Central Bank–Driven Mispricing*

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Abstract

We use millisecond-stamped data from the Mercato dei Titoli di Stato (MTS) cash Treasury bond and the Eurex Treasury bond futures markets to show that bond purchases, undertaken under the Public Sector Purchase Program (PSPP) by the European Central Bank (ECB), decoupled the close link between the cash bond and futures markets, thus driving a wedge between their prices. This result is robust even after controlling for market liquidity in both the markets and overall funding liquidity. In fact, although the ECB intervened only in the cash bond market, the futures market was also affected, as the central bank's intervention depleted market liquidity in both markets and, thus, increasing liquidity commonality, notwithstanding the arbitrage opportunities that persisted. However, the impact of this dislocation on the volume of trade is ambiguous. Finally, we shed light on the degree of substitution between the two markets, with regard to where traders decide to accumulate their positions: There is a slight reduction in the volume of trade in the cash bond market, as represented by the MTS, accompanied by a large and significant increase in the volume of trade in the corresponding futures market.

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I Introduction

The 2007-2009 global financial crisis forced central banks to explore uncharted territory—a battery of unconventional monetary policy measures that brought interest rates close to their economic lower bound, equal to or even slightly less than zero, in some cases. With cash being a risk-free asset with a zero rate of interest (and only potentially small handling costs), central banks are constrained by this rate, and simply cannot lower their policy rates much lower to stimulate growth, when and if necessary. Consequently, they started to introduce new intervention tools, such as quantitative easing programs (QE), where they massively bought assets such as bonds from market participants to provide liquidity to the market, reduce the cost of capital in the economy and ultimately foster economic growth. While the purchases were initially confined to Treasury securities, the list of eligible securities was expanded to include mortgage securities, corporate bonds and even equities in the form of exchange traded funds (ETFs).

Not suprisingly, much of the existing literature on QE and near-zero policy rates has focused on macroeconomic issues, in particular on monetary policy, or on the effectiveness of the QE in increasing bond prices and lowering bond yields, and the channels that drive these price movements: the signalling effect of the QE announcements, duration risk and scarcity effects in the cash bond markets. However, it is equally important to understand the mechanics of the intervention through QE and the microstructure effects of the QE interventions. In liquid cash markets, the price impact of anticipated and repeated supply shocks are typically shown to be transitory and the near-arbitrage opportunities are temporary, because the cash-futures arbitrage is almost riskless, allowing quantity fluctuations in a particular security to be readily absorbed by the broader market. This is largely the case for the US Treasury market with a daily turnover of around USD 500 billion. The situation is different for the sovereign bond market in the Euro-zone, which is largely fragmented for the sovereign bonds of the 19 countries that belong to the Eurosystem. We investigate this dislocation, especially in the context of the Public Sector Purchase Program (PSPP) of the European Central Bank (ECB).

The aim of this paper is to twofold. First, we investigate the mispricing between the futures and cash market for one of the largest sovereign bond markets in the world: the Italian sovereign bonds (Buoni Tesoro Poliennali, or BTP) in the context of the the massive asset purchase program implemented by the European Central Bank (ECB). Second, we study the impact of the QE implemented by the ECB in both the cash and the futures market for Italian Treasury bonds. By analyzing the basis for each deliverable bond—the spread between the cash and futures contract—for every trading minute from June 2013 till December 2015 we document the existence of a futures-bond basis, i.e., the measure of mispricing, for BTP cash bonds and their corresponding futures contract, when the ECB implemented the PSPP, which is statistically significant at the 1% level. The mispricing is significantly positive, even after taking into account the bid-ask spreads of both the cash bonds and the futures contract.

It should be emphasized that arbitrageurs need to execute two opposite transactions in the cash and futures markets, virtually simultaneously, to take advantage of the arbitrage opportunity. Drawing upon the growing literature on commonality in liquidity, we expect that, if the ECB interventions have an impact on the liquidity of the cash market, they should also have an impact on the liquidity of the future markets (the closest substitute of the cash market if investors would like to invest in the Italian sovereign bonds); thus, periods of illiquidity in the cash and futures markets will tend to occur contemporaneously and would be driven by the same source. Arbitrageurs need to take this phenomenon into account, which also motivates our aim of testing the relationship between shocks to the liquidity of the two markets and identifying their driving forces. We document that the bid-ask spreads in both markets do contribute to the determination of the basis, but even considering the bid and ask prices that the arbitrageur has to pay (on a conservative basis), in order to implement the arbitrage, the mispricing is still persistent for a significant period while the ECB implemented the PSPP.

The specific objective of this paper is to understand the linkage between the cash and futures markets and the effect of a decline in liquidity in either market on the cash-futures relationship for Euro-zone sovereign bonds. An important consideration is to be mindful of the impact of ECB interventions on the linkage between these two markets in terms of both price and liquidity. We distinguish between the change in liquidity that comes from the increase in the bid-ask spread, i.e., the cost of the trades, and the change in liquidity that comes from the volume of trade that has been affected differently in the cash and the future markets because ECB interventions are realized principally through the Over the Counter (OTC) market. Our detailed data, from the Mercato dei Titoli di Stato (MTS) for the cash market and Eurex for the futures market, allow us to analyze the individual market makers' actions in posting quotes and, in particular, the arbitrage activity of those choosing to exploit the basis between the cash and futures markets. We find that the bid-ask spreads of both the cash and the futures market increase after the PSPP implementation. This is a relevant source of the future bond-basis, indicating that the ECB intervention induced a reduction of liquidity in the cash market and also had an impact on the arbitrage activity, causing an increase in the bid ask spread of the futures contract. The ECB intervention also increased the co-movement in the liquidity between the cash and the bond markets. However, the impact of the ECB on the volume of trade on both the markets is instead the opposite, i.e., it reduced in the MTS cash market and increased in the Eurex futures market.

