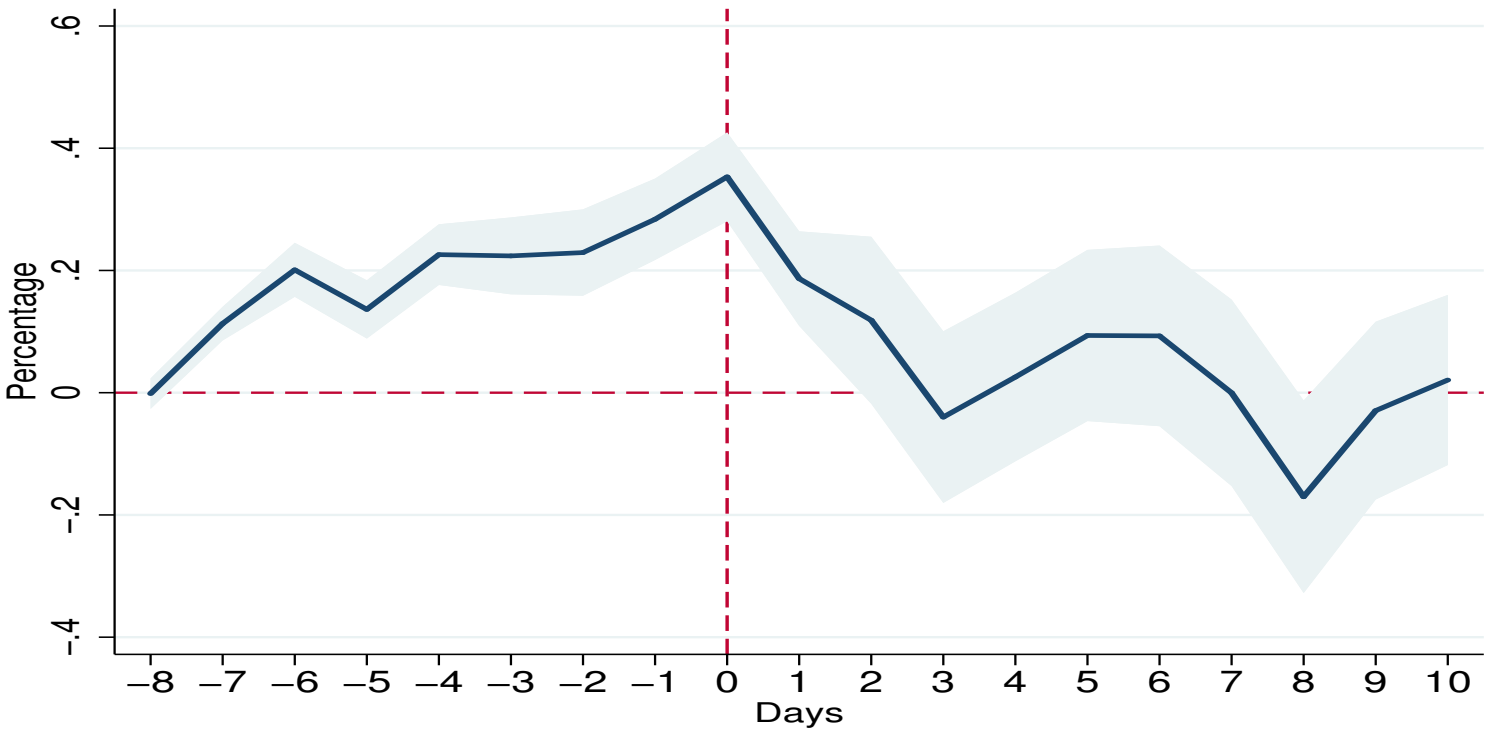
Price anomaly: Event study around end of month

- Follow bond price P_t (or yield Y_t) in 20-day window around EOM
  - 9 trading days before ($t = -9, -8, ..., -1$)
  - $t = 0$ end-of-month day
  - 10 trading days after ($t = +1, +2, ..., +10$)
  - $\rightarrow$ Change in yield: $Y_t - Y_{-9}$ for $t = -8, \ldots, +10$
  - $\rightarrow$ Cumulative log-return: $\log(P_t/P_{-9})$ for $t = -8, \ldots, +10$
- Run the following regression ($\sim$ Lou, Yang, Zhang (2013))

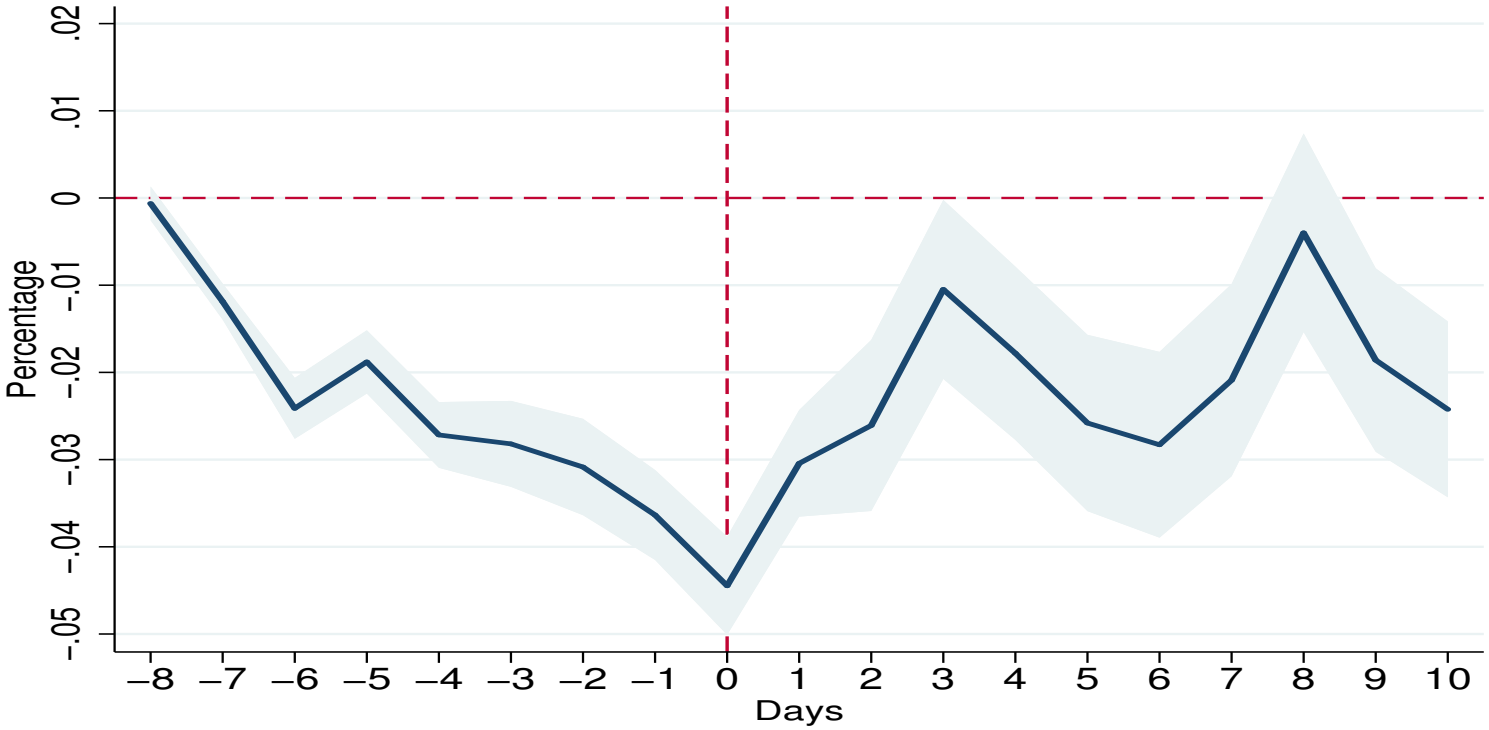
$$\log P_{i,j,t} - \log P_{i,j,-9} = \sum_{t=-8}^{T=10} \alpha_t \times \mathrm{D}.t + \epsilon_{i,j,t}$$

  - $P_{i,j,t}$ price of bond i on day t in window j
  - $\mathrm{D}.t$ dummy variable equal to one on day t

Anomaly: Log Return (α_t)



Anomaly: Yield changes (α_t)



Asymmetric pattern: the yield (average level is 0.10%)

- Decreases, on average, by 4.4 bps during the 9 days before the end-of-month
- Recovers within 2 days.

Anomaly: Robustness

- Bond-window fixed effects
- Different price sources: ECB executed prices vs. TraX traded prices vs. Bloomberg quotes (ECB executed price)
- Quarter-end effect (potential impact of Basel III balance sheet leverage constraint) (Quarter-end)
- Variation in repo funding costs
- Yield spread w.r.t non-elligible collateral (Yield spread)
- Bond Maturity Buckets (Maturity Buckets)
- Newly issued bonds (Newly issued bonds)
- Patterns in bid-ask spreads (Bid-ask spreads)
- 'Placebo' test on 2012-2013 (Placebo)

Road map

1. PSPP design and motivating evidence
2. **Theory: search-based model with imperfect competition among dealers**
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Outline of the model: Setup

- Sequential search-bargaining model:
  - CB wants to purchase U units of a bond from N dealers
  - CB has a per-unit reservation value v at T
  - Every dealer is contacted but quotes with **Prob** $\eta < 1$
  - T rounds of trading
- **CB**'s objective is to minimise total expected cost of acquiring the targeted number of bonds by T
- **Each dealer** maximizes expected profit from selling to the CB over T rounds
- Dealers are *ex ante* identical, supply the bond at a zero cost, and compete
  - with other dealers contacted in that same round
  - with dealers that will be contacted in subsequent rounds

Outline of the model: Equilibrium

- Derive the **equilibrium distribution of quotes** in every round, such that dealers :
  - quote from i.i.d. distribution with continuous support,
  - are indifferent between any quoted price.
- Derive the equilibrium average transaction prices at which the CB will buy targeted bonds

→ Contacted dealers have increasing bargaining power as time approaches T

→ They quote from a density whose mean is closer to the CB's reservation price v

- First, let's consider the case where the CB wants to buy 1 unit in T rounds.

