NEW YORK UNIVERSITY

Central Bank–Driven Mispricing

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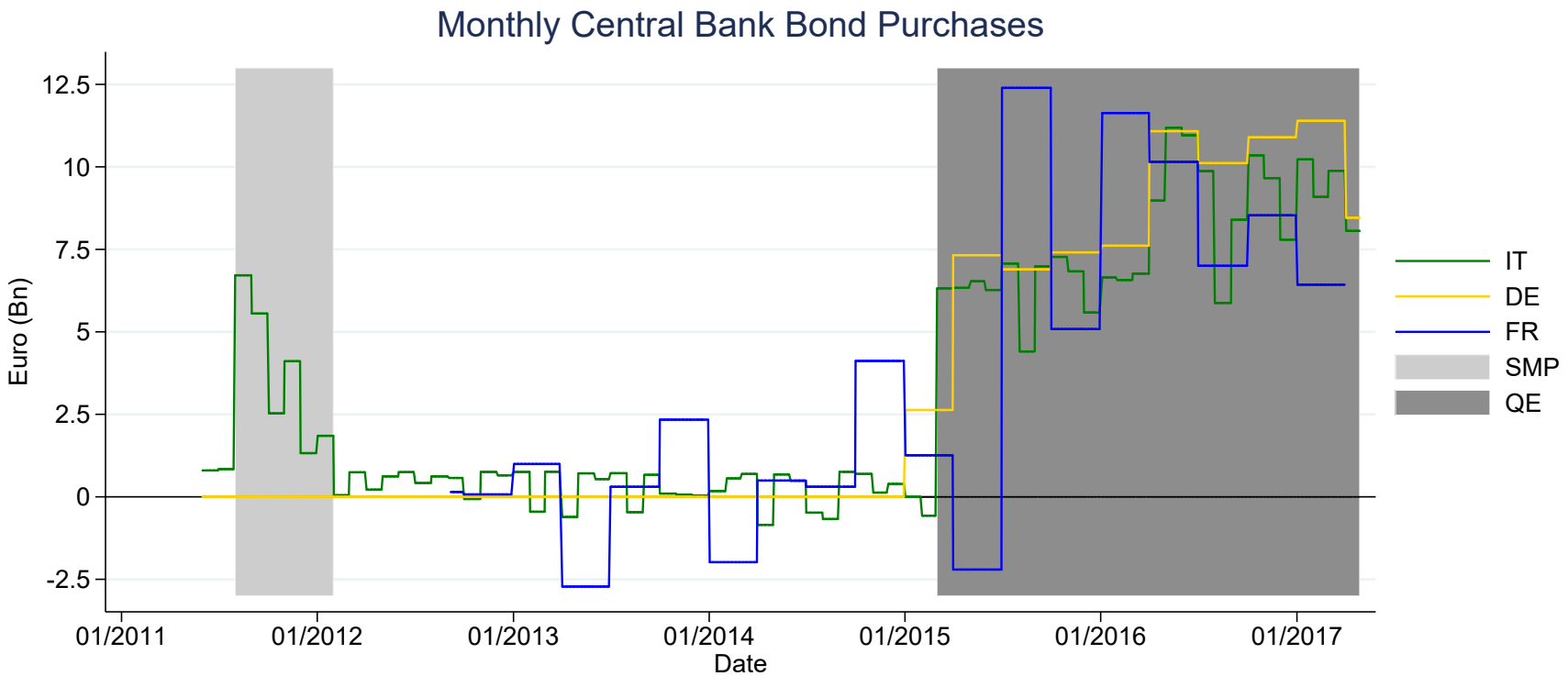
Motivation

- The ECB purchased between € 50 and 80 billion of bonds under the Asset Purchase Program (APP) since March 2015.
- The ECB recently purchased € 50 billion worth of bonds in December 2017. Purchases are projected to diminish to € 30 billion a month in 2018.
- On average, € 9 billion spent on Italian, French, and German sovereign bond, per month, per country, in the cash market, during 2015-2017.
- Large mispricing between sovereign bond cash and futures, even after transaction costs.



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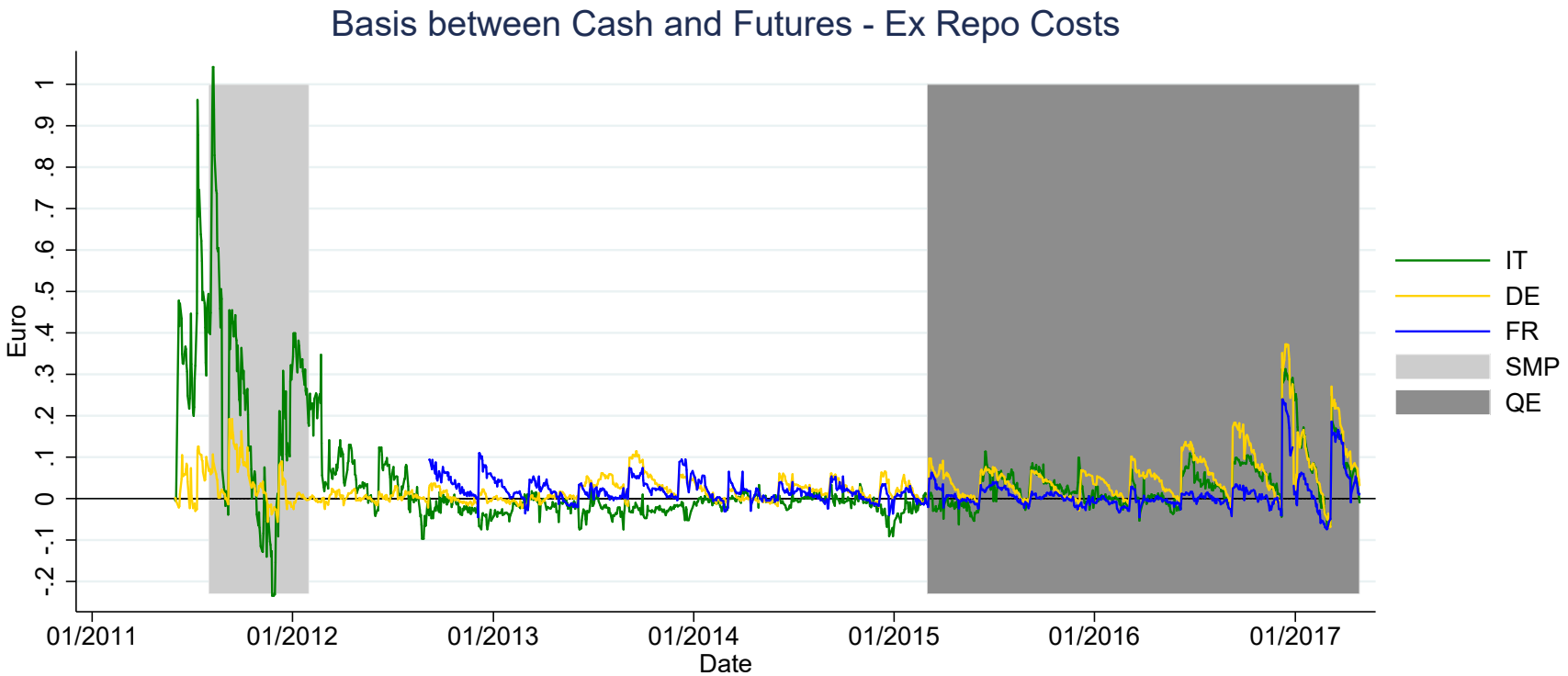

Findings

While the ECB's quantitative easing (QE) interventions were aimed at and succeeded in lowering bond yields, they affected markets that were not targeted:

- QE drove a wedge between sovereign cash bond prices and the corresponding futures contract.
- QE depleted market liquidity not only in the cash bond market, but also in the market for sovereign bond futures contracts.

Outline of the Presentation

- ECB Intervention and Hypotheses
- The Arbitrage Mechanism
- Data
- Results: Mispricing
- Results: Market Liquidity
- Conclusions

Literature Review

- Pelizzon, Subrahmanyam, Tomio, and Uno (WP, 2014): Effect of SMP and LTRO on the mispricing between BTP cash and futures and liquidity spillovers between markets.
- Buraschi, Menguturk, and Sener (RFS, 2014): Effect of FED interventions (TARP, TALF) on the basis between sovereign bonds in different currencies.
- Pelizzon, Subrahmanyam, Tomio, and Uno (JFE, 2016): ECB Intervention and market liquidity.
- Corradin and Rodriguez-Moreno (ECB-WP, 2016): ECB mandated margin changes affected the basis between sovereign bonds in different currencies.

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ECB Interventions Characteristics

After 2010, an array of interventions were conducted.

SMP

- Security Market Programme
- Direct Bond Purchases
- Italy and Spain
- Aug 2011 – Feb 2012

LTRO

- Long Term Refinancing Operations
- Bank Liquidity Provision
- All participating banks
- Dec 2011 – Feb 2012

PSPP

- Public Sector Purchase Programme
- Direct Bond Purchases
- All European Sovereigns
- April 2015 – ...

SMP and PSPP intervened in the market *directly*. PSPP is part of the larger Asset Purchase Programme (APP)

ECB QE Characteristics

From the speech by Benoit Coeure, Member of the Executive Board of the ECB, at the Second International Conference on Sovereign Bond Markets, Frankfurt, 10 March 2015.

On Market Neutrality

One key principle underlying the implementation of the PSPP is the minimisation of unintended consequences. This can be ensured by obeying the concept of market neutrality of our operations. [...] The concept of market neutrality means that, while we do want to affect prices, **we do not want to suppress the price discovery mechanism**. We will operationalise this principle by ensuring a high degree of transparency around our interventions and by closely monitoring their impact on liquidity and collateral availability.

On the Future-Bond Basis

[...] We will take particular care to avoid exacerbating any existing market frictions. More specifically, **we will try to avoid, to the extent possible, purchasing specific securities such as current cheapest-to-deliver bonds underlying futures contracts**, securities commanding "special" rates in the repo market as a sign of temporary scarcity, and other assets displaying significant liquidity shortages.