This paper is the first to address the pricing and liquidity consequences of the current PSPP intervention and document the sizable mispricing that a direct open-market bond purchase had, even when conducted (i) outside the sovereign crisis period and (ii) in a relatively liquid market, such as the Italian BTP cash bond market. The paper is organized as follows. Section II discusses the related literature. Section III reviews the various phases of ECB monetary policy interventions. Section IV describes the law of one price in sovereign bond cash and future markets and introduces and defines the concept of the basis. We describe the MTS cash and the Eurex futures markets, as well as our data in Section V. Section VI presents our empirical results. Finally, Section VII offers concluding remarks.

II Related Literature

Since the first round of quantitative easing by the Federal Reserve was implemented in 2008, the financial literature has investigated the effect that QE had on market aggregates, e.g., on inflation, unemployment and GDP (see Chen, Cúrdia, and Ferrero (2012); Gambacorta, Hofmann, and Peersman (2014); Kapetanios, Mumtaz, Stevens, and Theodoridis (2012); Chung, Laforte, Reifschneider, Williams, et al. (2011)) and on financial markets, e.g., on sovereign and corporate bond yields and mortgage backed securities' prices (see Krishnamurthy and Vissing-Jorgensen (2011); D'Amico and King (2013); D'Amico, Fan, and Kitsul (2015); McLaren, Banerjee, and Latto (2014); Li and Wei (2013); Pericoli and Veronese (2017)). The findings in these papers represent a natural starting point for this paper, where the emphasis is on the microstructure effects of the policy measures, specifically on their effect on limits to arbitrage and market liquidity. Previous studies focus on the increase in bond prices and reduction in bond yields following the QE interventions, speaking to important aspects of the effectiveness of QE programs. However, this literature is largely silent on the effects of unconventional monetary policies on limits to arbitrage and market liquidity in the sovereign bond cash and futures markets, which are the focus of this paper.

Central Banks interventions generally only interest the cash bond markets while they leave derivatives markets for sovereign bonds untouched, although these markets are closely related to the cash markets. One example of such a market is the one for bond futures contracts. In very liquid cash markets, the price impacts of anticipated and repeated supply shocks are typically shown to be transitory, as the arbitrage opportunity, if any, that is created, is quickly eliminated. The current literature has highlighted that the presence of frictions such as funding constraints and market segmentation may play an important role in propagating the mis-pricing in financial markets. More recently, Brunnermeier and Pedersen (2009) and Garleanu and Pedersen (2011) highlight the role of funding constraints, the limited ability of financial institutions to borrow against their securities. It is reasonable to expect that these effects are accentuated during crisis periods. However, as we highlight with this paper, they should also be important during normal times, even when funding constraints is not a particular relevant issue as in the recent years. Another strand of the literature has recently revised the preferred habitat theory of Modigliani and Sutch (1966) and emphasizes that the massive asset purchase programs by central banks targeting a specific security class can be expected to affect the price of such securities at times where segmentation are high (see Vayanos and Vila (2009), Gromb and Vayanos (2002) and Greenwood and Vayanos (2010))), due to the well known "scarcity" effect.

In this spirit the papers of Buraschi et al. (2014) and Corradin and Rodriguez-Moreno (2014) investigate the US and Euro-denominated emerging market and European sovereign bond basis respectively, generated by the eligibility of the Euro sovereign debt pledged to the ECB in exchange for liquidity. Our study is in spirit related to this strand of the literature but differs from previous studies for several reasons. First, we investigate the arbitrage opportunities *created* by the unconventional monetary policies implemented recently by ECB in the cash bond markets in the Euro-zone. In particular, we focus on the interaction between the arbitrage opportunities, reflected by the basis, and the corresponding liquidity effects in the cash and futures markets. Hence, we bridge the two strains of literature, studying arbitrage relations with a focus on market liquidity, which we can do thanks to the exceptional granularity of our data, and by investigating the commonality (correlation) of liquidity between two securities that have *identical* cashflows and credit risk, focusing on the arbitrage trades and quotes between them. Second, our study relates to the growing literature on commonality in liquidity. The microstructure literature, as surveyed in O'Hara (1995) and Hasbrouck (2007), primarily focuses on single stock attributes, and generally deals with them as the solution to an optimization problem by the stock's market maker(s). Chordia et al. (2000) shift the focus from a single stock to the interaction between stocks; fitting a market model to a liquidity measure, they show that the single stock co-moves with the market-wide average liquidity.

The strand of literature that is most closely related to our paper deals with liquidity-motivated limits to arbitrage. Similar to the literature on commonality in liquidity, trading in multiple securities is considered; however, these securities are linked by an arbitrage condition, and market illiquidity is generally identified as a factor limiting the convergence of the securities' prices and eliminating arbitrage opportunities. Studies by Brenner et al. (1989) and Roll et al. (2007) are driven by the same motivation as ours, and are worthy of special mention.