1-unit model: Dealer's problem (I)

- Start from final round (T) and move backward
- If dealer (D) quotes $\overline{p}_T = v$ (the max price CB is willing to accept), the expected profit is

$$\underbrace{(1-\eta)^{N-1}}_{\substack{\text{Prob no other Ds}\\ \text{are quoting}}} v \tag{1}$$

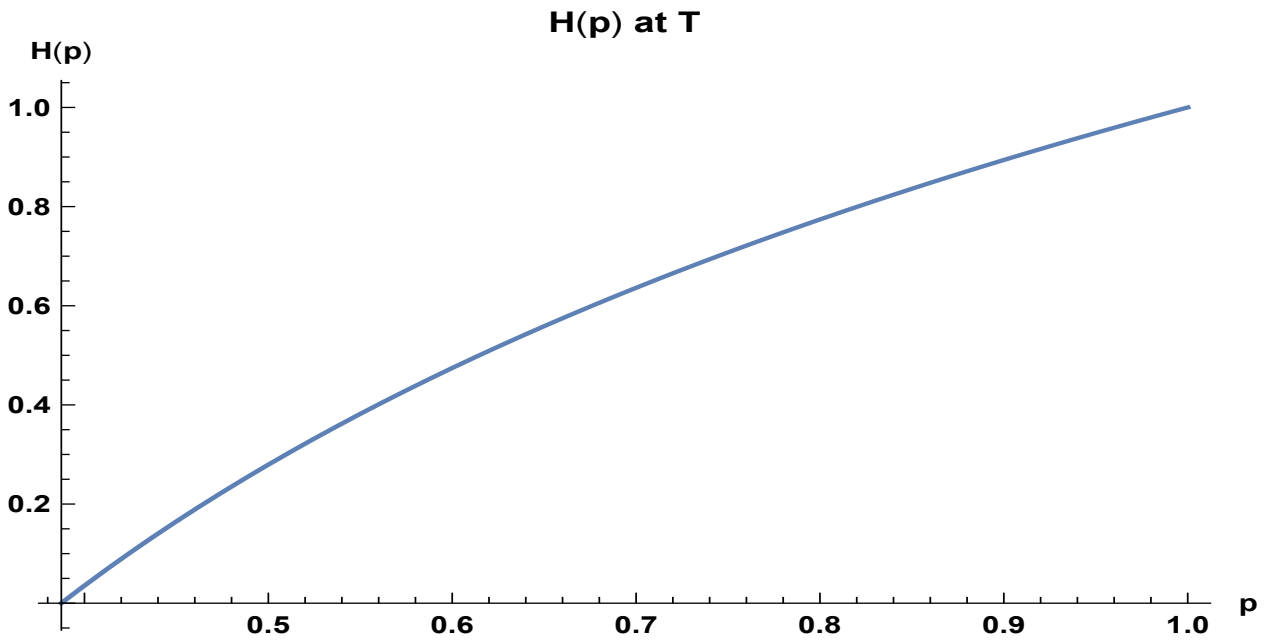
- If dealer quotes p drawn from probability distribution $H_T(p)$ defined on $[\underline{p}_T, v)$, the expected profit is

$$p \sum_{k=0}^{N-1} \underbrace{C_{N-1}^{k} \eta^{k} (1-\eta)^{N-1-k}}_{\substack{\text{Prob. } k \text{ other Ds}\\ \text{are quoting}}} \underbrace{(1-H_T(p))^{k}}_{\substack{\text{... and}\\ \text{quote price} > p}} \tag{2}$$

1-unit model: Dealer's problem (II)

- Dealers are **indifferent** between all prices in the support of $H \rightarrow (1) = (2)$

$$H_T(p) = \frac{1}{\eta} + \left(1 - \frac{1}{\eta}\right)\left(\frac{\overline{p}_T}{p}\right)^{\frac{1}{N-1}}$$



Numerical example: $\overline{p}_T = v = 1$ and **lower bound** $\underline{p}_T = 0.38 \rightarrow H_T(\underline{p}_T) = 0$

1-unit model: Dealer's problem (III)

- Similarly, in every round $t < T$ we derive the equilibrium quoting density: $H_t(p) : [\underline{p}_t, \overline{p}_t] \to [0, 1]$ from Dealer indifference condition:

$$p \sum_{k=0}^{N-1} C_{N-1}^{k} \eta^k (1-\eta)^{N-1-k} (1 - H_t(p))^k = \overline{p}_t (1-\eta)^{N-1}$$

- Need to solve the CB's problem to find **upper bound** $\overline{p}_t$.
- The **lower bound** $\underline{p}_t$ solves $H_t(\underline{p}_t) = 0$.

1-unit model: CB's problem

- At T the CB's maximum acceptable price is $\overline{p}_T = v$, its reservation value.

- In every round $t < T$, the maximum acceptable $\overline{p}_t$ is such that the CB is **indifferent** between trading at that price or continuing to search:

$$\underbrace{v - \overline{p}_t}_{\text{Trade at } t} = \underbrace{\beta\,\mathbb{E}[\underbrace{\hat{s}_{t+1}}_{\text{Trade in round } t+1} + \underbrace{\mathbf{1}_{\hat{s}_{t+1}=0}(v - \overline{p}_{t+1})}_{\text{trade in round } \geq t+2}]}_{\text{Continuation value}}$$

where $\hat{s}_t = \max[s_t^1, \ldots, s_t^N]$, and
$s_t^i = (v - p_t^i)\mathbf{1}_{i\,\text{quotes}}$ is **surplus** from trade with Dealer i

- In the 1 unit version CB buys the asset the first time a dealer quotes an "executable" price
  - $\rightarrow$ Probability of a trade in a given round is $1 - (1 - \eta)^N$

1-unit model: CB's problem (II)

- To compute the **expected trading surplus** $\mathbb{E}[\hat{s}_{t+1}]$ need:

$$\begin{aligned}\hat{H}(v-p) &:= \text{Prob}(s^1 \leq v-p, \ldots, s^N \leq v-p) \\ &= (\underbrace{1-\eta}_{\text{Prob no quote}} + \underbrace{\eta}_{\text{Prob quote}} \underbrace{\cdot(1-H(p))}_{\cdot\text{Prob price} > \text{p}})^N \\ &= (1-\eta)^N \left(\frac{\overline{p}}{p}\right)^{\frac{N}{N-1}}\end{aligned}$$

- We then obtain:

$$\begin{aligned}\mathbb{E}[\hat{s}_{t+1}] &= -\int_{\underline{p}}^{\overline{p}} (v-p) d\hat{H}(v-p) \\ &= v(1-(1-\eta)^N) - \overline{p}_{t+1} N\eta(1-\eta)^{N-1}\end{aligned}$$

1-unit model: Solution

- Putting all together the **upper bound** $\overline{p}_t$ solves:

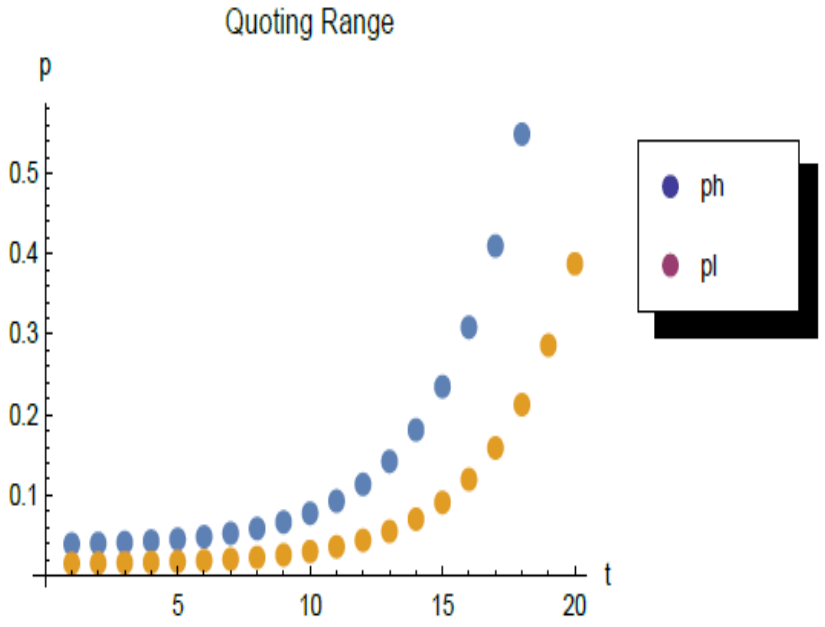
$$v - \overline{p}_t = \beta \left\{ v - \overline{p}_{t+1}(1-\eta)^{N-1}(1+(N-1)\eta) \right\} \quad \forall t < T$$

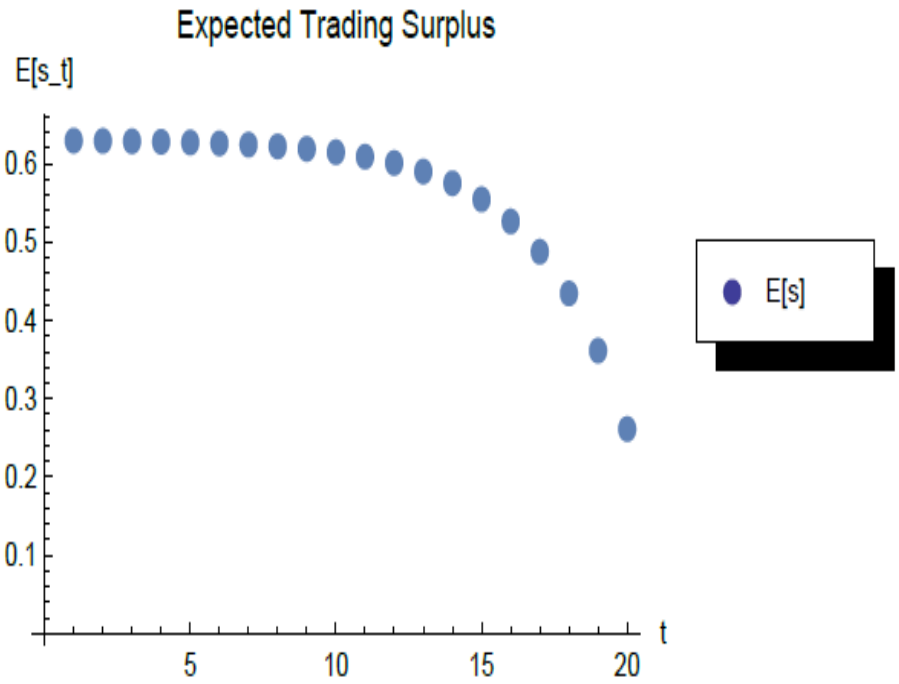
- The **price range** (with $\beta = 1$) is given by:

$$\overline{p}_t = (1-\eta)^{N-1}(1+(N-1)\eta)\overline{p}_{t+1}$$
$$\underline{p}_t = \overline{p}_t(1-\eta)^{N-1}$$

Prediction (I): Maturity price pattern

- The price range increases over the trading rounds, because dealers' bargaining power increases.
- The average transaction price increases towards maturity, as CB expected surplus decreases.