ECB Interventions: Hypotheses

Hypotheses

Consider two securities linked by arbitrage. When arbitrageurs are present on the market:

1) the prices are close to each other, within the bonds of the bid-ask spread.
2) the returns of the two markets are more positively correlated than in the arbitrageurs' absence.
3) the bid-ask spreads of the two securities co-move more than in the arbitrageurs' absence.

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The Futures Contract

- Fairly standardized contract, similar across all major countries, e.g., the US, Japan, the UK, Germany, France, and Italy.
- A bond futures contract is an exchange-traded instrument, whereby the futures seller agrees to deliver a bond to the futures buyer by delivery date
- The price the buyer pays is decided on trade date.
- The traders' positions are marked-to-market every day.
- Each contract requires delivery of bonds for a total of € 100,000 in face value.
- Bonds that are deliverable by investors who are short in the futures contract need to satisfy a set of requirements. For the Italian bond futures contract, for example, bonds need to:
  - Have less than 16 years to maturity at issuance
  - Have between 8.5 and 11 years to maturity at delivery
  - Have an issue amount larger than € 5 billions.
- Similar requirements for German and French contracts.
- Prices of deliverable bonds differ, but are made comparable with conversion factors.

The Arbitrage Trade

An arbitrageur would take advantage of a mispricing as follow, if the cash bond is "rich":

1. At trade date t: Go long the futures contract.
2. At trade date t: "Borrow" the bond on the repo market.
3. At trade date t: Sell the bond.
4. At delivery date T: Receive the bond from the trader.
5. At delivery date T: Close the repo transaction by delivering the bond.

- An arbitrageur who already owns the bond would simply sell it and buy the futures.
- We consider the arbitrage trade with the *highest* cost, to be conservative, i.e., a trader starting with no position, trading at (not inside) the spread.

The Arbitrage Profit

- Futures contract to deliver a bond.
- Typically, the futures trade at a slight discount, due to many frictions (repo costs, funding constraints, bid-ask spreads...). The reverse is less likely, due to lesser frictions.
- Most often profitable: Sell a bond, buy futures contract
- Details: Conversion factor, repo rate, CTD.
- Basis:

$$Basis_t = \underbrace{(B_t + A_{t+2})\left(1 + \frac{T-(t+2)}{360} r_t\right) - A_T}_{\text{Forward Bond Price}} - \underbrace{F_t \cdot CF_b}_{\substack{\text{Futures} \\ \text{Equivalent}}}$$

- At time t, B is bond price, A_{t+2} is the accrued coupon at settlement date, A_T is the accrued interest at delivery date, r_t the risk free rate, F_t the futures price, and CF_b the conversion factor for bond b.

Basis Measures

- We calculate two measures: Amount of profit and frequency.
- We calculate $Basis_{i,t,m,b}$ per country i, day t, trading minute m and (cheapest) deliverable bond b. We select the basis for the cheapest to deliver bond, $Basis_{i,t,m} = \min_i Basis_{i,t,m,b}$, and average throughout the day. The dependent variable, for each day t, is

$$Basis_{it} = \frac{1}{M} \sum_{m} Basis_{i,t,m}$$

- $Basis_{it}$ indicates the *average* size of the arbitrage. We calculate the frequency of arbitrage opportunities as an alternative measure:

$$Freq_{it} = \frac{I\left[\sum_{m=1}^{M} Basis_{i,t,m} > 0\right]}{M}$$

Unaccounted for Arbitrage Costs

$$Basis_t = \underbrace{(B_t + A_{t+2})\left(1 + \frac{T-(t+2)}{360} r_t\right) - A_T}_{\text{Forward Bond Price}} - \underbrace{F_t \cdot CF_b}_{\text{Futures Equivalent}}$$

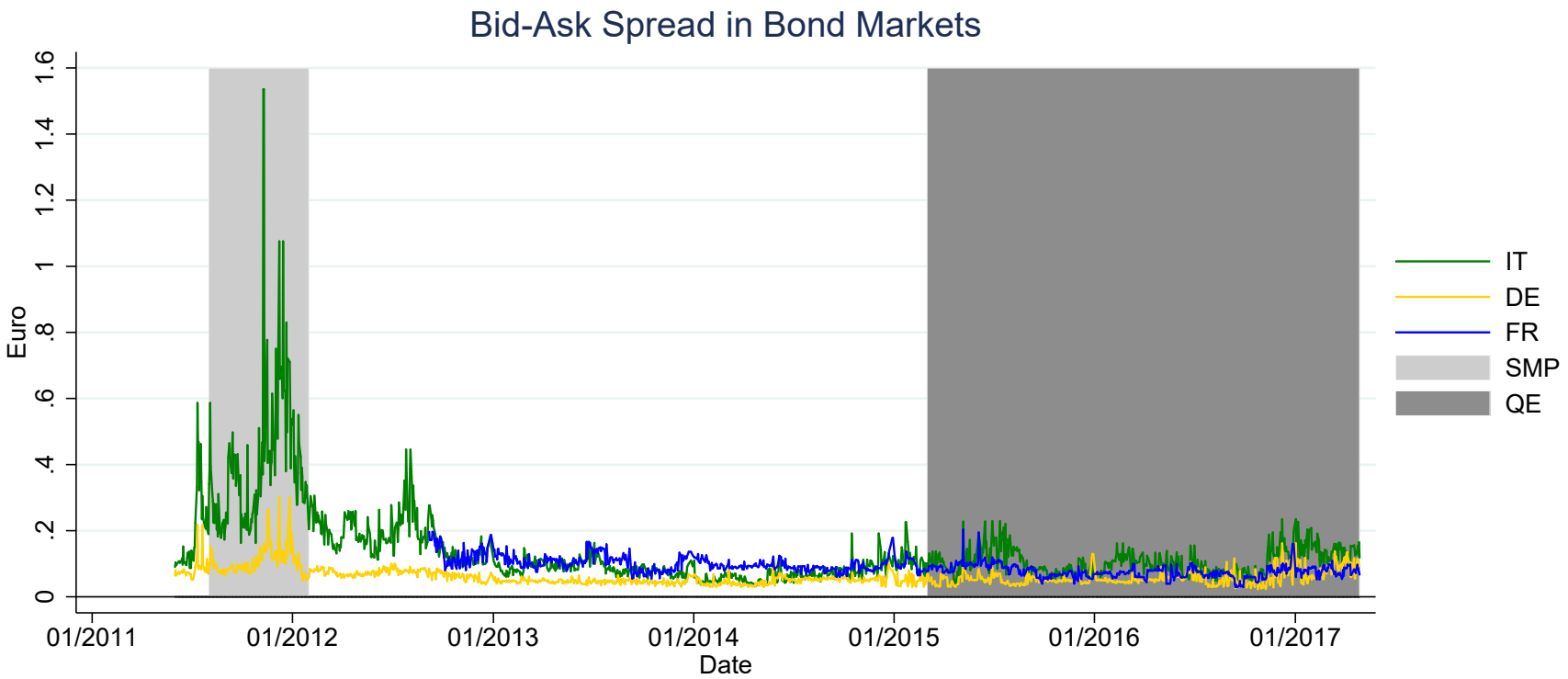
The standard definition of basis ignores significant costs:

- Selling the bond does not take place at the bond midquote, but at the bid.
- Buying the futures does not take place at the futures midquote, but at the ask.
- Borrowing the bond does not result in a gain of r_f.
- The term repo rate is generally increasing in the repo term.

These costs could also depend on the ECB intervention. Identifying the mispricing channel needs to attribute the right price effects to the ECB intervention.

Arbitrage Costs
Cash Market Bid-ask Spread

- The basis trade includes paying half the spread on both markets, by operating at the mid-price.
- Market liquidity could itself be affected by the ECB intervention.