III ECB Intervention

The ECB's monetary intervention as a response to the 2007-2009 global financial crisis and the Euro-zone sovereign crisis of 2010-2012 takes many forms, ranging from the jaw-boning and formal guidance by its board members, in particular its President, to the injection of liquidity into the major banks in the Euro-zone (the fixed-rate tender, full-allotment) and even to direct purchases of sovereign bonds in the cash markets. During the Euro-zone crisis, the policy interventions by the ECB consisted of (i) the Security Market Program (SMP), initiated in May 2010, (ii) Long Term Refinancing Operations or LTRO, announced and implemented in December 2011, (iii) policy guidance, including the famous "whatever it takes" speech by Mario Draghi on July 26, 2012, which unveiled the potential for new tools to ease the European sovereign debt crisis, and (iv) Outright Monetary Transactions or OMT, also announced in December 2011. In a context of prolonged low inflation and in a dramatic change of policy, the ECB announced in January 2015 a prolonged period of quantitative easing, i.e., a large scale asset purchase program focused on government bonds (Public Sector Purchase Program, PSPP), with purchases commencing in March 2015, with an expected balance sheet expansion of more than € 1 trillion in the following 18 months. The program began on March 9th, 2015 and it was scheduled to last up to March 2016, but has since been prolonged multiple times and is currently slated to end in 2017 or "until we see a sustained adjustment in the path of inflation" (ECB Governing Council Press Conference, January 2016). The program consists of monthly purchases of public and private sector securities initially at the rate of € 60 billion a month, which was increased to € 80 billion between April 2016 and March 2017, when it was scaled back to € 60 billions. The size and extraordinary nature of these interventions, unprecedented in the history of the ECB and other modern central banks, are bound to impact the cash sovereign bond market in a significant manner, and caused the intervention's effects to reverberate in markets connected to the sovereign bond markets, such as the futures market.[1] Possibly because the ECB does not intervene directly in derivatives markets, the effects of quantitative easing on their markets have not been investigated yet, in

[1]Around the same time, the Bank of Japan's QE program of yearly bond purchases of 80 trillion yen, equivalent to € 666 billion a year, or about € 55 billion per month, was launched, and is currently the largest intervention targeting a single country.

any detail.

As the measures described above were conducted with remarkably different procedures (e.g., the LTRO consisted of the provision of funding liquidity to financial institutions, while the securities market program, the SMP, consisted of direct bond purchases) and to achieve diverse purposes, they can be expected to have different effects on the financial markets, primarily, in terms of price impact and market liquidity, the two quantities we focus on in this paper. The measures in place between 2010 and 2012 had largely the objective of stabilizing the banking sector and reducing the spillover effects during the sovereign crisis. The more recent program, the PSPP, what we refer to as quantitative easing, aims instead to generate inflation, and was explicitly designed to minimize "unintended consequences, which can be ensured by obeying the concept of market neutrality." The ECB does not "want to affect market prices but [...] will not suppress the price discovery mechanism" (Coeuré, "Embarking on public sector asset purchases", 10 March 2015). Predictably, these programs have had an ameliorative effect on bond yields in the sovereign bond market, as has been widely noted. However, they have also had an impact on the financial market conditions and market liquidity in the sovereign bond markets and their derivatives, which has not been studied adequately. This paper aims to cover this void.

More specifically, the purpose of this paper is to investigate the impact of the PSPP, which involved the purchase of significant amounts of individual securities in a repeated manner. The peculiarity of the ECB interventions compared to other markets, principally those of the Federal Reserve System (Fed) in the US, is that the sovereign bond market targeted by the ECB is far less liquid than the US Treasury market and fragmented. Therefore, the demand shock generated by the asset purchase program would be expected to be far more significant than the one engineered by the Fed. Moreover, the PSPP was not implemented during a crisis period as was the SMP, when the ECB purchased, on the open market, a vast amount of sovereign bonds issued by the Portuguese, Greek, Italian, and Spanish governments, between 2010 and 2011. In the previous case the sheer buying pressure exerted by such a dominant market player caused the prices in the underlying BTP cash market to increase and decouple from the prices in the corresponding derivatives market, trading the BTP futures contract. In Pelizzon et al. (2014), we previously documented that during the SMP, the prices on the bond market rose substantially, relative to those corresponding futures contracts, in the case of Italy, the only targeted country with a traded sovereign futures market. However, during the PSPP intervention, in contrast, all European sovereign bond markets were simultaneously targeted, without a country focus (with purchases proportionally to each country's market size).

To provide the reader with an idea of the size of the intervention in the Italian Sovereign bond market, we report the quantity the ECB bought of Italian Sovereign bonds each month (based on data available in the Bank of Italy webpage). ΔECB_t^Q is the change in monthly holdings between the month each date t falls in, and the previous month. The average monthly change is € 6.38 billions, during the QE, and € 0.133 billions otherwise. The time series of the stock and change in the holding of central banks of Italian sovereign bonds are shown in Figure 1.

Insert Figure 1 here.

IV The Law of One Price and the Basis

A bond futures contract is an exchange-traded instrument, i.e., a contractual obligation, whereby the futures seller agrees to deliver a bond to the futures buyer, on or before delivery date, and the buyer agrees to contextually pay a price agreed on trading day and marked-to-market on each following day. The seller can deliver any bond in the basket of deliverable bonds, for a total (adjusted) face value of €100,000.[2] The bonds that are eligible to be delivered, however, can differ markedly, as for their coupon, time-to-maturity, and, therefore, price. To obviate the seller's incentive to shortchange the buyer by delivering a bond that is substantially cheaper than the others, the futures's buyer will only pay a certain fraction of the agreed-upon price, specific to the bond that is actually delivered. This bond-specific fraction, i.e., its conversion factor, is determined as the price (as a fraction of face value) that the bond would have, at delivery, if the term structure was flat at 6%. For the September 2016 BTP futures contract, for example, four bonds could be delivered. The smallest coupon rate among the deliverable bonds was 1.5% and the largest was 4.5%. Obviously, the two bonds had widely different prices, which were reflected in their respective conversion factors of 0.702604 and 0.898551. A futures seller that delivered the more expensive bond with the more sizeable coupon would receive an invoice about 27% larger.