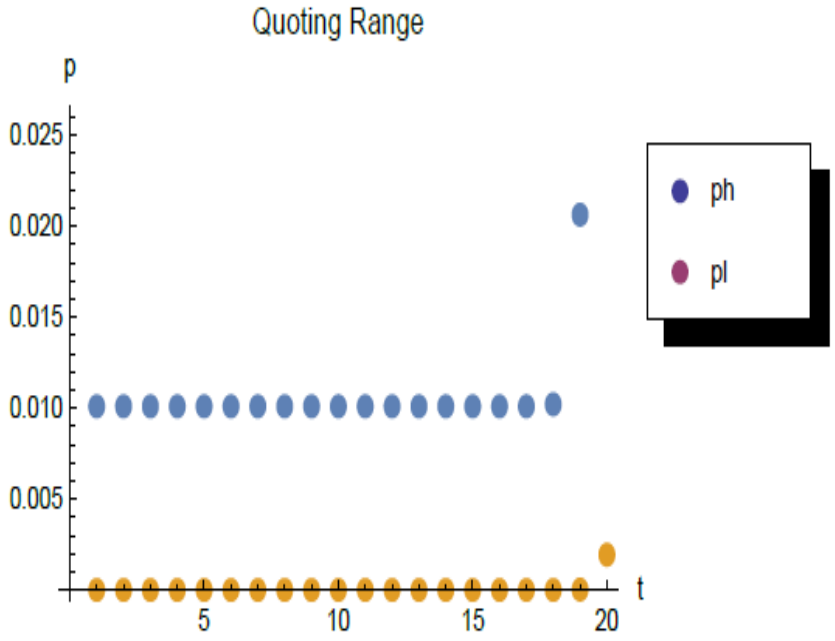


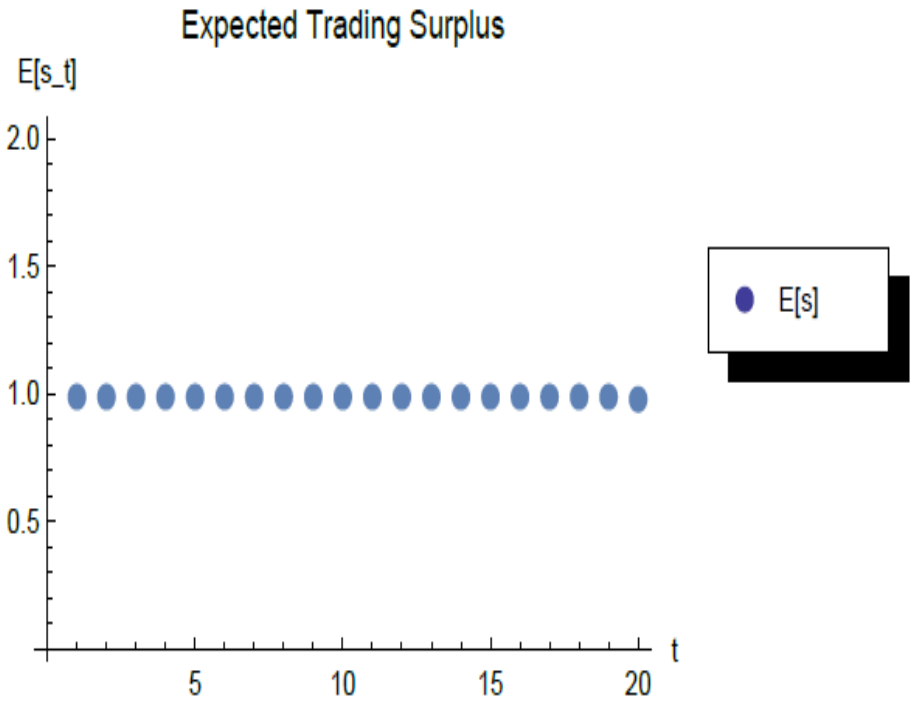


Parameters: $v = 1, N = 10, T = 20, \eta = 0.1, \beta = 0.99$

Prediction (II): Effect of Competition

- If competition among dealers is high then the trading range is approximately constant over the trading horizon
- With $\eta = 0.5$ and $N = 10$, on average 5 dealers quote a price in every round and the CB extracts full surplus.





Multi-unit model: Final trading round

CB wants to purchase **multiple units** $U\,(< N)$ at Maturity.

- In the final round T the dealer receives the maximum price $\overline{p}_T = v$ only if there are at most $U-1$ dealers who quote a price among the remaining $N-1$ dealers

$$v \sum_{k=0}^{U-1} C_{N-1}^{k} \eta^{k} (1-\eta)^{N-1-k} \tag{3}$$

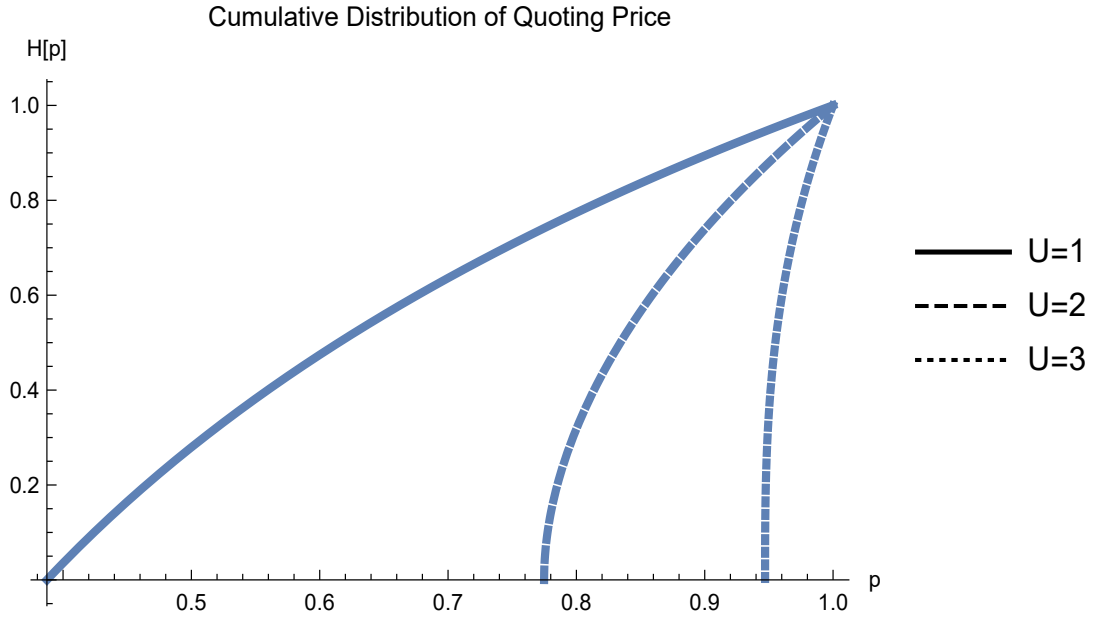
- If the dealer quotes $p < v$, the expected profit is

$$p \sum_{k=0}^{U-1} C_{N-1}^{k} (\eta\, H(p))^{k} (1-\eta\, H(p))^{N-1-k} \tag{4}$$

- **Indifference** $\Rightarrow \{(3) = (4)\} \Rightarrow$ quote density $H_{T,U}(p)$.

Multi-unit model: Prediction (III)

- If there are more units to be purchased $H_{T,U}(p)$ shifts to the right: $\underline{p}_{T,1} \leq \underline{p}_{T,2} \leq \underline{p}_{T,3} \leq (\ \overline{p}_{T,1} = ... = \overline{p}_{T,3} = v)$
- Dealers have an incentive to quote higher prices in the final round, the more units the bank still has to purchase to achieve its target



Multi-unit model: several trading rounds

- Solve for the quote distribution in every round before T, as in 1-unit case, using dealers' indifference condition.
- The **upper range** $\overline{p}_{t,U_t}$ in every round solves an indifference condition for the CB and depends on how many units she still needs to buy prior to maturity U_t.
- Setting $\overline{p}_{t,0} = v$ and $U_t = u$:

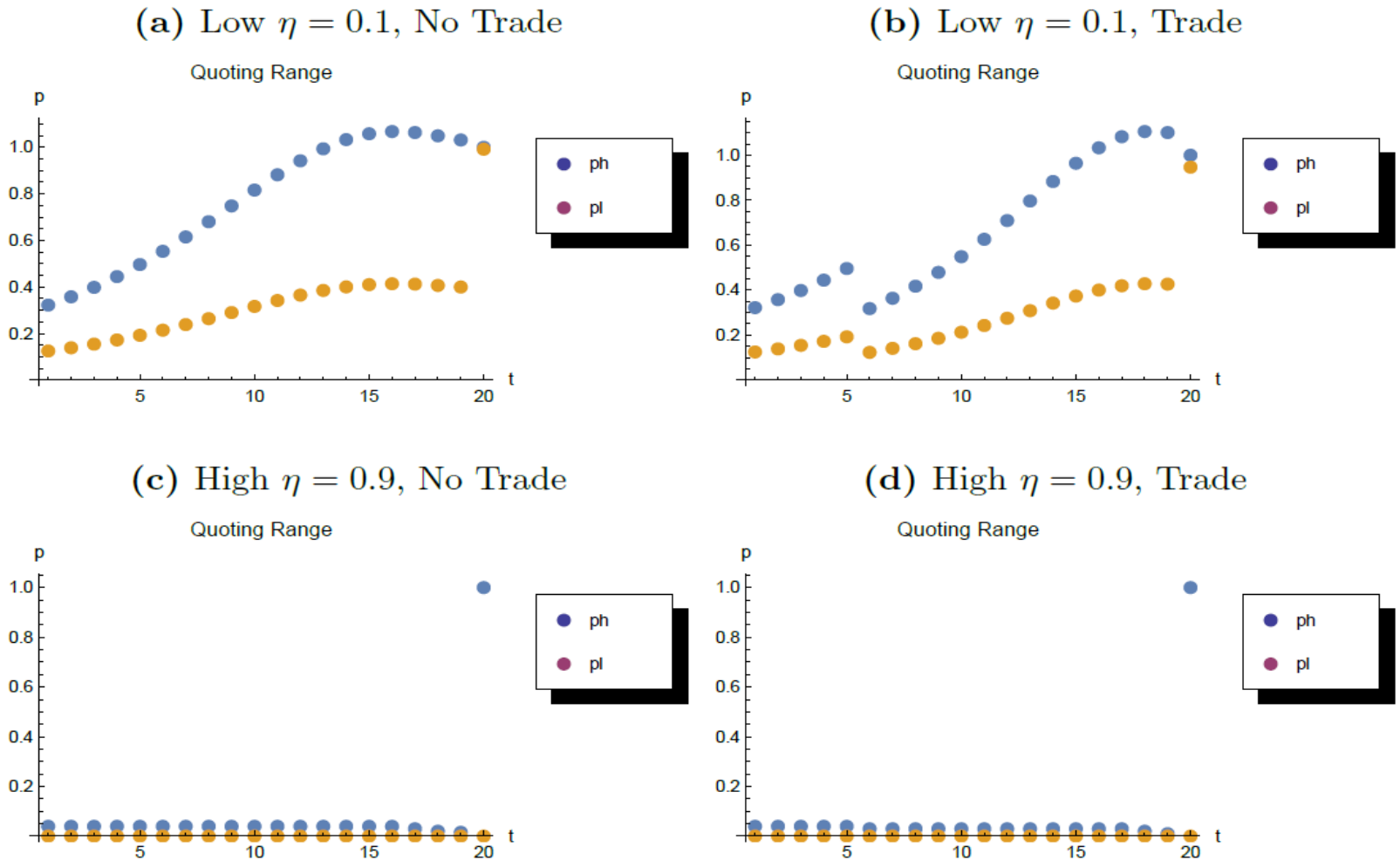
$$\overline{p}_{T,u} = v \;\; \forall u > 0$$

$$v - \overline{p}_{T-1,u} = \beta\, \mathbb{E}\left[\sum_{j=1}^{u} \hat{s}^j_{T,u} - \sum_{j=1}^{u-1} \hat{s}^j_{T,u-1}\right]$$

$$v - \overline{p}_{t,u} = \beta\, \mathbb{E}\left[\hat{s}^1_{t+1,u} - \hat{s}^1_{t+1,u-1} + (1-\eta)^N (v - \overline{p}_{t+1,u}) + (1-(1-\eta)^N)(v - \overline{p}_{t+1,u-1})\right]$$

$$\forall t < T-1$$

Multi-unit model: Trading Range



Parameters: $v = 1, N = 10, T = 20, \beta = 0.99, \ U_0 = 5$

Multi-unit model: Prediction (IV)

- The CB has incentive to buy in earlier rounds to reduce the dealers' market power in the final round
- If the market is not competitive (low η), the upper price $\overline{p}_t$ can exceed her time-T-reservation value v prior to maturity! (Intuition)

$\rightarrow$ Maximum run-up in the price may occur shortly before the End-of-Month ($= T$).