Arbitrage Costs
Futures Market Bid-ask Spread

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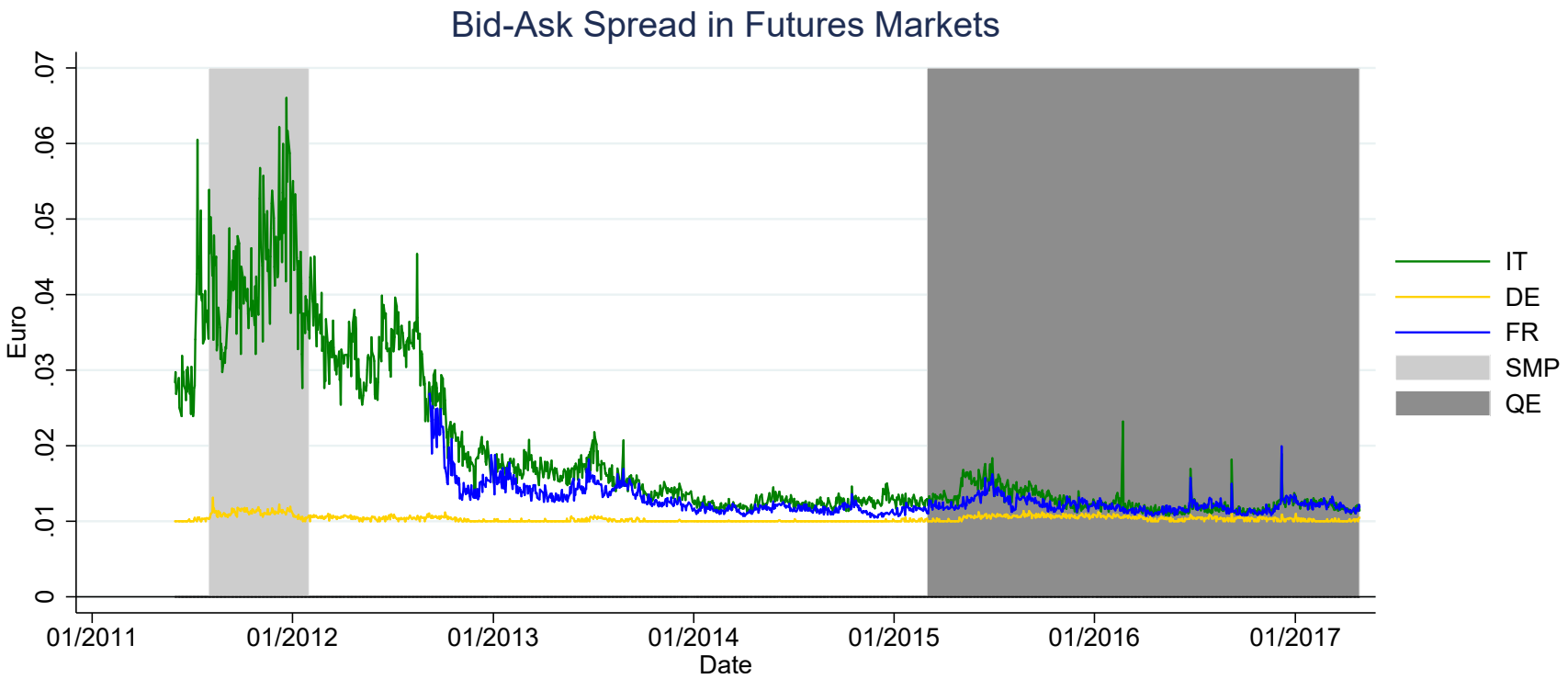
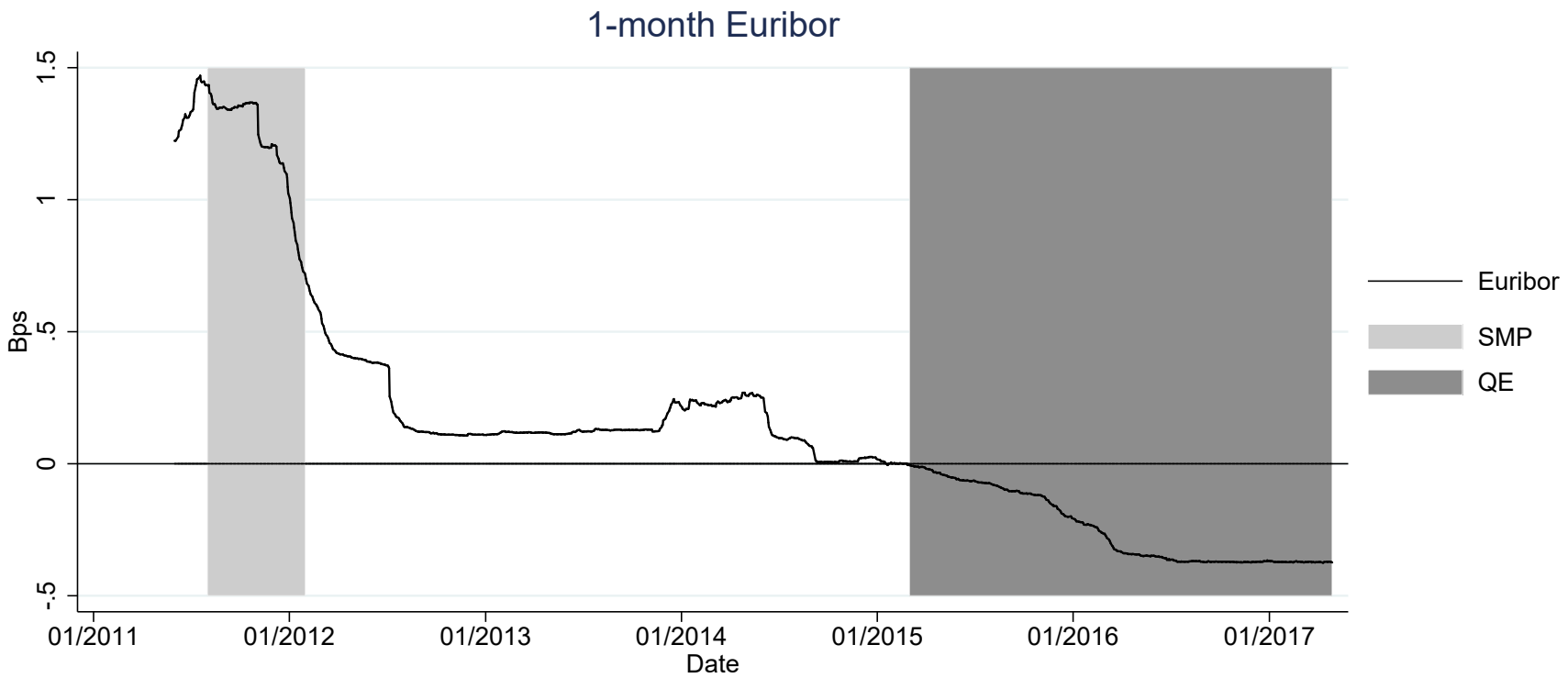
- Market liquidity could itself be affected by the ECB intervention.



Arbitrage Costs
Funding Liquidity

We can think of funding liquidity in two ways:

- Capital constraints generally applied to trading positions (measured by the Euribor).
- The "cost of carry" of actually financing the position (the reverse repo rate).



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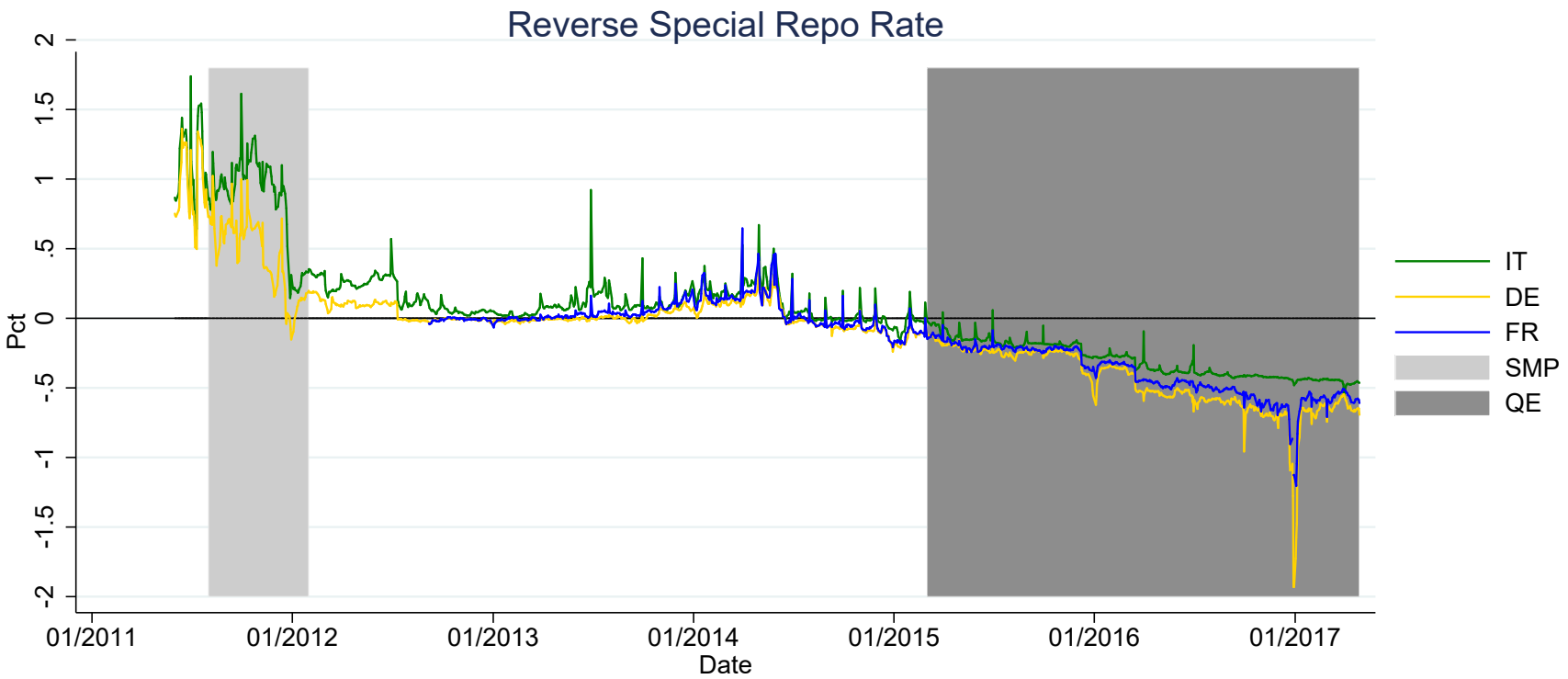