While conversion factors are meant to level the price differences between deliverable bonds, for every futures contract, one of the bonds can generally be identified as the futures seller is most likely to deliver (since it costs less, overall) and is, thus, referred to as cheapest-to-deliver (CTD). Which of the deliverable bonds is CTD depends on multiple factors ranging from supply- and demand-side considerations, e.g., whether the bond is in large supply or the on-the-run issue, to conversion factor biases and the level and slope of the bond yield curve. Since conversion

[2]For the Italian long-term bond future contract we focus on, a bond is deliverable if it has between 8.5 and 11 years to maturity at delivery, if its original maturity is below 15 years, and if it was issued in an amount larger than five billion euros. Short- and medium-term futures are also traded, but are substantially less liquid than their long-term counterpart, which is the focus of this study.

factors are calculated as the bond price if it had a 6% yield, therefore, when yields are below (above) 6%, the conversion factor convention is likely to select short (long) duration bonds (with high (low) coupon and short (long) maturity) as CTD. The price difference between every deliverable bond the futures price is a basis, yet, in the remainder of the paper, when we refer to the mispricing between the bonds and the futures contract, we refer to the basis of the bond that the short position will likely deliver, i.e., the CTD.[3]

The basis represents the profit that an arbitrageur makes when shorting the CTD bond and going long the futures contract. A precise estimation of the arbitrageur's profit needs to take into account that any bond transaction entails the exchange of accrued interest and that an arbitrageur who is short the cash leg of the arbitrage "borrows" the bond by reverse-repo. Accordingly, we consider that, when the arbitrageur sells the bond at time t, she is compensated for the coupon accrued from the previous coupon date (or the issue date) on top of the market price B_t, and that, at delivery, the trader with the long position in the futures is compensated by the one with the short position, i.e., the arbitrageur, for the coupon accrued until the delivery date T. Moreover, we include the cost of carry incurred by the arbitrageurs, who would pay the repo-rate as compensation for borrowing the bond from day t, when she enters the position, to the delivery date of the contract, day T.[4]

Taking into account the conversion factor, the interest the CTD bond accrues between the trade date and delivery into the futures contract, and the cost of carry, we calculate the basis as

$$Basis_t = (B_t + A_{t+2})\left(1 + \frac{T-(t+2)}{360} r_t\right) - A_T - F_t \cdot CF_i \tag{1}$$

where B_t is the mid-quote of the bond, F_t is the mid-quote of the futures, CF_i is the conversion factor, $\frac{T-(t+2)}{360}$ is the length of the term repo, considering a $t+2$ settlement for the underlying bond, multiplied by the repo rate at time t, r_t, AC_{t+2} is the coupon accrued from the last payment before settlement until the trade settlement date $t+2$, and A_T is the coupon accrued from the last payment before settlement until delivery.[5]

We expect the QE intervention by the ECB to affect the relative pricing between the futures contract and the underlying bond. That is, we expect that the buying pressure exerted by a central bank purchasing € 60 to 80

[3]Everything else constant, the higher the conversion factor of a bond, the lower the associated basis. If yields are below 6%, as is the case during the period we consider, the price of a bond calculated as if it carried a 6% yield, i.e., the conversion factor, is higher the smaller is the duration of the bond.

[4]BTP futures have deliveries on a quarterly basis, in March, June, September and December. Up to three futures contracts with up to 9 months to delivery may be traded at any point in time. We focus in this study on the nearest delivery.

[5]Coupon accrual is calculated using the ACT/ACT convention, while the repo interest is based on the ACT/360 convention.

billions in bond a month would drive the bond prices up. While in a frictionless world arbitrageurs would step in, we expect that, when funding liquidity is not readily available, the buying pressure of the ECB actions creates arbitrage opportunities that go untapped, given the sizes of the price movement.

V The data

The data we use in this study are obtained from diverse sources. Prices and volume data for the cash sovereign bonds traded on the MTS are obtained from the MTS Group. This new and unique dataset consists of detailed quote, order and transaction data for all European sovereign bonds in MTS, an interdealer market. The MTS market is fully automated and effectively works as an electronic limit order market. The bond futures data, obtained from Reuters until December 2014 and directly from Eurex from January 2015 until December 2015, encompass all trades and quotes for futures contracts on long-term coupon-bearing bonds on Eurex, a major stock and futures exchange, owned by the Deutsche Boerse group. Both datasets are time-stamped at the millisecond level and allow us to analyze the dynamics of the high-frequency interaction between the cash and futures markets, which are linked by arbitrage. In addition, we obtained data on contract definitions, including details of the basket of bonds deliverable into the futures contract, from the Eurex website.

V.A The MTS Bond Market

The MTS data include trade and quote data for fixed-income securities, mostly those issued by the national treasuries and local governments of twelve Euro-zone countries: Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, Slovenia and Spain. The MTS system is the largest interdealer market for Euro-denominated government bonds. The time-series data are based on all MTS interdealer markets making up the MTS system, including EuroMTS (the "European market"), EuroCredit MTS and various domestic MTS markets. The MTS interdealer trading system is fully automated and works as a quote-based electronic limit order market. According to the MTS data manual, "EuroMTS is the reference electronic market for Euro benchmark bonds, or bonds with an outstanding value of at least 5 billion Euro."[6]

The dataset we analyze in the present study is, by far, the most complete representation of the Euro-zone sovereign bond market available, and has been released only recently. It covers *all* trades, quotes, and orders that

[6]See also Dufour and Skinner (2004) and Pelizzon et al. (2016), for details about the MTS market.

took place on the MTS market. Every event is stamped at the millisecond level, and the order IDs permit us to link each order to the trade that was eventually consummated from it. Every quote in this market, henceforth called "proposals," can be followed in the database in terms of their "revisions" over time, thanks to an identifier.

Market participants can decide whether they want to trade a government bond on the European market (EuroMTS) or on that country's domestic market, within the MTS platform. While every Euro-zone bond is quoted on the respective domestic market, only bonds that were issued with an amount outstanding higher than a certain threshold can be traded on the EuroMTS. Even though the two markets are not formally linked, most dealers participate in both venues. The previous literature (Cheung et al. (2005), Caporale and Girardi (2011)) has shown that the two markets essentially constitute a single venue.[7] Thus, in our analysis we consider data from trading in *both* markets.