Road map

1. PSPP design and motivating evidence
2. Theory: search-based model with imperfect competition among dealers
3. **Empirical analysis**
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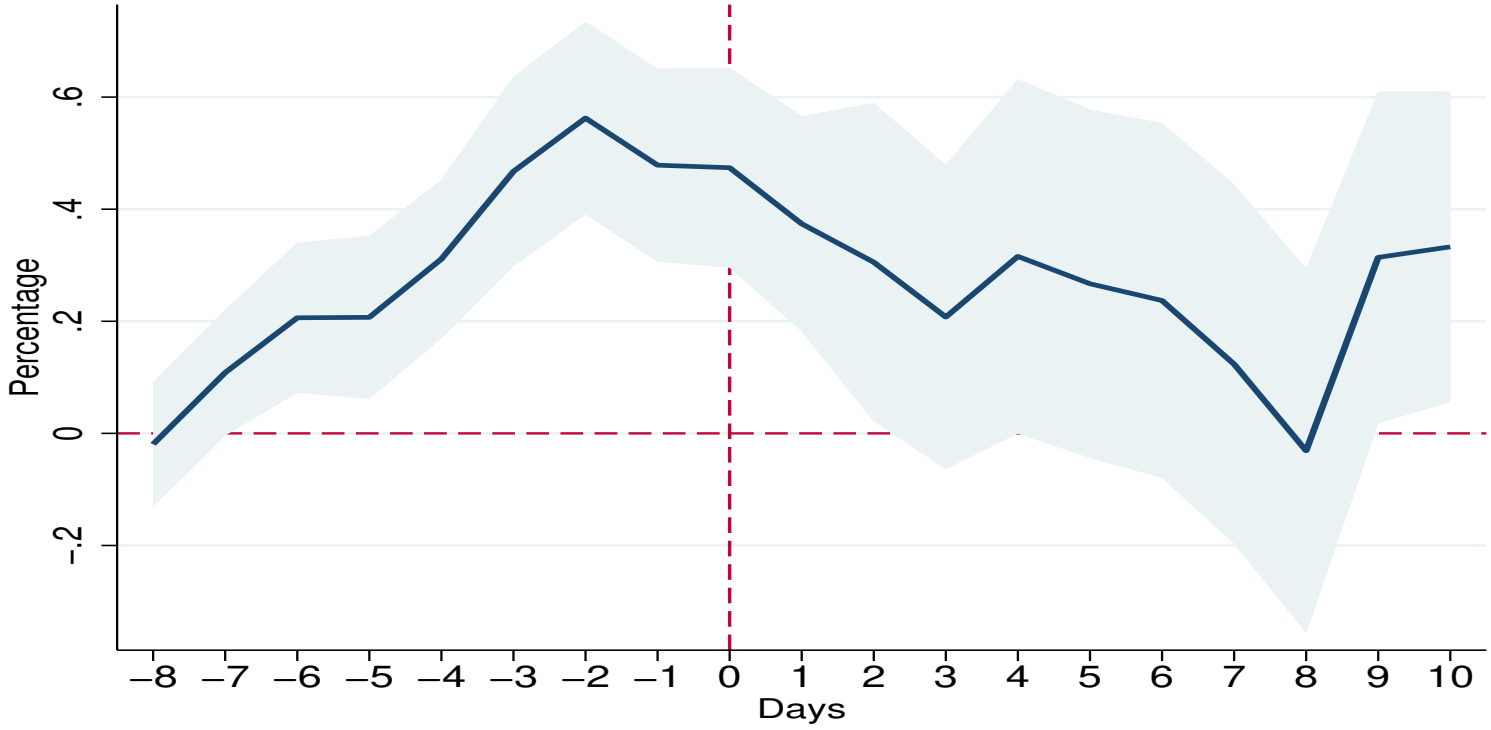
Is anomaly caused by ECB purchases? (I)

- **Prediction** 1**:** Price increases over the trading rounds as we approach the end-of-month
- Measure the impact of ECB trading on targeted bonds:

$$\log(P_{i,j,t}/P_{i,j,-9}) = \gamma \times \text{D.buy}_{i,j,t} + \sum_{t=-8}^{T=10} \alpha_t \times \text{D}_t$$
$$+ \sum_{t=-8}^{T=10} \beta_{\mathbf{t}} \times \text{D.buy}_{i,j,t} \times \text{D}_t + \gamma_{i,j} + \epsilon_{i,j,t}$$

D.buy$_{i,j,t}$: dummy equal to 1 when bond i is bought at day t in window j

Is anomaly caused by ECB purchases? (II)



- β_t: Purchased bond prices increase relative to non-purchased bond as we approach end-of-month
- Differential effect peaks 2-days before month-end ($\sim$ 2-day settlement period).
- Robustness

Is anomaly stronger when ECB trades with less Ds?

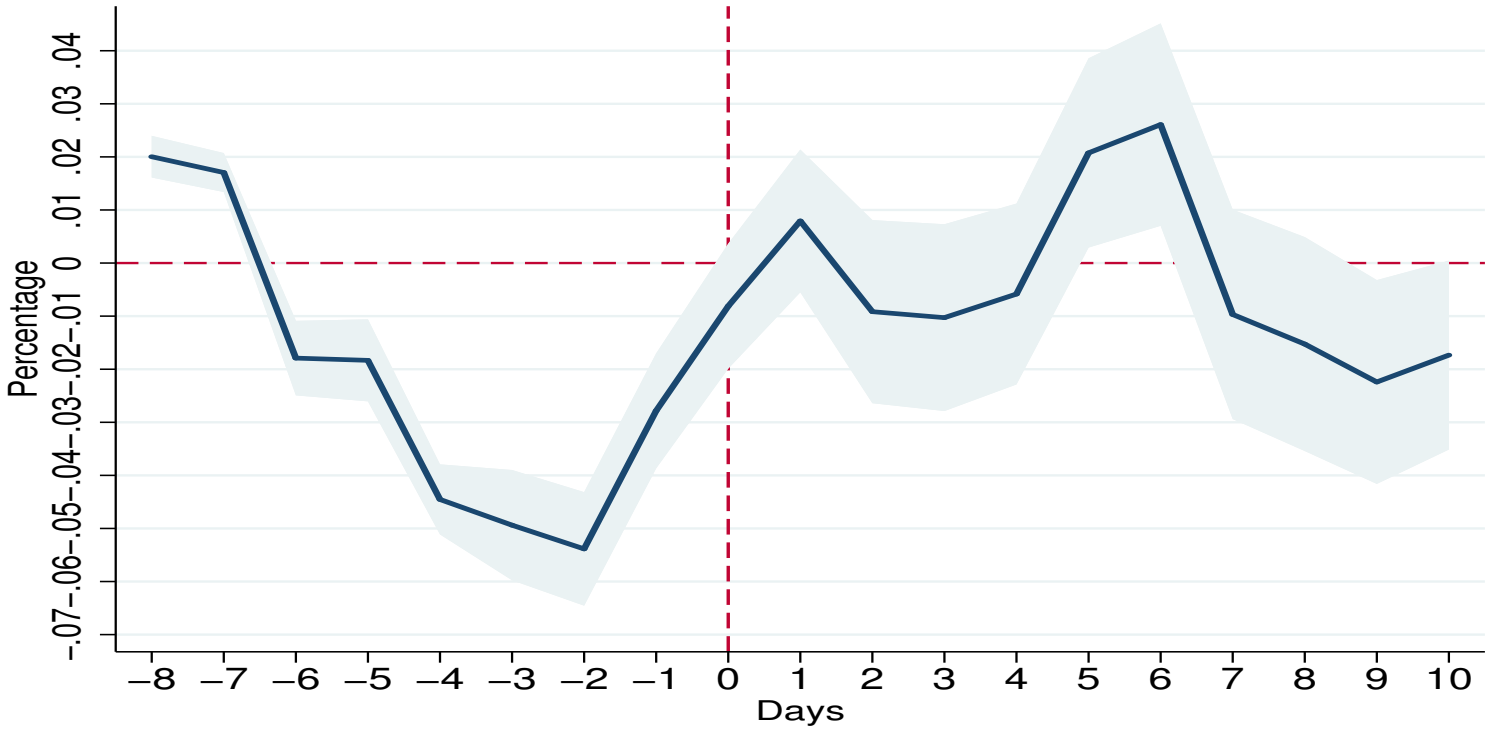
- **Prediction** 2**:** The lower the competition, the higher the price increase as we approach the end-of-month
- Differential effect between windows that have a lower (higher) number of counterparties of executed trades

$$Y_{i,j,t} - Y_{i,j,-9} = \gamma \times \text{D.Few Dealers}_{\,j} + \sum_{t=-8}^{T=10} \alpha_t \times \text{D.}t$$
$$+ \sum_{t=-8}^{T=10} \beta_{\mathbf{t}} \times \text{D.Few Dealers}_j \times \text{D.}t + \gamma_{i,j} + \epsilon_{i,j,t}$$

D.Few Dealers$_j$: dummy equal to 1 when window j has number of dealers of executed trades below median

Is anomaly stronger when ECB trades with less Ds?