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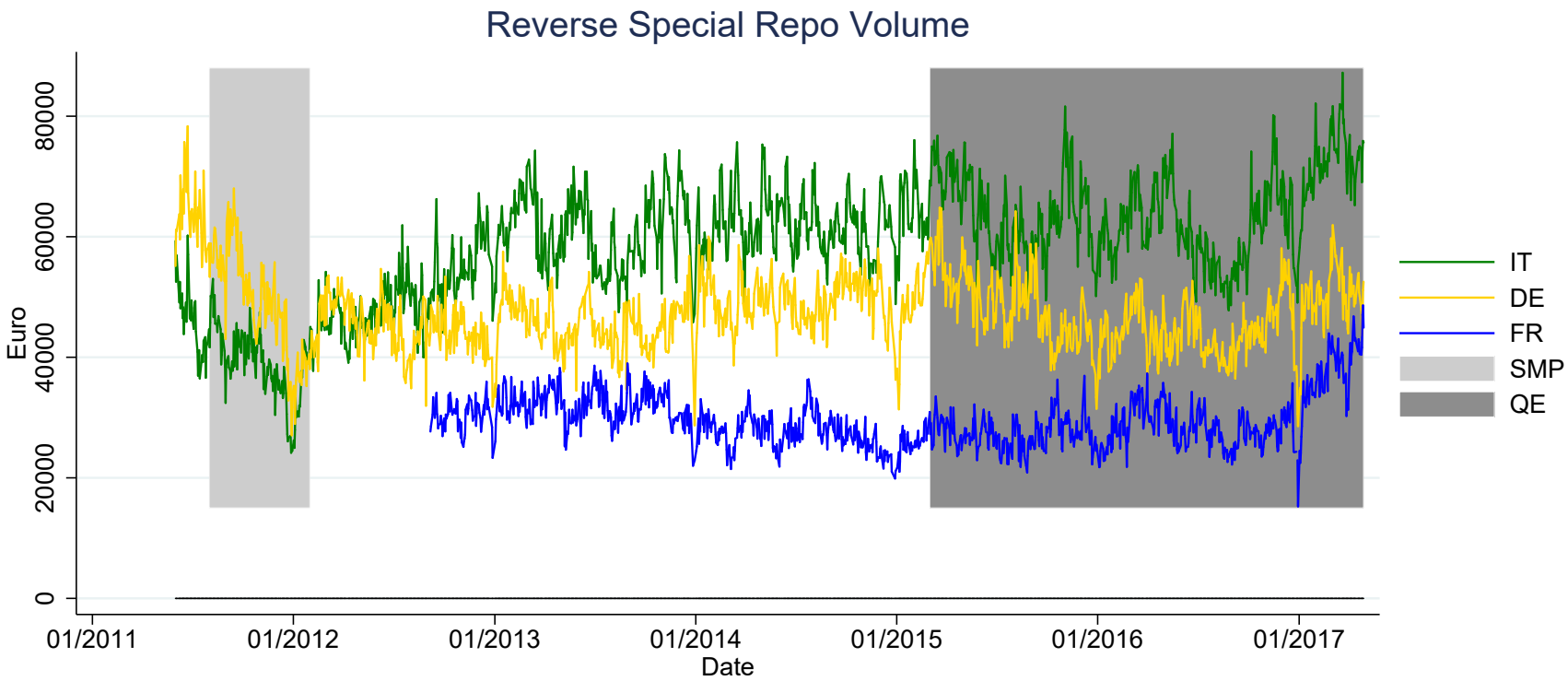

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Data

MTS, Mercato dei Titoli di Stato, is an Electronic, Inter-Dealer market.

- Dealer to Retail client: not covered.
- Primary Dealers and Price takers

We observe:

- Trade-by-Trade data.
- Order-by-Order data, uniquely linked to the trades.
- Every quote, every update, un-netted.

Eurex is an Electronic, limit order market for futures

- Only one designated market maker but many competitive traders.
- High frequency data for best bid- and ask-prices.

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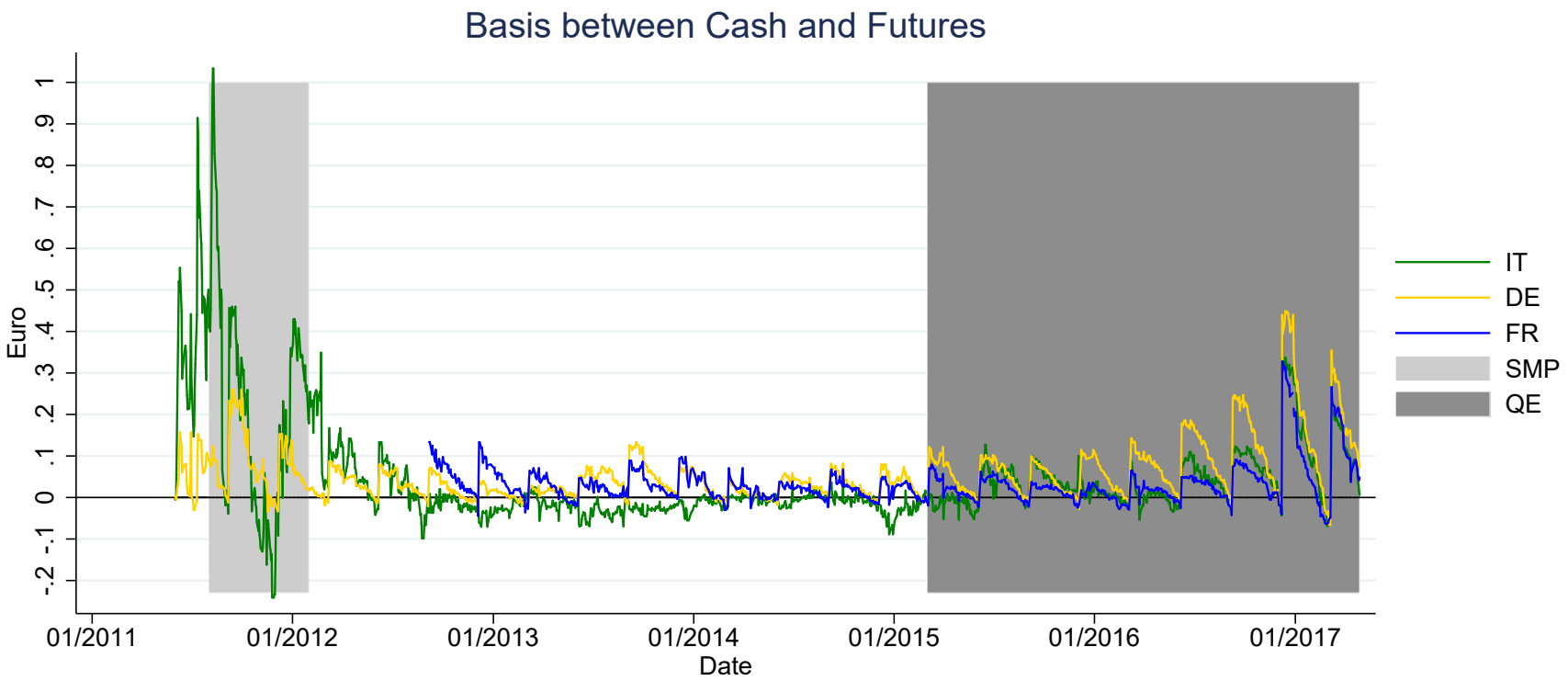
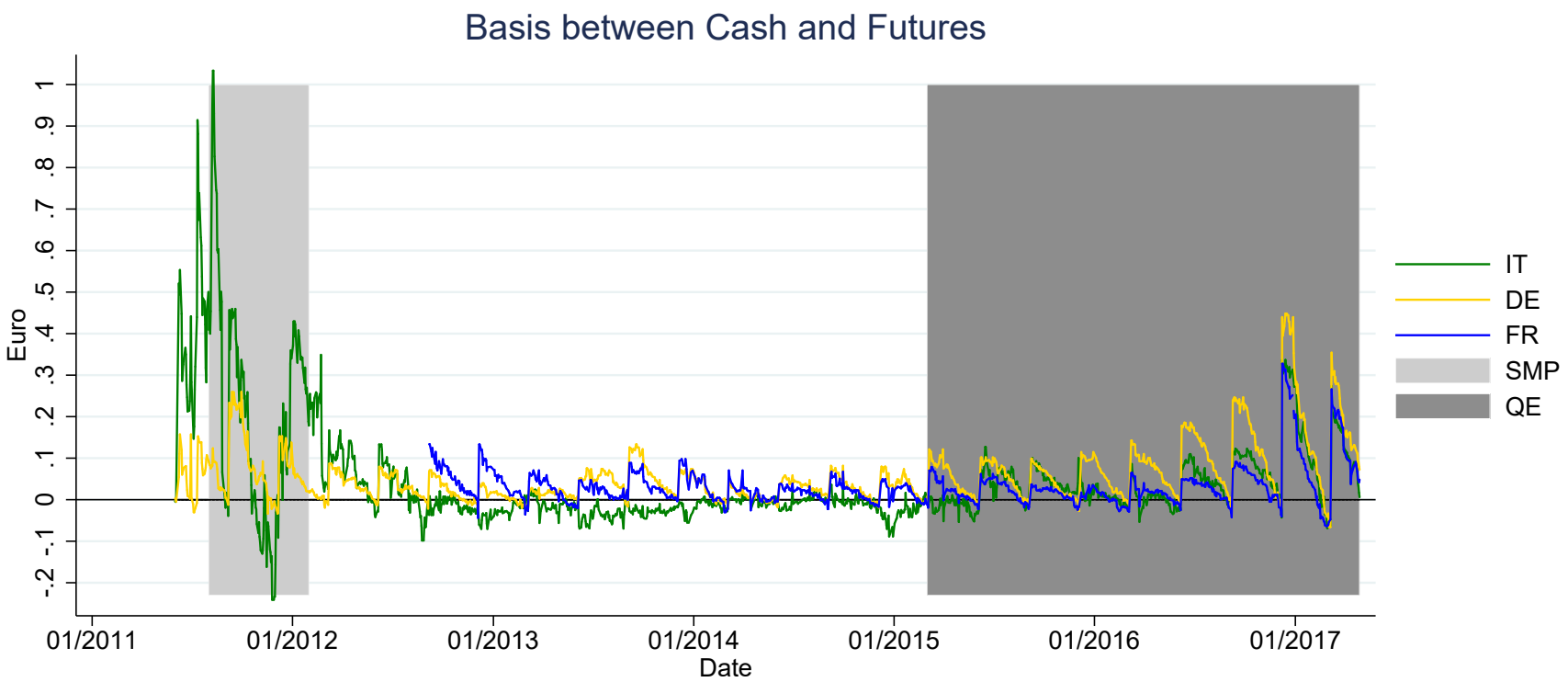
Basis: No Costs