There are two kinds of trader in the sovereign bond markets, primary dealers and other dealers. Primary dealers are authorized market-making members of the market. That is, they issue standing quotes, which can either be single-sided or double-sided, on the bonds they have been assigned. The dealers indicate the quantity they are willing to trade and the non-negative fraction of that quantity they are willing to "show" to the market. Primary dealers can be on the passive side of the market, when their proposals are hit, and/or on the active side, when they submit orders aimed at hitting another primary dealer's standing quote. Primary dealers have market-making obligations that, in spite of some relaxation after 2007, still require each primary dealer not to diverge from the average quoting times and spreads calculated among all market makers. In this market, the event of crossed quotes is guaranteed not to occur, except by chance, since, when the opposite sides of two proposals cross, a trade takes place for the smaller of the two quoted quantities.[8] Other dealers, with no market-making responsibilities, can originate a trade only by "hitting" or "lifting" the primary dealers' standing quotes with market orders. However, it should be noted that primary dealers are also on the active side of 96% of the trades present in our database.[9]

[7]By this we mean that an order could "trade-through" a better price if the trader sent the order to the market with the worse bid- or ask-price. However, MTS assures market participants that their trading platforms always show quotations from both the domestic and the European market, when available.

[8]While this is one way for the primary dealers to trade, it seldom happens. Hence, we do not include trades originating in this manner in our sample.

[9]The MTS dataset does not suffer from misreporting issues on the same scale as other datasets (such as TRACE). However, we apply some data-cleaning procedures to ensure the consistency of the quotes, as detailed in Pelizzon et al. (2014).

V.B The Futures Market

Italian government bond futures contract are traded on the Eurex Exchange, which offers a continuous, electronic trading platform where liquidity is provided by diverse participants who act as market makers. However, there is only one designated market maker in the futures market compared to around 25 designated market makers in the cash bond market for Buoni del Tesoro Poliennali (BTP), the long term coupon-bearing Italian sovereign bonds. Three futures contracts, based on Italian sovereign bonds, are listed on this exchange: Long-term, Mid-Term, and Short-Term Euro-BTP contracts. The underlying bonds are debt instruments issued by the Republic of Italy. The Long-Term Euro-BTP futures contracts, which were introduced in 2009, are the focus of this study, since they are, by far, the most liquid of these contracts.[10]

The minimum price change (tick) is expressed as a percentage of the par value, up to two decimal places, and is €0.01 during most of our sample period. The trading hours are 8 AM to 7 PM CET on most business days, and 8 AM to 12:30 PM CET on the last trading day of the contract. The notional value per contract is €100,000 with a coupon of 6%. The contract terms specify that a delivery obligation arising from a short position on a long-term contract may only be fulfilled by the delivery of coupon-bearing debt securities issued by the Republic of Italy (BTP), with a remaining life of 8.5 to 11 years and an original maturity of no longer than 16 years. The debt securities must have a minimum issue amount of €5 billion and a nominal fixed payment. Starting with the contract month of June 2012, debt securities of the Republic of Italy have to maintain a minimum issuance volume of €5 billion no later than 10 exchange days prior to the last trading day of the current front month contract. The contracts months are on the March, June, September and December quarterly cycle, and the delivery day is the tenth calendar day of the month. The last trading day is two exchange days prior to the delivery day of the relevant maturity month.

V.C Descriptive Statistics

We consider the period from June 2013 to December 2015. This sample provides us with a window in which to study the behavior of the Italian cash bond and futures markets that is unaffected by the turmoil of the sovereign debt crisis that invested the Euro-zone between 2010 and 2012. Following a number of significant sovereign events that directly affected the liquidity in Euro-zone government bond markets and, in general, the wider loss of confidence

[10]The Short- and Mid-Term contracts of Euro-BTP futures were launched in October 2010 and September 2011, respectively, but are less liquid than the long-term Euro-BTP futures contract.

in European efforts to manage the sovereign debt crisis. Since Italy has the largest number of bonds traded in the Euro-zone out of the whole sample, with the largest volume, and was the bellwether country during the European sovereign crisis, we focus our analysis on Italian government bonds, based on the most detailed historical dataset that MTS makes available to the public. By starting in June 2013 we have a "no QE period" of more than one year before the ECB started to send signals to the market regarding the possibility of implementing a massive intervention of public securities purchases.

Since the focus of our analysis in on the future-bond basis, we concentrate our analysis on the 11 quarterly futures contracts and the corresponding CTD bonds, identified on from the website of the Eurex market. Table I reports the bond unique identifier code (the "Bond ISIN"), the coupon rate, the issue date and the maturity date.

Insert Table I here.

Table I shows that the CTD bond is not always the 10 year on the run bond. For example, the CTD bond for the most recent futures contract is a 15 year bond, with a remaining time to maturity of 9 years.

The descriptive statistics of these bonds are reported in Table II. We report the distribution of several variables, where the observational unit is a day in our dataset, rather than a bond. In other words, the distribution of the coupon rate, for example, will take into account that a given bond was present in the sample more often than another. The variables we report are: the yield-to-maturity of the bond, $Yield_t$; its time to maturity, TtM_t; its original maturity at issuance, OM_b; its duration, $Duration_t$; its coupon rate, $Coupon_b$. We also report the conversion factor of the nearest futures contract, CF_t, the bid-ask spread of the CTD bond, BA_t^B, the bid-ask spread of the futures contract BA_t^F, the volume traded in the Italian sovereign bond market (total for all bonds) in billions of euros of face values, $Volume_t^B$, and the volume traded on the futures market, $Futures_t^F$, in millions of contracts.