- β_t: the lower the number of counterparties the ECB trades with, the more the bond yield (price) decreases (increases) as we approach the end-of-month



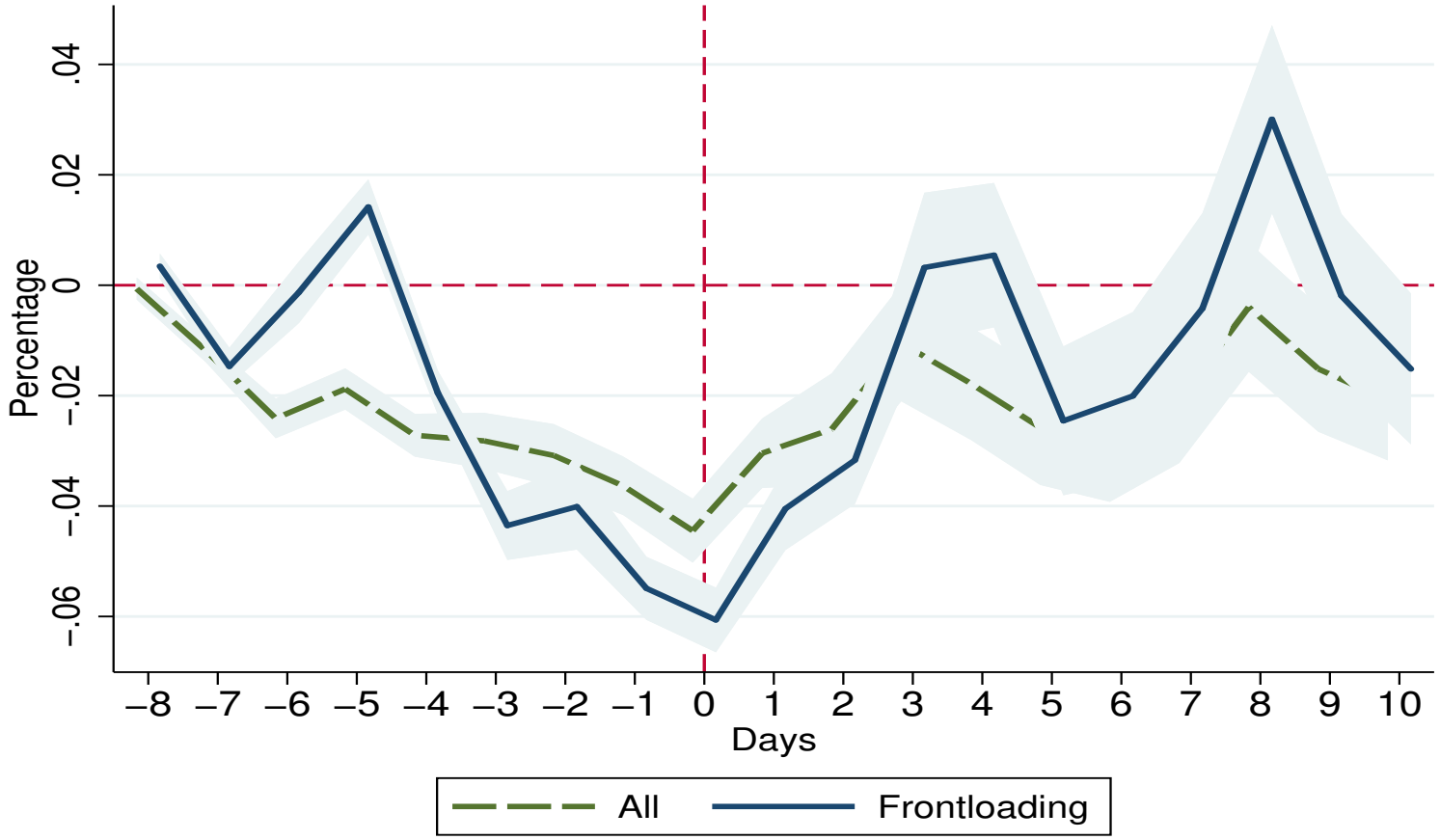
Is anomaly stronger when ECB buys more?

- **Prediction** 3**:** Prices increase more when the CB has to buy a larger number of bonds
- ECB implemented **frontloading**: increased the amount of purchases before the summer and the end-of-year 2015 and 2016

Benoit Couere (18 May 2015) *"Against this background, we are also aware of seasonal patterns in fixed-income market activity with the traditional holiday period from mid-July to August characterised by notably lower market liquidity. The Eurosystem is taking this into account in the implementation of its expanded asset purchase programme by moderately* **frontloading** *its purchase activity in May and June, which will allow us to maintain our monthly average of 60 billion, while having to buy less in the holiday period."*

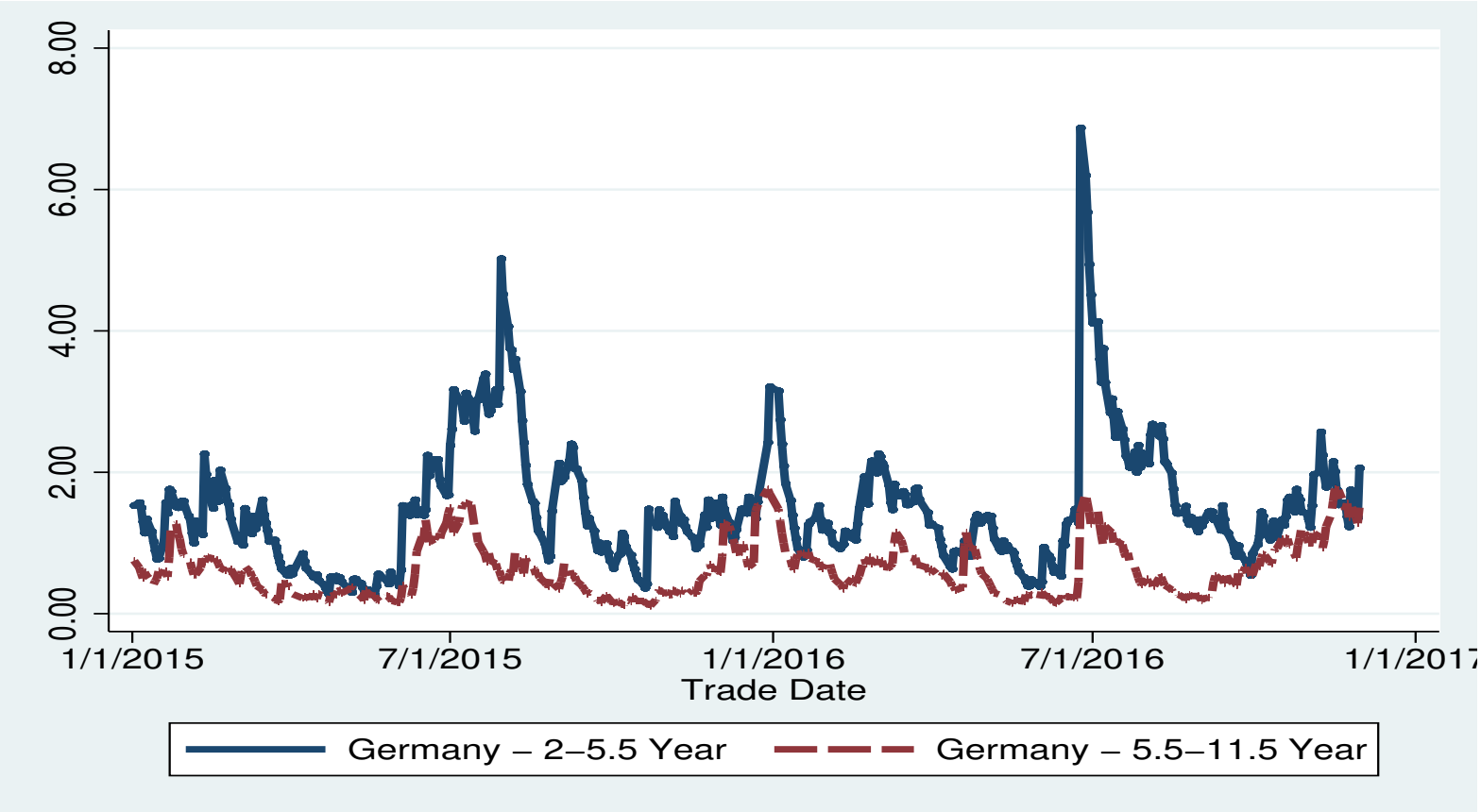
Is anomaly stronger when ECB buys more?

- Price pattern more pronounced for frontloading windows mid-May to mid-June and mid-June to mid-July 2015 and 2016 and mid-October to mid-November 2015 and 2016.



Is anomaly stronger when ECB buys more?

- And yet, bond market liquidity deteriorates during the summer and end-of-year!



Tradeweb liquidity indicators based on executed prices and volume data from the Tradeweb platform comparing the executed price to the mid price at security level.

Road map

1. PSPP design and motivating evidence
2. Theory: search-based model with imperfect competition among dealers
3. Empirical analysis
4. **Discussion and policy implications**

Cost of the PSPP implementation

Implementation shortfall to assess the economic impact of bond prices increasing at the end of the month

1. Compute the real portfolio $\sum_{t=-9}^{T=0} \sum_{i=1}^{N} w_{i,t} \times p_{i,t}$ where
   - $w_{i,t}$ is number of bond i purchased on day t by the CB
   - $p_{i,t}$ is the Bloomberg or CB price
2. Compute the beginning-of-period portfolio as $\sum_{t=-9}^{T=0} \sum_{i=1}^{N} w_{i,t} \times p_{i,-9}$ where
   - $p_{i,-9}$ is the bond price we observe at time -9

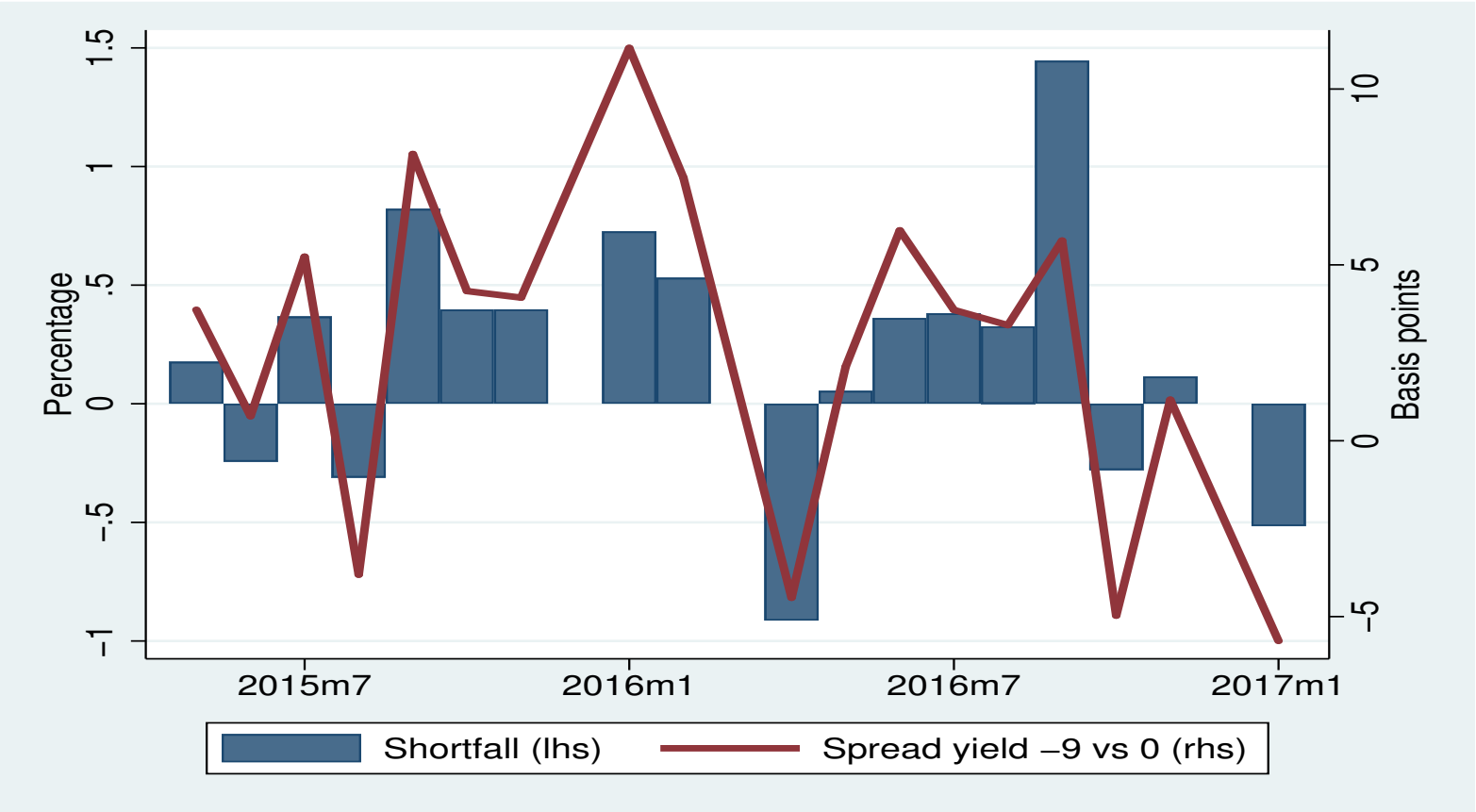
$$\text{Impl. Shortfall} = \sum_{t=-9}^{T=0} \sum_{i=1}^{N} w_{i,t} \times p_{i,t} - \sum_{t=-9}^{T=0} \sum_{i=1}^{N} w_{i,t} \times p_{i,-9}$$

$$\approx \textbf{€296} \text{ million}$$

$\rightarrow$ 12.3\$ million per month or 0.2% of market value.