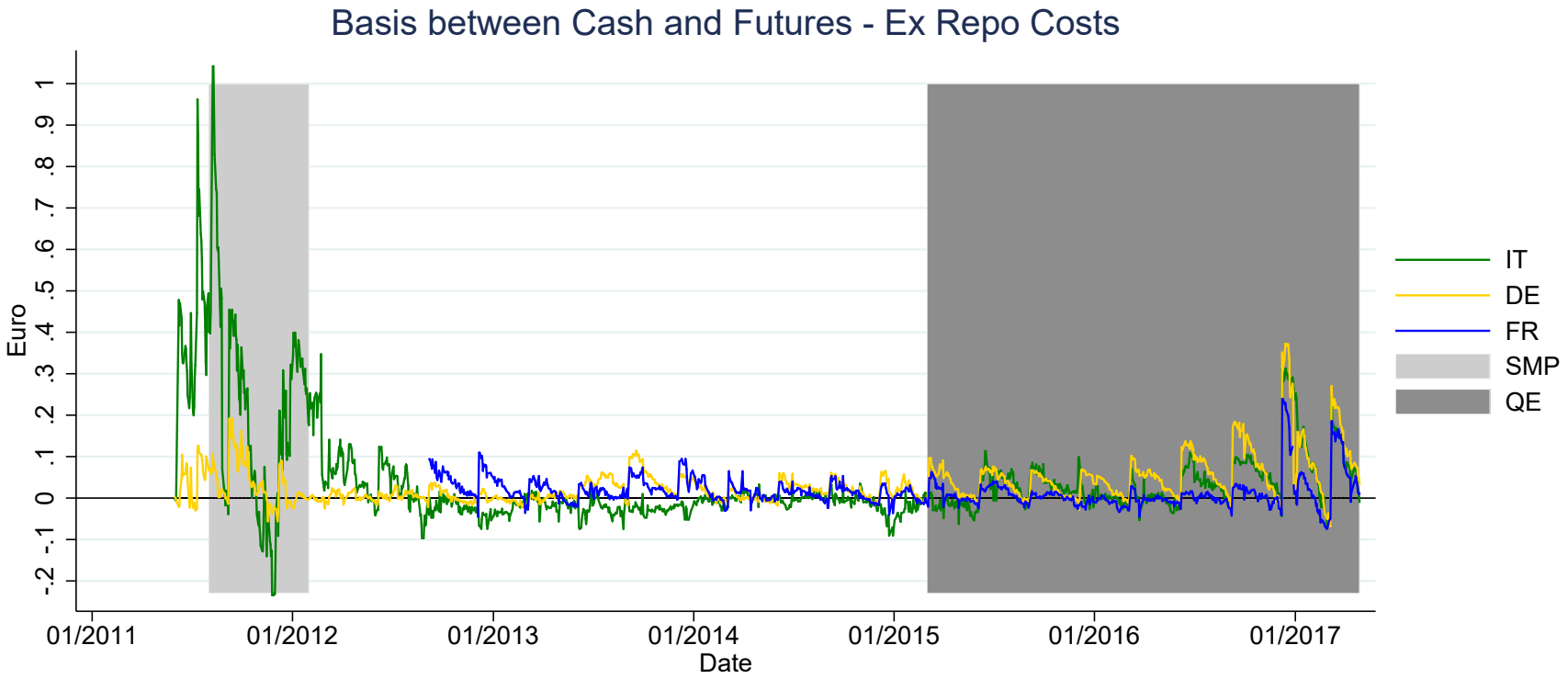
- The basis does not take any cost/friction into account. It is, on average, positive, more so during the QE (€ 0.07 vs. €0.03). Next slides adjust for various costs/frictions.
- The basis is very similar across the three markets, despite the differences in underlying bonds (Bund, BTP, OAT). This is especially true in 2015-2017, when the bonds of all three countries were targeted by the ECB in the QE.
- Consistent with an arbitrageur allocating trades, equalizing the bases, at the margin.

Basis: No Costs



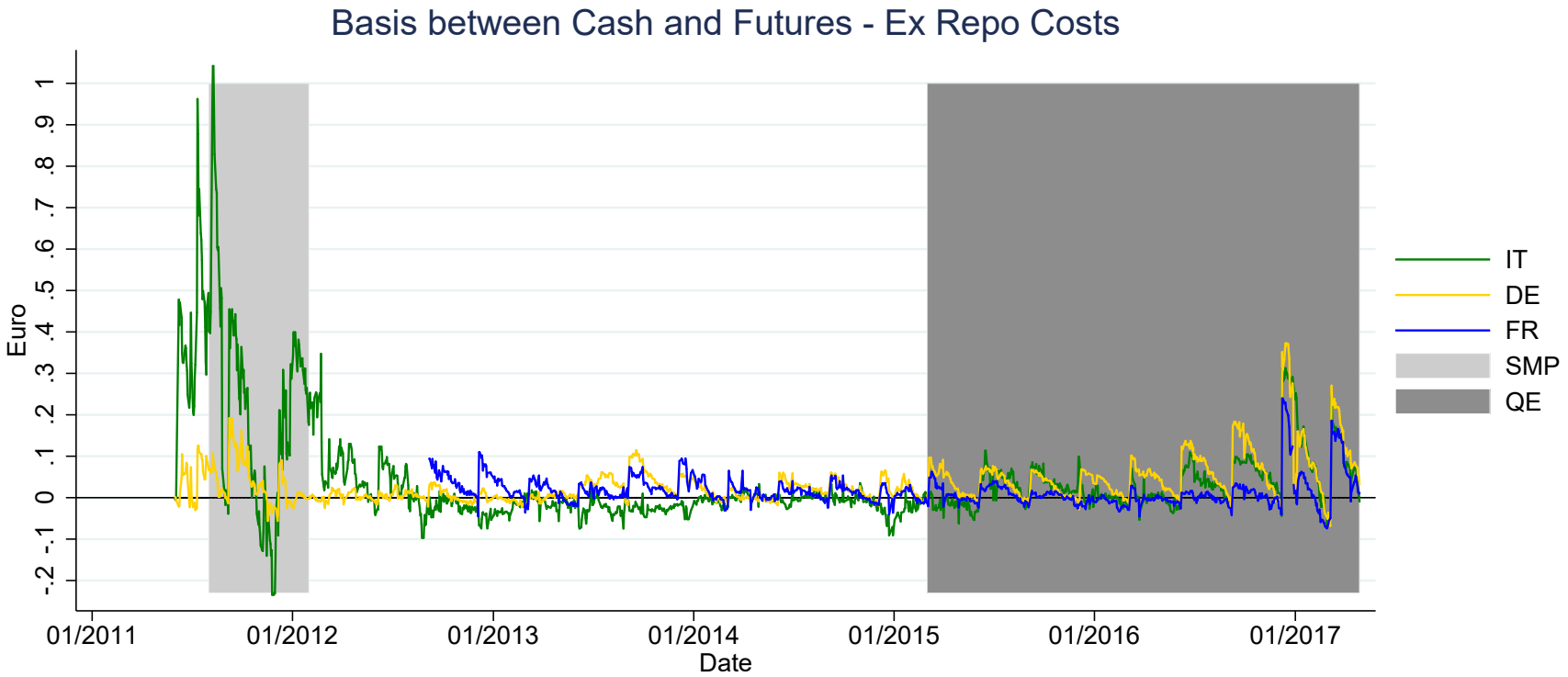
	All	DE	FR	IT
$Basis_t$ outside QE	0.028	0.037	0.027	0.018
$Basis_t$ during QE	0.070	0.091	0.036	0.079
Difference	0.042***	0.054***	0.010***	0.061***

Basis: After Borrowing Costs



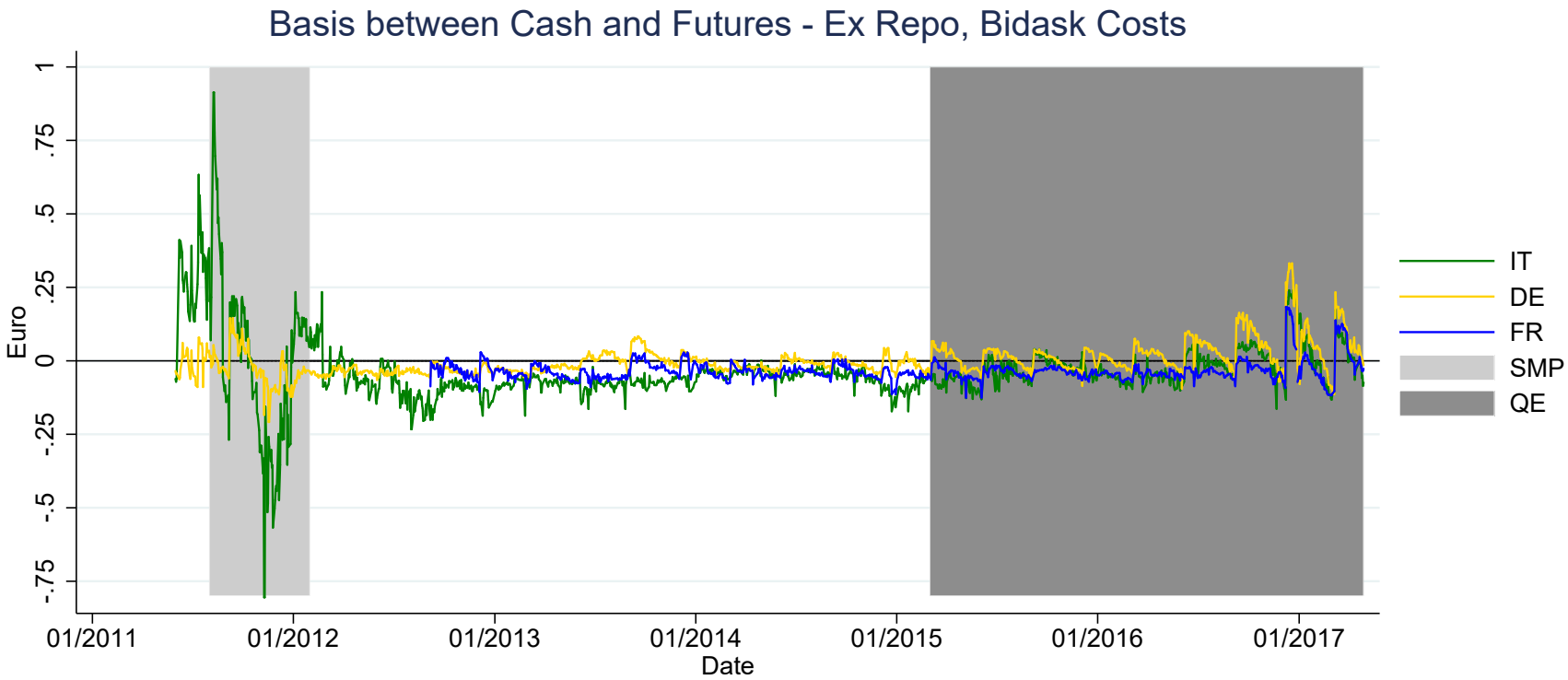
- Accounting for the bond borrowing costs, the basis is still, on average, positive. It is larger during the QE (€ 0.05 vs. €0.02).
- The basis is wider for Italy and Germany. The French futures-bond basis is smaller during the QE (taking trading costs into account reverses this, as shown later).
- Borrowing costs alone do not explain the mispricing. We need to include trading costs.