Insert Table II here.

Table II shows that the bond CTD in the sample has a yield, on average, of 2.663%, ranging between 1.270% and 4.373%. The time to maturity ranges from 8.7 to 9.6 years, in line with the rule that the CTD bond should have a maturity, at delivery date, between 8.5 and 10.5 years. The duration of these bonds is on average 7.5 years and their average coupon is 9.95%. The bid-ask spread for these CTD bonds is, on average, 8.6 cents for € 100 of face value, but varies considerably from 4.3 cents to 15.2 cents. Averaging 1.4 cents, the bid-ask spread of the futures contract is far lower than the one of the CTD. The futures contract liquidity measure is also less volatile, ranging from 1.2 to 1.7 cents, in 90% of the observations. The volume of trade per day in the cash market is, on average, € 4.695 billions but it varies widely, ranging from a fifth percentile of € 1.9 billions to a 95th percentile of € 8.071 billions. The volume of trade of the futures is on average 66,000 contracts a day, corresponding to € 6.6 billions in face value, ranging from 2.1 to 13.6 billions, between the 5th and the 95th percentile.

Among the factors that affect the mispricing between the bond and the futures contract, we consider several global funding liquidity factors, including the Euribor rate (the rate at which banks borrow and lend to each other in euro); the cross currency basis swap, the spread of the cross-currency basis swap between the three-month Libor in Euros and in Dollars; and the Italian sovereign credit risk, measured with the 5-year sovereign CDS spread. Panel B of Table II reports the descriptive statistics of these variables. In the same panel, we report the distribution of the repo rate we employ to calculate the futures-bond basis. The repo rate is derived from transactions that took place on the MTS repo platform and is aggregated at a daily level.

VI Results

In Subsections VI.A and VI.B we report the basis for the sample period considered and show that the quantitative easing intervention by the ECB drove a wedge between the pricing of the cash Italian sovereign bonds and the corresponding futures that have the bonds as the underlying asset. The mispricing was, on average, €0.03 larger and three times more likely to take place during the ECB intervention, than before it. We show that the results are robust to controlling for the liquidity of the cash bond and futures markets, both indirectly, the traded volume in the markets, and more directly, by modifying the mispricing measure we employ.

In Subsection VI.C we turn the focus to the effect that the intervention by the ECB had on the liquidity of the cash bond and futures markets. We show that the extensive bond purchases in the QE context depleted the bond market liquidity. Contemporaneously, the liquidity of the futures market was diminished, which we attribute to arbitrage activity and asset substitution by the market participants to take advantage of the mispricing.

VI.A The Basis

We calculate the basis defined as in Equation 1 for each deliverable bond for every trading minute between July 2013 and December 2015. For each delivery date, we identify as the CTD the bond most frequently with the smallest basis. Table I indicates the fraction of time each of the bonds we identify as CTD indeed has the smallest basis. The fraction ranges from 76% to 100%, with a median of 99%, suggesting that, for each delivery, a single bond turns out to be the cheapest. To support our claims, we report, for each contract, the proportion of all bonds delivered accounted for by the bond we identified as CTD. This percentage ranges from 78% to 100%, with a median of 100%, hence supporting the identification of the CTD based on the basis defined in Equation 1.

Panel A of Figure 2 shows the average daily basis in our dataset. The basis ranges from €-0.05 in the beginning of the sample in 2013 to €0.1 in 2015, per 100 euro of face value, corresponding to a maximum of a sizeable 10 bps mispricing between the CTD bond and the futures contract. The mispricing measure in Equation 1 and Panel A of Figure 2, however, falls short of identifying realizable arbitrage profits, in that it assumes that the arbitrageur is able to trade bonds and futures at the *mid-prices*, i.e., it abstracts from market liquidity. To identify actual arbitrage opportunities that having gone untapped, we estimate the basis in Equation 1, taking into account the possibility that the arbitrageur sells the bond at the bid-price (instead of the mid-quote B_t) and goes long the futures contract at the ask-price (instead of the mid-quote F_t). [11] We indicate this "executable basis" as $Basis_t^B$, where the index B indicates that the trader buys the future. Panel B of Figure 2 shows the daily time series of $Basis_t^B$. The pattern of Panel A is substantially unchanged, except that the curve appears to be moved down. While some arbitrage opportunities in Panel A disappear once market liquidity is taken into consideration, the basis is still positive for a substantial amount of time in the second half of the sample.

Insert Figure 2 here.

$Basis_t$ and $Basis_t^B$ indicate the average mispricing on day t; however, if price dislocations are large but fleeting, these average measures are unsuitable to capture them. To address this shortcoming, we define an alternative arbitrage measure, $Freq_t$, as

$$Freq_t = \frac{I\left[\sum_{m=1}^{M} Basis_{mt} > 0\right]}{M} \tag{2}$$

that is, the fraction of t-day minutes with a positive basis. $Freq_t^B$ is similarly defined as $Freq_t^B = \frac{I\left[\sum_{m=1}^{M} Basis_{mt}^B > 0\right]}{M}$. Panel A and B of Figure 3 report the time series of the two measures. The measures behave similar to those reported in Figure 2, although Panel B of Figure 3 indicates even more starkly the difference between the infrequent mispricing in 2014 and the much more stable dislocation of 2015.

Insert Figure 3 here.

[11]This is admittedly a conservative assumption that the arbitrageur pays the full spread in both legs of the trade. To the extant that she pays less than the full spread, our calculations are a lower bound on the mispricing.