Shortfall evolution

- The shortfall for all Bund trades in the last 10 days of each month from 2015 to 2017 amounts to €12.3 million per month, or 0.2% of market value.
- A positive shortfall occurs in most of the windows



Conclusion

- We document an end-of-month anomaly in European Government bond markets:
  - bond yields drop steadily 9 days before the EOM and recover shortly thereafter.
- The pattern is more pronounced:
  - For bonds on days when they are purchased by ECB.
  - In 'front-loading' month when the ECB targets more purchases (outside the summer and December periods that are typically less liquid).
  - In months when ECB trades with less counterparties.
  - End of quarters, when more constrained banks are less likely to act as intermediaries.

Conclusion

- The evidence is consistent with a sequential search-bargaining model where the CB buys several units over several rounds of trading.

→ With imperfect competition among dealers, their bargaining power and their expected rents increase, as maturity approaches.

→ The CB has incentive to buy in earlier rounds to reduce the bargaining power of dealers.

Implications for design of asset purchase programs

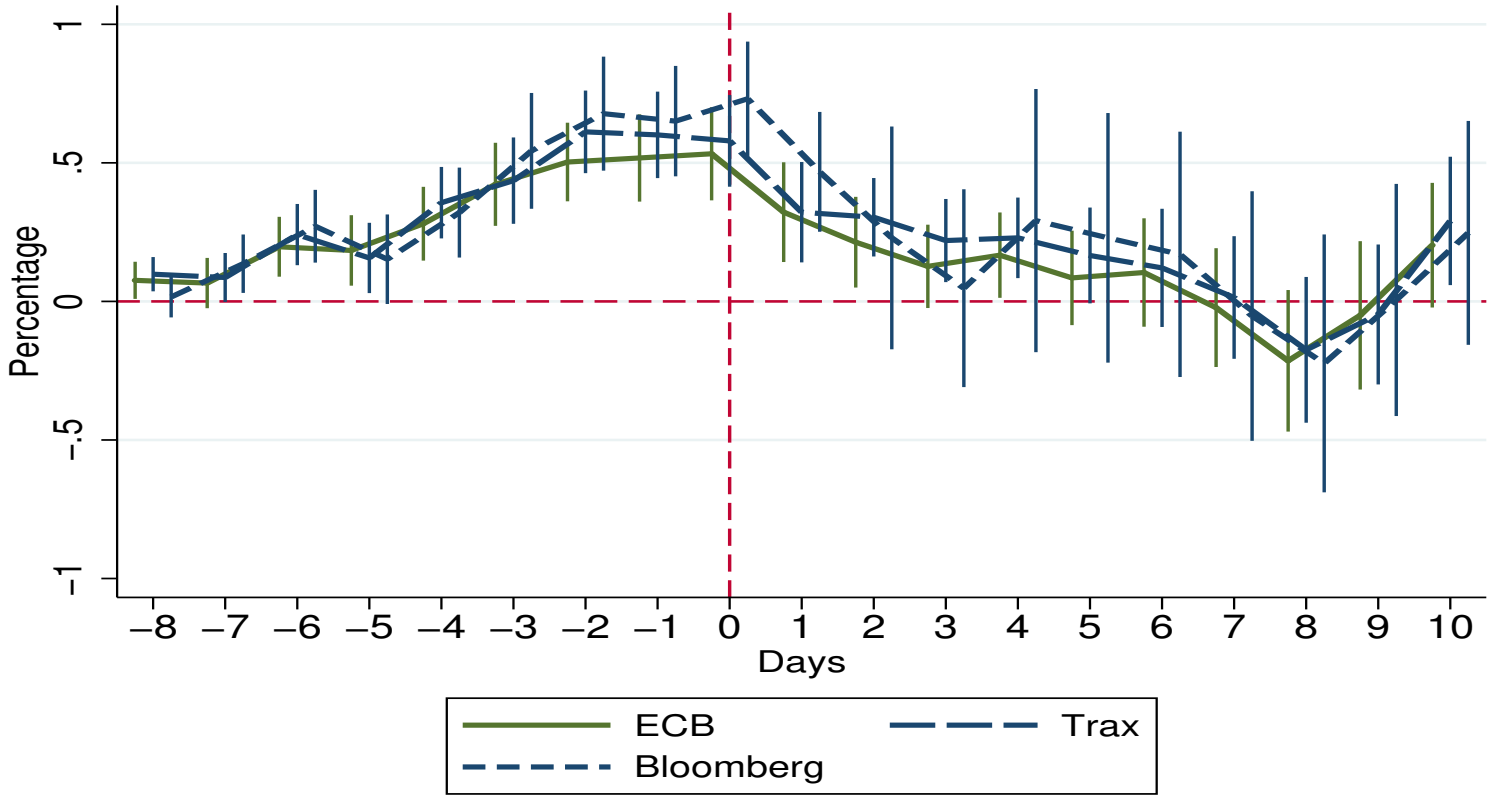
- Avoid targeting fixed euro notional purchases at fixed dates
  - Having to fill the mandate by the end of each month, increases the price pressure effect by giving more bargaining power to dealers at each end-of-month
  - Is it consistent with a market neutrality stance? *"Minimize the impact on relative prices and unintended side effects on market functioning"*
  - The current PEPP (Pandemic Emergency Purchase Programme) has no monthly targets and is more flexible
- Promote more competition among dealers:
  - More open (to buy-side, insurance companies) trading platform to run regular auctions

Implications

- The CB's role as a buyer of last resort.
  - Some NCBs have conducted auctions to encourage more competition from "natural" sellers (i.e. insurance companies) but still limited use
  - A more "open" trading platform might be useful in times of severe stress when the CB acts as a "buyer of last resort" (Duffie (2020))
- The Bond OTC market Structure and the role of Dealers.
  - Leverage and liquidity regulation reduce the intermediation capacity of certain dealers in specific times (e.g., EOQ), which can lead to less competitive prices at times.

Additional slides

ECB executed price vs. Trax traded price



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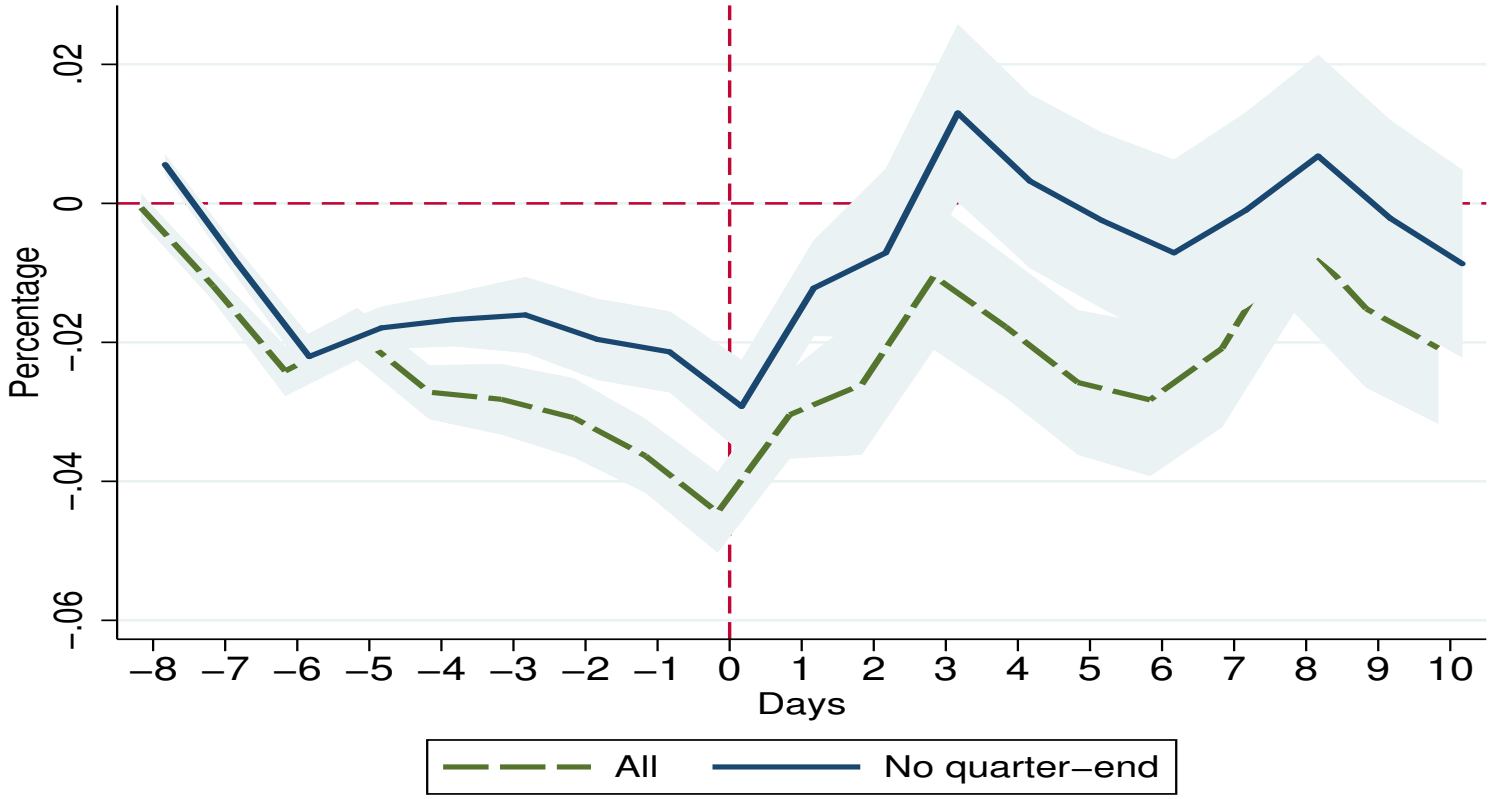
Yield Anomaly Excluding quarter-end windows