Basis: After Borrowing Costs



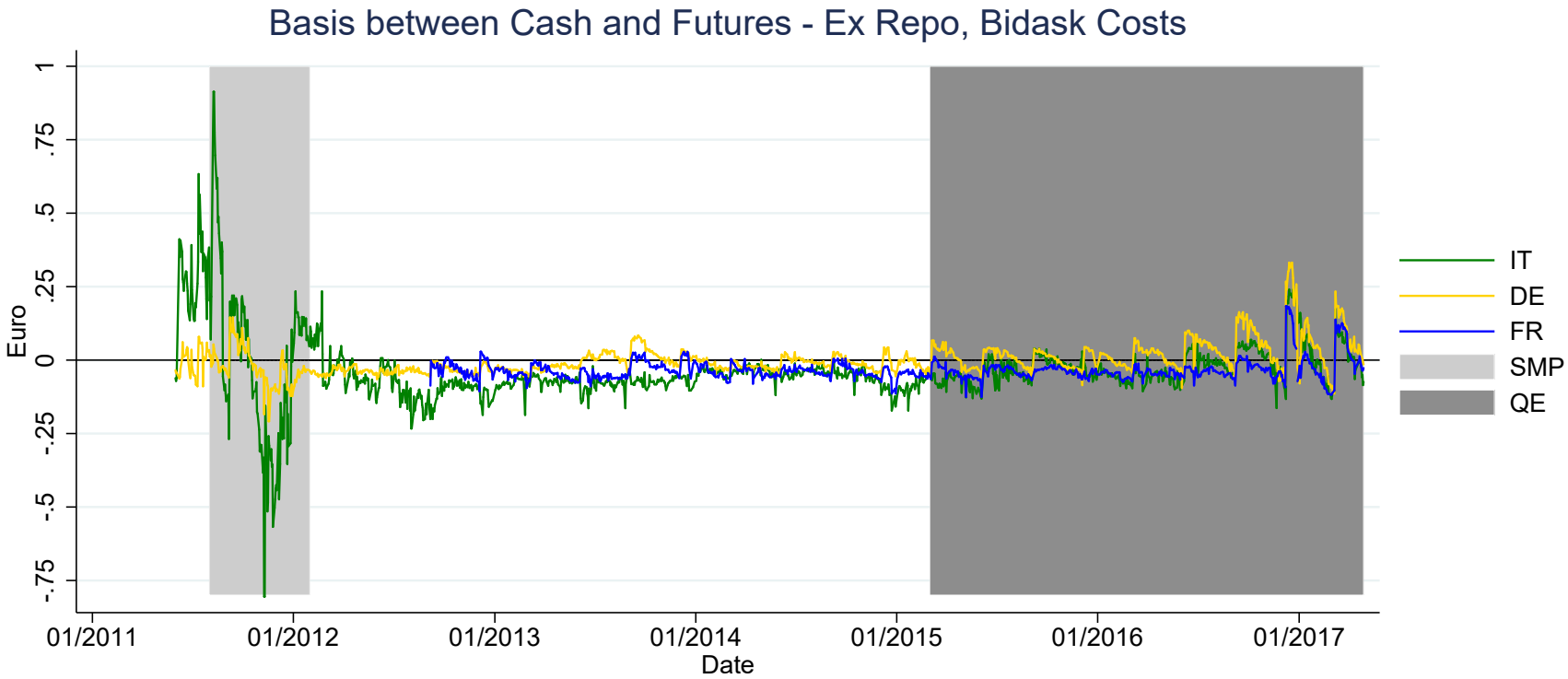
	All	DE	FR	IT
$Basis_t$ outside QE	0.018	0.019	0.019	0.018
$Basis_t$ during QE	0.050	0.060	0.011	0.073
Difference	0.032***	0.034***	−0.015***	0.043***

Basis: After Borrowing, Trading Costs



- The basis corrects for the bid-ask bounce, borrowing costs (but not their term structure).
- The mispricing is, on average, negative. Trading costs contribute the most to the basis.
- The difference in mispricing before vs. during QE is € 0.01 (31%) smaller once these costs are taken into account.

Basis: After Borrowing, Trading Costs

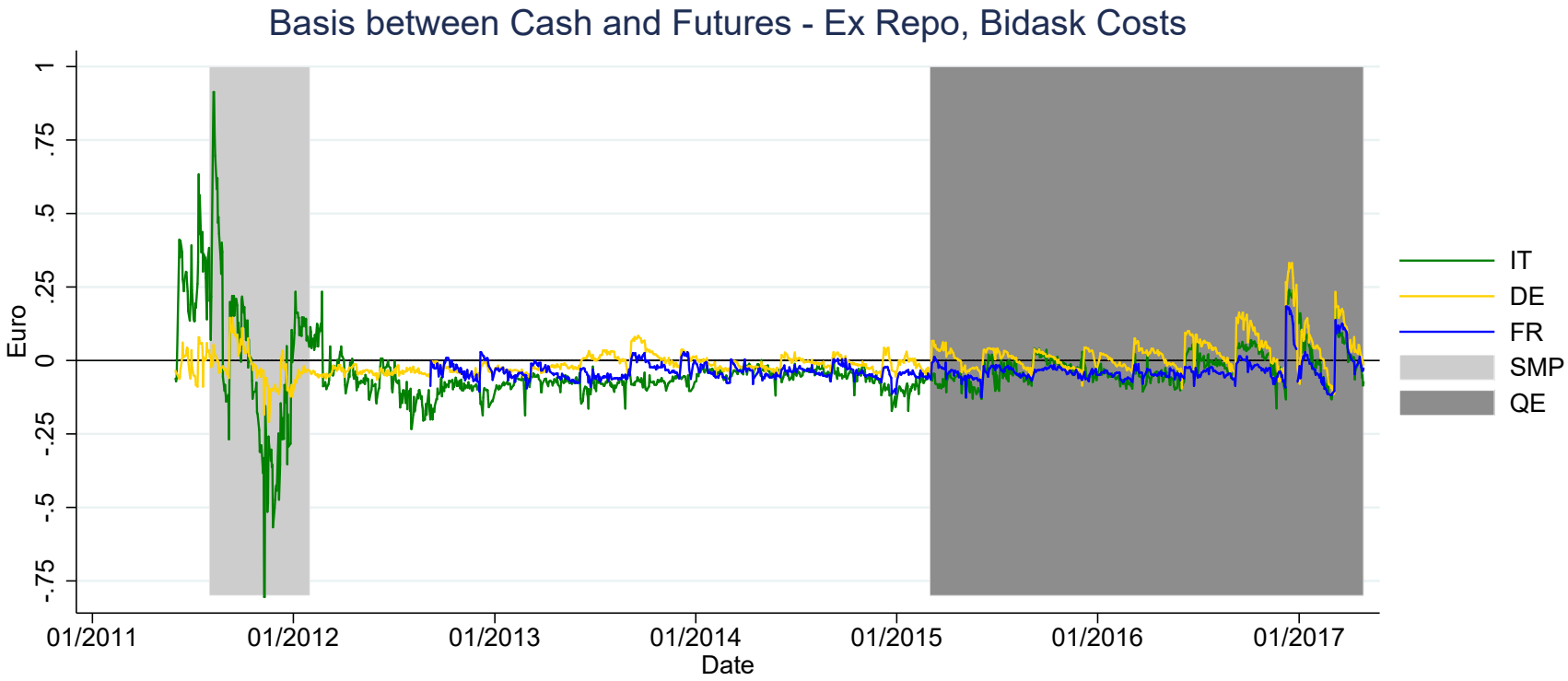


	All	DE	FR	IT
$Basis_t$ outside QE	−0.034	−0.017	−0.038	−0.050
$Basis_t$ during QE	−0.008	0.027	−0.032	−0.019
Difference	0.023***	0.045***	0.007***	0.031***