The measures we report above focus on the arbitrage trade that is long in the futures contract and short in the cash bond. Clearly, the opposite arbitrage could also be performed, in case the mispricing reversed. We report the time series of the corresponding measures $Basis_t^S$ and $Freq_t^S$, where the index S indicates that the trader sells the future contract and buys the cash bond, in Figure 4. The profits from this alternative strategy are essentially null, after taking trading costs into consideration. Because of the characteristics of the ECB intervention described in the next section, where the central bank purchased cash bonds, driving their prices upwards, for the remainder of the paper we focus on the profits of the arbitrage strategies involving shorting the cash bonds and buying the futures contract. Hence, we describe the effect that the ECB intervention has on the mispricing in Section VI, based on this strategy.

Insert Figure 4 here.

Table III reports statistics on the basis and the frequency variable:

Insert Table III here.

VI.B Mispricing

VI.B.1 Univariate test

To determine the effect that the QE intervention had on the mispricing between the cash bond and the futures contract, we first consider Figure 2, where the period when the quantitative easing intervention by the ECB was in place is shaded in grey. Both Panels A and B show that the price dislocation was substantially higher during the QE period. In order to test whether the difference between the basis before and during the ECB intervention is statistically significant, we first conduct a simple t-test, allowing for the two periods to have different levels of volatility. We report the results in Table IV.

Insert Table IV here.

In Panel A of Table IV, we report the averages of the mispricing measures we introduced in Section IV, separately for the periods before and during the QE intervention by the ECB, their differences, and t-test for the difference to be null. Before the ECB intervention, the average mispricing was negative, € −0.013, while in the QE period the average basis was € 0.020. The € 0.032 difference is positive and statistically different from zero at the 1% level. $Basis_t^B$ indicates that the result is robust to considering transaction costs. $Freq_t$ and $Freq_t^B$ offer a different characterization of the same result, in that also the frequency of a positive basis, rather than its magnitude, is substantially higher in the QE period. $Freq_t^B$ can be interpreted as testifying that, before the ECB intervention, executable arbitrage opportunities are very infrequent, occurring only 0.4% of the time, i.e., two trading minutes a day. During the QE intervention, however, arbitrage opportunities are 50 times more frequent, taking place 18.4% of the time, i.e., one and a half trading hours a day. $Basis_t^S$ and $Freq_t^S$ offer the mirror image of these results, suggesting that it is much more frequent that the cash bond is relatively more expensive than the futures contract, when the ECB is actively purchasing sovereign bonds on the market.

VI.B.2 Regression Analysis

Even though graphical and univariate analyses clearly convey the effect of the ECB's actions on price dislocations across markets, they fail to take into account the drivers of the arbitrageurs' ability to take advantage of the mispricing other than the ECB buying pressure. Panel A of Figure 5 shows the time series evolution of two variables that measure the availability of funding to European banks, the principal players in the sovereign bond markets. The variables are the cross-currency basis swap spread, measuring the premium that European banks are willing to pay to borrow in dollars rather than in Euros, and the 3-month Euribor rate, a rate at which European institutions are willing to lend unsecured funds to each other. The cross-currency basis swap spread is significantly higher, and, hence, the funding liquidity available to the banks is significantly lower, during the ECB intervention. If we don't control for funding liquidity, for example, we risk attributing the existence of arbitrage opportunities to the actions by the ECB, rather than to the contemporaneous lack of funding liquidity.

Insert Figure 5 here.

We regress the mispricing measure $Basis_t$ on a variable capturing the ECB intervention and other covariates. The central bank intervention is captured by the variable ECB_t, which is a dummy variable equal to one if QE took place during day t, and zero otherwise. An alternative and more direct measure of central bank intervention is the increase in the quantity of Italian sovereign bond held at central banks. In Section III, we described and reported in Figure 1 the monthly holding of the ECB of Italian sovereign bonds. For our analysis here, we calculate the ΔECV_t^Q, the change in monthly central bank holdings of Italian cash bonds between the month day t falls in and the previous month.

The regression we estimate is the following:

$$Basis_t = \alpha + \beta_1 ECB_t + \beta_2 DtD_t + \beta_3 Volume_t^B + \beta_4 Volume_t^F + \beta_5 Euribor_t + \beta_6 CCBSS_t + \varepsilon_t \tag{3}$$

where DtD_t is the numbers of days between day t and the following delivery date, divided by 90, to obtain a variable between zero and one; $Volume_t^B$ is the traded volume on the bond market, in billions; $Volume_t^F$ is the traded volume on the futures market, in millions of contracts; $Euribor_t$ is the three-month Euribor rate, measuring the funding liquidity available to arbitrageurs; $CCBSS_t$ is the spread of the cross-currency basis swap between the three-month Libor in Euros and in Dollars.

The results for several specifications of the regression above are presented in Table V. The first specification corresponds to the t-test in Table IV and allows us to establish that 27% of the variation in the futures-bond basis is driven by the ECB intervention, considering the R^2 of the regression. Specification 2 shows the pull-to-delivery effect, i.e., the futures and CTD bond prices need to converge at delivery. The closer the trade date is to the delivery date, the smaller the mispricing. Specification 3 allows us to rule out the possibility that the larger arbitrage opportunities are driven by a lower market liquidity. The parameter for the volume of trading on the futures market is negative but not significant, while a higher bond market volume correlates positively with the basis. We interpret this finding as consistent with Acharya and Pedersen (2005), in that market participants are more willing to pay for a more liquid asset: when the cash bond is more liquid, it is also more expensive (compared to the futures contract), leading to a higher basis. Specification 4 indicates that funding liquidity measures have no effect on the futures-bond basis. In Specification 5 we include the lagged basis and the interaction between the lagged basis and ECB_t, to verify whether the speed of adjustment of the basis changed during the QE period, finding that the basis is strongly auto-correlated, but that this auto-correlation does not depend on the actions of the central bank. In Specification 6, we use the change in bond holdings by central banks ΔECB_t^Q, instead of the ECB_t dummy, and we find the same results, that during the QE period, as the central bank purchased larger and larger amounts of bonds, the price on the cash market grew faster than its counterpart on the futures market.