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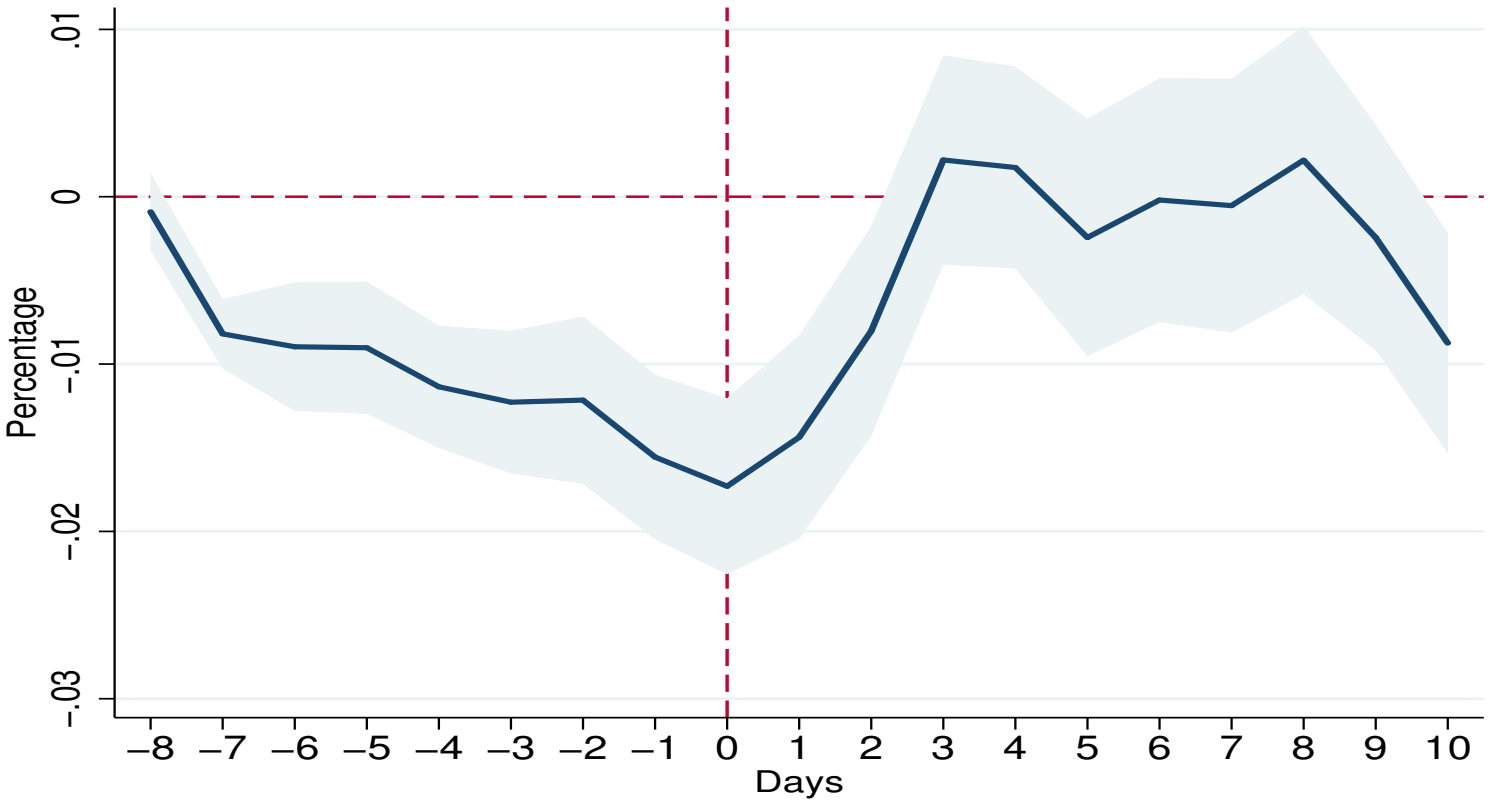
Yield-spread anomaly relative to inelligible bond

- Pair a bond issued by the German central government with a bond issued by a German state (i.e. Hessen) that was no-eligible for purchases from March 2015 to December 2015



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Bond Maturity Buckets

	(1) $0 < 2$	(2) $2 - 5$	(3) $5 - 10$	(4) > 10
-8	-0.012***	-0.005	0.022	0.095**
-7	-0.021***	0.004	0.090***	0.322***
-6	-0.026***	0.024***	0.110***	0.366***
-5	-0.036***	0.010	0.082***	0.230***
-4	-0.041***	0.014	0.135***	0.459***
-3	-0.047***	0.014	0.133***	0.460***
-2	-0.054***	0.025**	0.169***	0.478***
-1	-0.071***	0.002	0.151***	0.495***
0	-0.077***	0.007	0.184***	0.590***
1	-0.086***	-0.012	0.093*	0.272*
2	-0.091***	-0.013	0.025	-0.059
3	-0.105***	-0.044***	-0.092	-0.418
4	-0.117***	-0.042***	-0.043	-0.275
5	-0.125***	-0.032**	0.038	-0.105
6	-0.127***	-0.024	0.022	-0.202
7	-0.138***	-0.037**	-0.054	-0.458
8	-0.152***	-0.082***	-0.186***	-0.850**
9	-0.162***	-0.073***	-0.088	-0.565*
10	-0.167***	-0.059***	0.029	-0.158
Obs.	4,769	5,733	6,251	5,090
R^2	0.5336	0.6378	0.6026	0.5370

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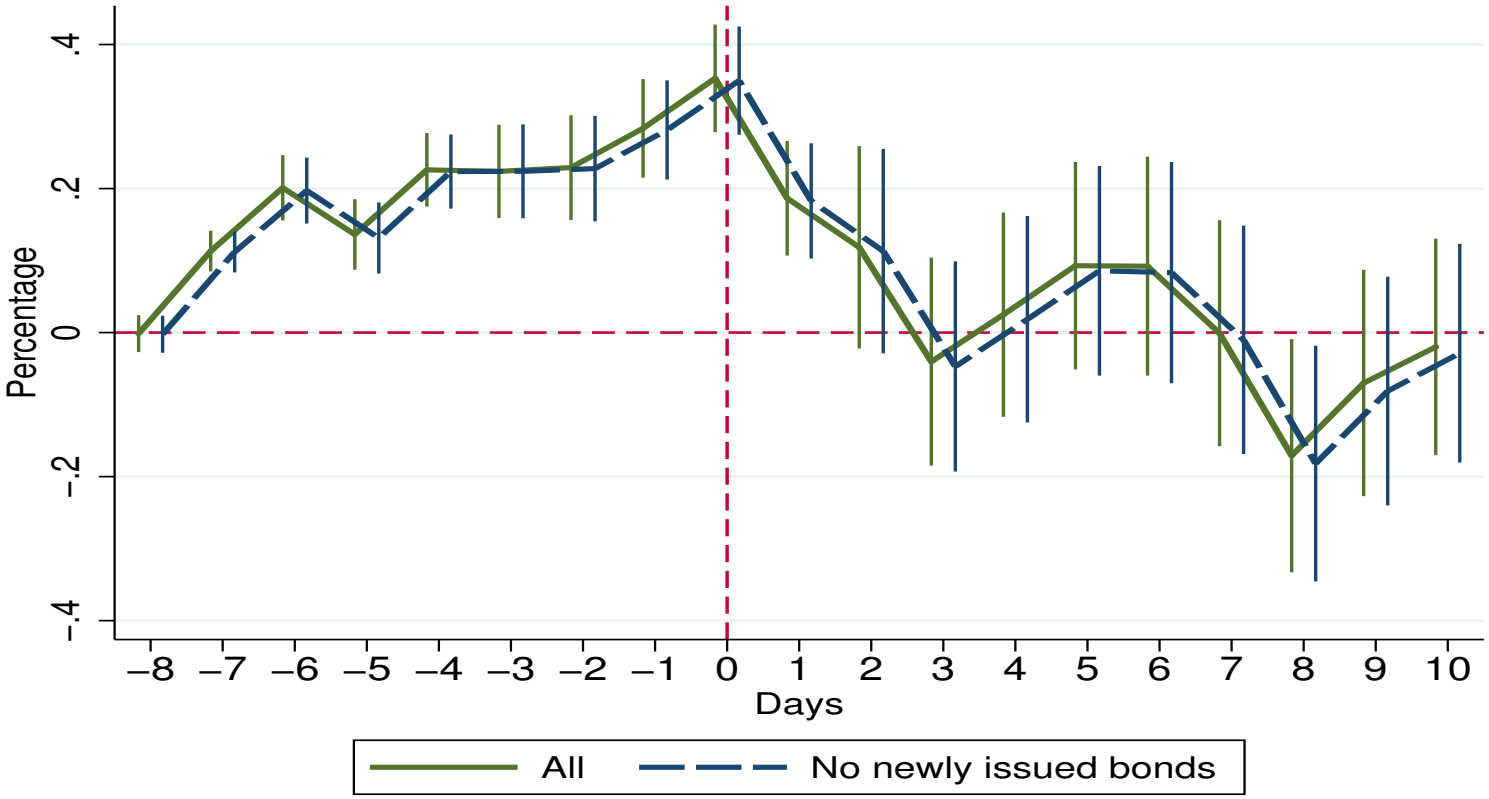
Price anomaly: Newly issued bonds

- We exclude newly issued bonds (bond's age below 3 or 6 months)



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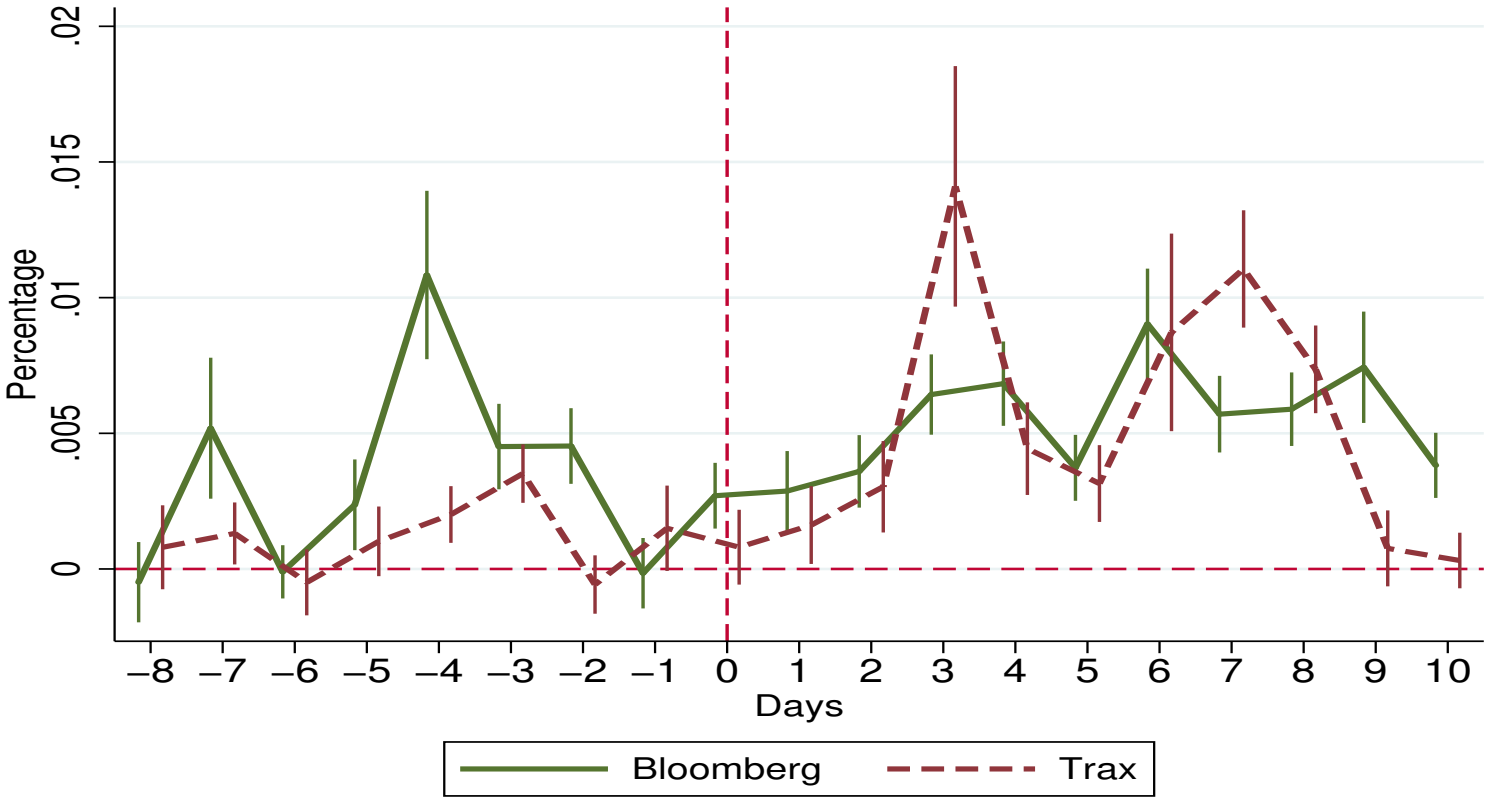
Bid-ask around end-of-month