Accounting for Term Repo Rates

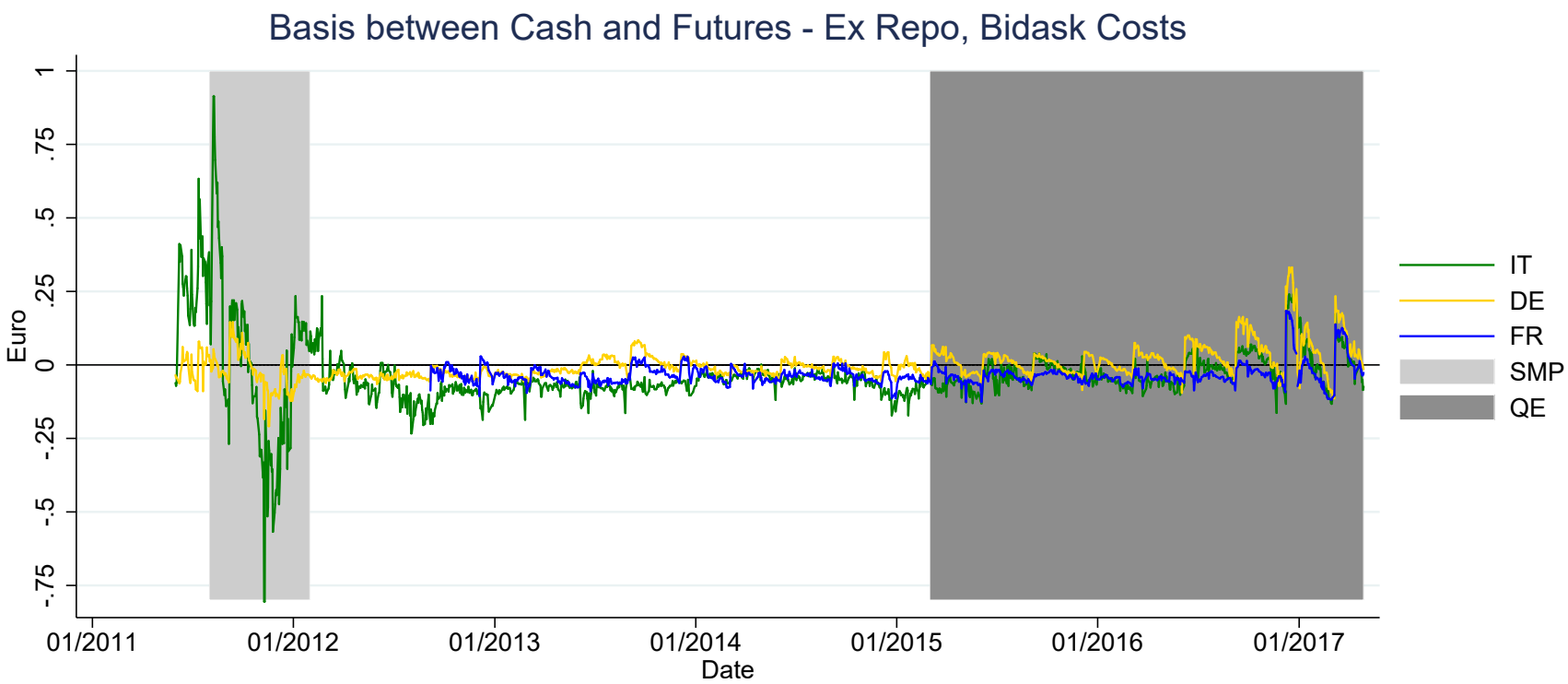
- The special repo rate index consists of the average repo rate at which bonds that are on special are borrowed/lent at.
- 90% of all special repo transactions span two trading days or less (overnight).
- To account for the term repo trade an arbitrageur would enter, to borrow the bond for a prolonged period of time, we do the following:
  - For every day t, we obtain a series of maturities for Euribor rates ($E_{t,1}$, $E_{t,7}$, $E_{t,14}$, $E_{t,21}$, $E_{t,30}$, $E_{t,60}$...). We use the overnight Eonia as 1-day Euribor.
  - We estimate a polynomial term structure model: $E_{t,j} = \alpha_t + \beta_{1t} j + \beta_{2t} j^2 + \beta_{3t} j^3 + \varepsilon_j$
  - We calculate the interpolated Euribor rate $E_{t,DtD}$, from day t to the futures contract delivery date (the end of the term repo): $E_{t,DtD} = \alpha_t + \beta_{1t} DtD_t + \beta_{2t} DtD_t^2 + \beta_{3t} DtD_t^3$
  - We estimate the appropriate term repo rate by subtracting the overnight Eonia rate and adding the repo rate index (i.e., the overnight repo rate): $RRate_{t,DtD} = E_{t,DtD} - E_{t,1} + RRate_{t,1}$
- Repeating the analysis using the Eonia term structure, instead of Euribor rates, leads to very similar results.

Basis: After Borrowing, Trading, Term Costs



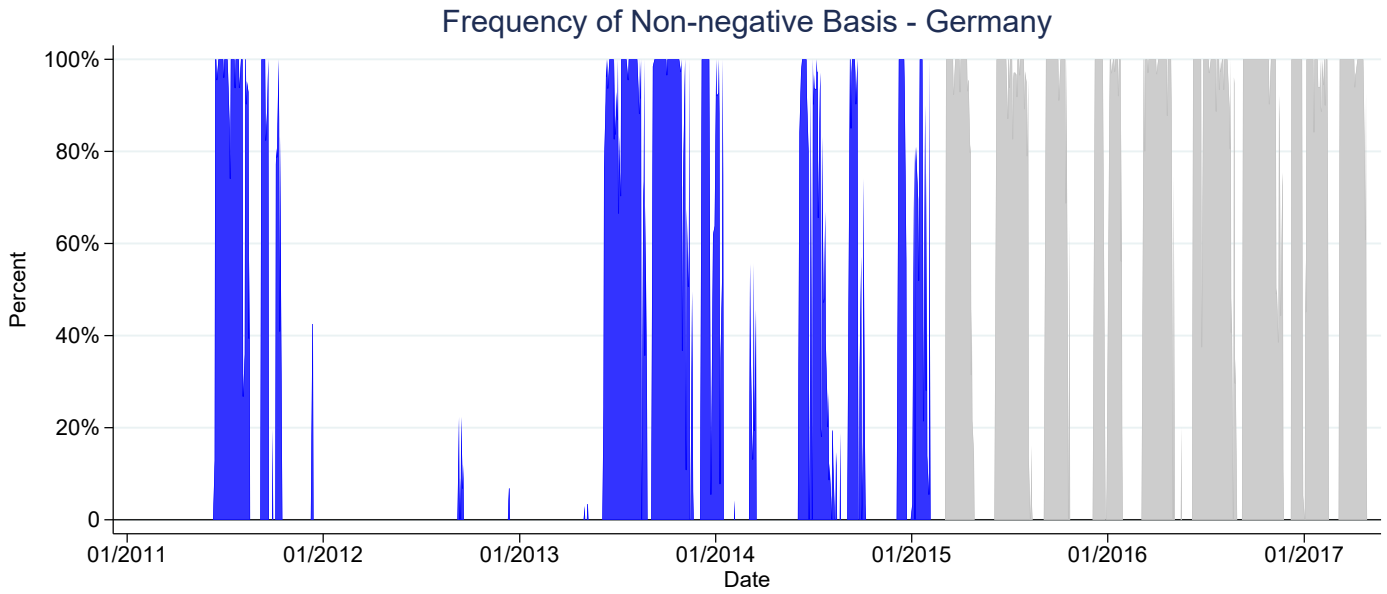
- We correct for the bid-ask bounce, borrowing costs, and the term structure of the repo rate.
- Arbitrage opportunities increase € 0.02 during the QE. More significantly for German (+€ 0.05) and Italian (+€ 0.03) futures-cash bonds couples than for their French counterparts.
- The negative basis suggests that the basis trade was, on average, not profitable. The frequency of arbitrage opportunities presents a better picture.

Basis: After Borrowing, Trading, Term Costs



	All	DE	FR	IT
$Basis_t$ outside QE	−0.034	−0.018	−0.038	−0.048
$Basis_t$ during QE	−0.010	0.027	−0.033	−0.022
Difference	0.023***	0.045***	0.005***	0.026***

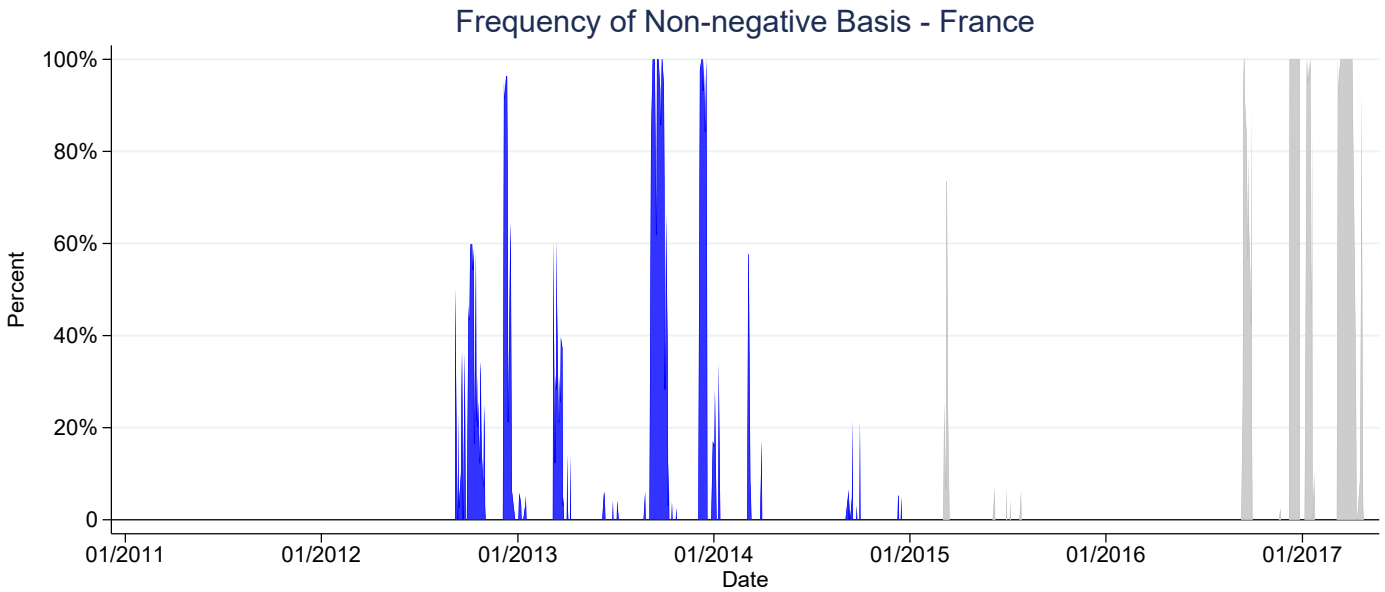
Frequency: Borrowing, Trading, Term Costs



	All	DE	FR	IT
$Freq_t$ outside QE	0.154	0.261	0.089	0.080
$Freq_t$ during QE	0.362	0.639	0.106	0.344
Difference	0.207***	0.378***	0.017	0.264***

- Arbitrage opportunities are 20% more frequent when the ECB is purchasing bonds (gray).
- Arbitrage opportunities increase more significantly for German (+38%) and Italian (+26%) futures-cash bonds pairs than for their French counterparts.