- The bid-ask spread is computed as $(P_{ask} - P_{bid})/P_{mid}$
- Sample: Front-loading windows



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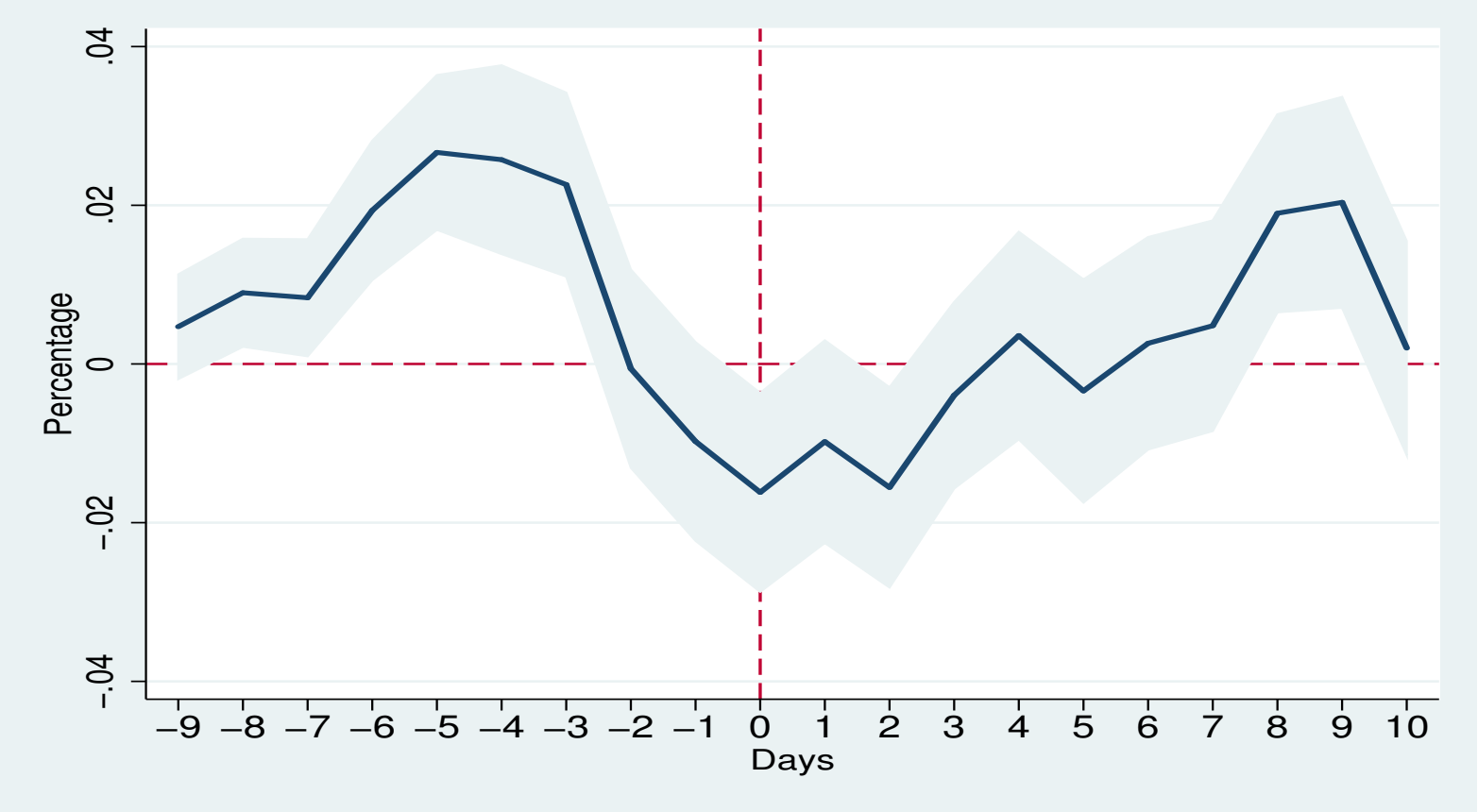
Yield anomaly: 'placebo' test on 2012-2013



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Robustness of the effect of ECB purchases (on day t of window j) on bond-i return

	(1) Full	(2) Without Bund Tantrum	(3) Eligible bonds	(4) Without quarter-end
-8	-0.019	-0.015	-0.105	-0.087
-7	0.108	0.052	0.005	0.050
-6	0.206**	0.214***	0.076	0.158*
-5	0.207**	0.188**	0.104	0.147
-4	0.311***	0.282***	0.179	0.190**
-3	0.467***	0.423***	0.373***	0.393***
-2	0.563***	0.541***	0.495***	0.468***
-1	0.479***	0.487***	0.413***	0.358***
0	0.474***	0.503***	0.368**	0.282**
1	0.374***	0.389***	0.327**	0.202
2	0.305*	0.367**	0.325	0.086
3	0.208	0.285*	0.305	-0.066
4	0.316	0.345*	0.427*	0.117
5	0.267	0.368*	0.292	0.060
6	0.237	0.300	0.284	0.049
7	0.124	0.195	0.220	-0.048
8	-0.031	0.108	0.086	-0.165
9	0.314*	0.269	0.435*	0.199
10	0.333**	0.411**	0.323	0.268
Obs.	21,419	19,391	13,233	16,339
R^2	0.5370	0.5112	0.5312	0.5106

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Why can maximum price exceed the T-reservation value? a simple two period example

- CB wants to purchase 2 units in 2 rounds from 2 dealers, who quote with probability 1 in every round
- CB reservation value is 1 per unit in the **last** round.
- **First case:**
  If CB enters round 2 and still needs to buy 2 units, then both dealers will quote a price of 1
- **Second case:**
  - If CB enters round 2 and only needs to buy 1 unit, then Bertrand competition between Ds drives price to 0
  - CB has an incentive in period 1 to pay up to $2 - \epsilon$ to buy 1 unit, because then
  - CB obtains the low price in round 2 reducing the cost of the 2 units to $2 - \epsilon$

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US Treasury Yields around Auctions

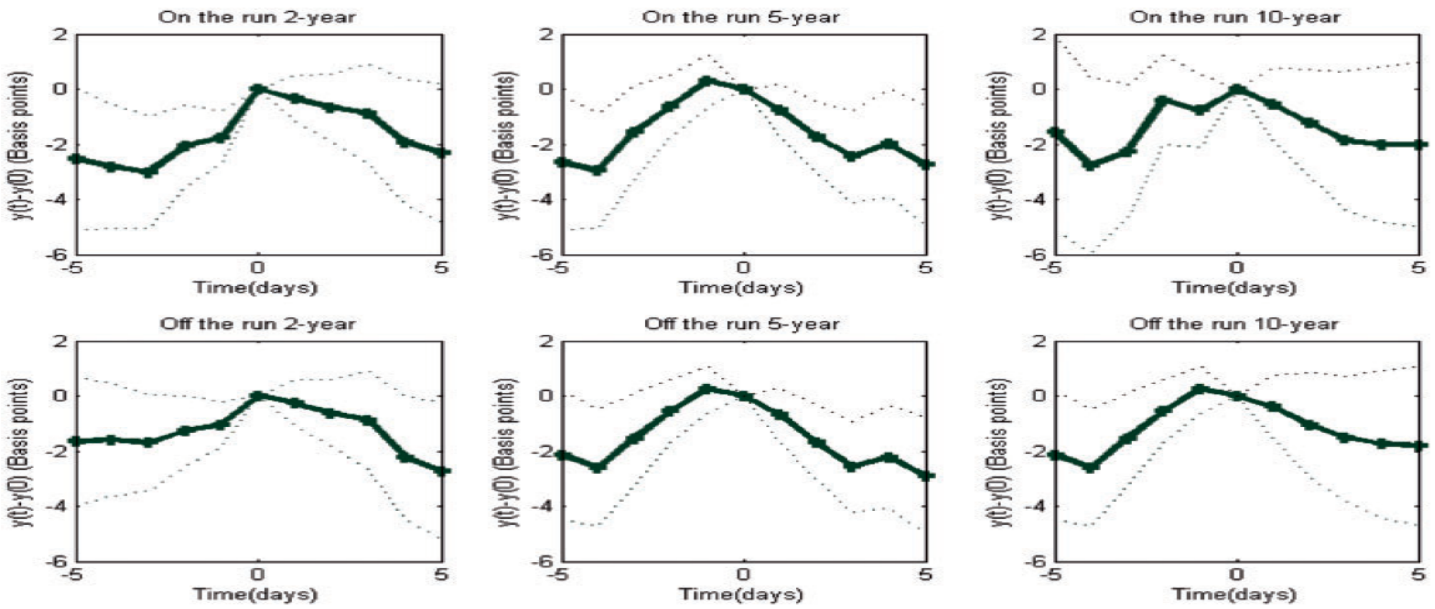

Figure 1
Treasury yields around auctions
Solid lines correspond to the time series average of $Y(t)-Y(0)$, where $Y(t)$ is the yield of an n-year Treasury note ($n=2,5,10$) on day t, with t ranging from -5 to 5 (including $t=0$) and $t=0$ being the day when an n-year note auction is conducted. We track the same note before and after auctions. For the three figures in the first row, the note is on-the-run before the auction and becomes off-the-run after the auction. For the three figures in the second row, the note is first off-the-run before the auction and becomes second off-the-run after the auction. The dotted lines are the 95% confidence interval. The sample period is from January 1980 to June 2008. All yields are expressed in basis points.

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