Frequency: Borrowing, Trading, Term Costs



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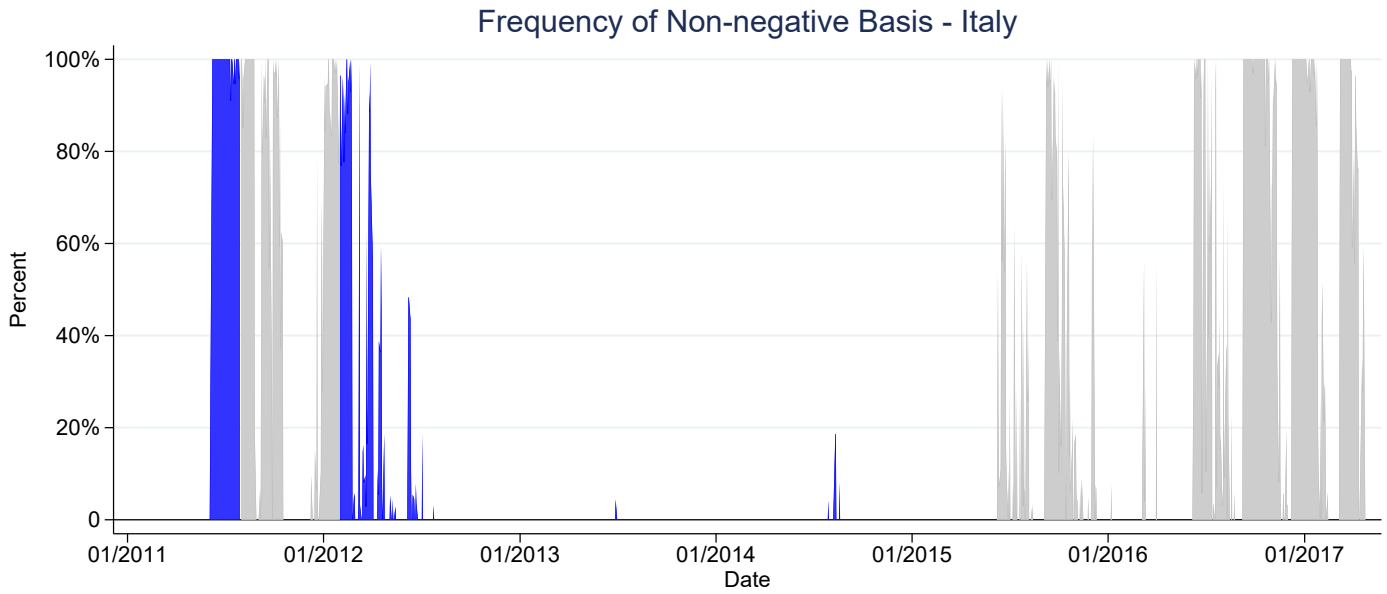

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Multivariate Setting

$$Basis_{it} = \alpha_i + \beta_1 ECB_{it} + \beta_2 DtD_{it} + \beta_3 RVolume_{it} + \beta_4 RRate_{it} + \beta_5 BA^F_{it} + \beta_6 BA^B_{it} + \beta_7 Euribor_t + \varepsilon_{it}$$

We regress the basis (before and after accounting for costs/frictions) on the following variables:

- ECB_{it} is a dummy, 1 if the ECB purchases bonds of country i on day t
- DtD_{it}, Days to delivery, the difference between date t and the contract delivery date
- $RVolume_{it}$, country i, day t volume of special repo transactions
- $RRate_{it}$, average special repo rate
- BA^F_{it} (BA^B_{it}), average bid-ask spread on the futures (cash) bond market
- $Euribor_t$, 1-month euribor rate.

We cluster errors at the delivery/country level and include country fixed effects. Alternatively, we employ the rate of country-specific monthly purchases by the ECB (ΔECB^Q_{it}) as our main variable of interest.

Basis: No Costs, Multivariate Analysis

	(1) $Basis_{it}$	(2) $Basis_{it}$	(3) $Basis_{it}$	(4) $Basis_{it}$	(5) $Basis_{it}$	(6) $Basis_{it}$	(7) $Basis_{it}$
ECB_{it}	0.042***	0.043***	0.076***	0.047***	0.053**	0.049**	
ΔECB^{Q}_{it}							0.008**
DtD_{it}	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***
$RVolume_{it}$		−0.003*			0.000	0.000	0.000
$RRate_{it}$			0.081		0.016	−0.119*	0.033
BA^{F}_{it}				6.233*	5.919**	5.472**	5.800**
BA^{B}_{it}				−0.068	−0.075	−0.148	−0.050
$Euribor_{t}$						0.135***	
Adj. R^2	0.186	0.239	0.252	0.332	0.334	0.377	0.355
Obs	4103	4103	4103	4103	4103	4103	4085
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	DC	DC	DC	DC	DC	DC	DC

- Before taking trading costs into account, the mispricing between futures and cash bonds is €0.04 larger, when the ECB is hoarding bonds and inflating their prices.
- The basis decreases as delivery approaches (increases in days to delivery, *DtD*).
- The basis is increasing in market participants' opportunity costs (*Euribor*). The basis includes (and increases in) trading costs (BA^{F}).
- Every extra billion purchased in a month increases the basis by 0.8 eurocents a day.

Basis: All Costs, Multivariate Analysis

	(1) $Basis_{it}$	(2) $Basis_{it}$	(3) $Basis_{it}$	(4) $Basis_{it}$	(5) $Basis_{it}$	(6) $Basis_{it}$	(7) $Basis_{it}$
ECB_{it}	0.026***	0.026***	0.038	0.034***	0.051*	0.049*	
ΔECB^{Q}_{it}							0.007**
DtD_{it}	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***
$RVolume_{it}$		0.000			0.000	0.000	0.000
$RRate_{it}$			0.028		0.041	−0.023	0.058
BA^{F}_{it}				6.026	5.185*	4.971*	5.086*
BA^{B}_{it}				−0.603***	−0.620***	−0.655***	−0.596***
$Euribor_{t}$						0.064	
Adj. R^2	0.129	0.129	0.139	0.244	0.258	0.270	0.283
Obs	4103	4103	4103	4103	4103	4103	4085
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	DC	DC	DC	DC	DC	DC	DC

- Even after taking all trading costs into account, the mispricing between futures and cash bonds is €0.03 larger, when the ECB is hoarding bonds and inflating their prices.
- The relationship between bid-ask spreads and the basis is mechanical.
- Our arbitrage estimate is conservative. The arbitrage profit would be larger if the trader already held the bond.
- Every extra billion purchased in a month increases the basis by 0.7 eurocents a day.

Frequency: All Costs, Multivariate Analysis

	(1) $Freq_{it}$	(2) $Freq_{it}$	(3) $Freq_{it}$	(4) $Freq_{it}$	(5) $Freq_{it}$	(6) $Freq_{it}$	(7) $Freq_{it}$
ECB_{it}	0.225***	0.226***	0.273***	0.241***	0.251***	0.249***	
ΔECB^{Q}_{it}							0.033***
DtD_{it}	0.006***	0.006***	0.006***	0.006***	0.006***	0.006***	0.006***
$RVolume_{it}$		−0.003			0.003	0.003	0.003
$RRate_{it}$			0.114		0.020	−0.053	0.069
BA^{F}_{it}				15.901**	17.837**	17.595**	17.839**
BA^{B}_{it}				−0.856*	−0.889*	−0.929**	−0.755*
$Euribor_{t}$						0.073	
Adj. R^2	0.317	0.320	0.324	0.343	0.345	0.346	0.358
Obs	4103	4103	4103	4103	4103	4103	4085
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	DC	DC	DC	DC	DC	DC	DC

- Even after taking all trading costs into account, arbitrage opportunities are 23% more likely when the ECB is hoarding bonds and inflating their prices.
- Our arbitrage estimate is conservative. The arbitrage profit would be larger if the trader already held the bond.
- One extra billion purchased a month translates into 3% more arbitrage opportunities a day.

Outline of the Presentation

- ECB Intervention and Hypotheses
- The Arbitrage Mechanism
- Data
- Results: Mispricing
- **Results: Market Liquidity**
- Conclusions

Liquidity: Multivariate Analysis

	(1) BA^B_{it}	(2) $Volume^B_{it}$	(3) BA^F_{it}	(4) $Volume^F_{it}$
ECB_{it}	0.025**	−0.002	0.002*	0.031**
$Euribor_t$	0.062***	0.036	0.007***	0.086*
$Volume^B_{it}$	−0.202***			
σ^B_{it}	615.370***	196.665***		
BA^B_{it}		−0.238***		
DtD_{it}			0.000	−0.001**
$Volume^F_{it}$			−0.011***	
σ^F_{it}			51.458***	1023.435***
BA^F_{it}				−11.502***
Adj. R^2	0.666	0.353	0.702	0.841
Obs	4103	4103	4103	4103
FE	Yes	Yes	Yes	Yes
Cluster	DC	DC	DC	DC

- BA^B_t and BA^F_t are higher during QE (ECB_t).
- Traded volume moves to the derivatives market.
- Higher funding illiquidity, higher market illiquidity ($Euribor_t$)

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Conclusions

The ECB's QE interventions were aimed and succeeded at lowering bond yields but:

- Contributed to dislocating the price of futures contract vis-a-vis its underlying bond.
- Increased the amount traded on the futures market, which substituted for its cash counterpart.
- Depleted the liquidity of the cash bond market they acted on *and* of the futures market.

Thank you

Future Steps

We want to extend the paper in the following ways:

- **Estimate the quality option**
  The futures seller has the option of delivering the cheapest of all deliverable eligible bonds. The option is probably worth less than a few cents, but we should estimate it and account for it.
- **Verify the functioning of the repo market**
  To consider the highest cost arbitrage of a trader with no capital, we need to assume the bond is borrowed on the repo market and rolled over. If the ECB intervention disrupted the repo market, we should take that into account.
- **Elaborate on the correlation between the mispricing across countries**
  Do they tend to co-move more during ECB interventions?
- **Check the relevance of macro risk factors**
  Extending from our inclusion of the Euribor, what is the role of macro risk factors (e.g., the cross currency basis swap spread, the EuroVIX, the VIX) in determining the mispricing between cash bonds and futures?