Insert Table V here.

Rather than simply controlling for market liquidity in the form of traded volume, we describe in Section IV how we adjust $Basis_t$ to directly account for transaction costs from the arbitrageur's profits calculation. In Table

VI, we regress the resulting measure $Basis_t^B$ onto the same cohort of variables as we do for $Basis_t$ in Table V. The results are stronger for the control variables and unchanged for the variable of interest, ECB_t. In Specification 3, the volume of trade of both the bond market and the futures market is significant, yet, with different signs, as one would expect if the price of an asset is increasing in its liquidity. In Specification 4, both funding illiquidity variables are positive and significant, indicating that, when arbitrageurs have greater funding costs, they cannot engage in arbitrage trades as easily, thus causing the mispricing to increase, rather than taking advantage of it and eliminate it.

Insert Table VI here.

In Tables VII and VIII we repeat the analysis above for the frequency of arbitrage opportunities, $Freq_t$ and $Freq_t^B$, respectively, rather than their average size. The results are unchanged. Specification 5 in both tables takes into account the fact that the measures are bound between zero and one, by accounting for both left- and right-censoring.

Insert Table VII here.

Insert Table VIII here.

VI.C Market Liquidity

A peculiar characteristic of QE, as implemented by the ECB, is its large size, relative to macroeconomic measures of the Euro-zone sovereign bond market and economy. The central bank committed to buy up to € 80 billions in European government bonds a month and, while the ECB does not disclose how the amount is divided between countries, data from the Bank of Italy suggest that the ECB is purchasing 1% of the overall outstanding Italian debt for every three months of QE. We expect that (i) eliminating such a large amount of outstanding bonds from the market and (ii) increasing the demand for that bond creating a huge imbalance between the bid and the ask side of the market should negatively affect the liquidity of the cash bond market, and possibly that of the futures market as well, if investors substitute the less liquid bond market with the more liquid futures counterpart.

Figure 6 shows the bid-ask spread of the CTD bond and the futures contract in Panels A and B, respectively. Similarly to Figure 2, market liquidity appears remarkably lower during the period of the ECB intervention. We test for the difference in the bid-ask spread in Panel B of Table IV, where we show the average bid-ask spread for the futures contract and the cash bond market, before and during the QE intervention, the differences and the statistical significance of the latter. The bid-ask spread of the cash market increases from 7.8 cents for the period before the PSPP to 10.5 cents, i.e., it is 40% higher, while the central bank is active in its intervention. While the ECB did not intervene in derivatives markets directly, the bid-ask spread of the futures market is also 2% larger during the QE period, with the difference being statistically significant, although modest in economic terms.

We also investigate the volume of trade in both the markets. Panel B of Table IV, show the average daily volume of trade for the cash and the futures markets before and during the QE intervention. The volume in the MTS cash markets shows a reduction, on average, of 0.420 billion euros that is very close to the daily average volume of bonds bought by the ECB (6.38 billion per month corresponding to 0.319 billions per day) that is statistically different than zero, that is a reduction of 9%. The volume of trade of the future market increases from 52,000 contracts per day for the period before the PSPP to 91,000 per day, i.e., it is 75% higher, while the central bank is active. This result could be explained because the ECB is intervening in the OTC market not in the MTS exchange trade market generating a reduction of the trades in the MTS markets. Instead, the Eurex is the largest market where the bond futures contract could be traded and is where speculators, arbitrageurs and hedgers concentrate to exploit the opportunities generated by the ECB interventions.

In Table IX we control for other factors that influence the liquidity of the bond market: funding liquidity available to the market makers, $CCBSS_t$; the sovereign bonds' credit risk, CDS_t; the risk-aversion of the market, Vix_t; and the volume traded on the bond and futures market, $Volume_t^B$ and $Volume_t^F$. The coefficient of the dummy of the ECB intervention period, ECB_t, is positive and significant for every specification, confirming the finding that the ECB intervention negatively affected the market liquidity for both the cash bond and the futures market. The same applies to the variable ΔECB_t^Q confirming that the bid-ask spread in both the market increases when the ECB started to buy Italian Sovereign bonds.

Insert Figure 6 here.

Insert Table IX here.

We finally investigate whether the commonality in liquidity has increased between the two markets due to the ECB interventions. In Table X, we regress the volume of trading of the cash bond and futures market, $Volume_t^B$ and $Volume_t^F$, respectively, and the bid-ask spread of the cash bond and futures market, BA_t^B and BA_t^F, respectively, on the corresponding measure in the other market, the ECB_t dummy, and the interaction between the two. In

Specification 5, we regress BA_t^B on ECB_t, BA_t^F, and the interaction of the two. We find that the parameter for the bid-ask spread of the futures market is positive and statistically significant, indicating that an increase in the liquidity of the futures market is contemporaneous to an similar increase in the liquidity of the cash bond market. However, during the ECB intervention, the coefficient almost doubles, indicating a more significant commonality in liquidity among the two markets. The results are instead the opposite regarding the volume of trade. As the univariate analysis shows, the volume in the cash bond market reduces and the volume in the futures market increases during the ECB interventions. This has a strong effect on the commonality in liquidity regarding the volume of trade that drastically reduces by almost one half during the ECB intervention.

Insert Table X here.

Insert Table XI here.

VII Conclusions

We document the existence of a futures-bond basis, i.e., due to mispricing, the Italian sovereign cash bonds and the corresponding futures contract. By looking at the basis for each deliverable bond for every trading minute from June 2013 to December 2015, we find that the QE intervention of the ECB drove a wedge between the pricing of the Italian Sovereign bond and the futures contract that has the bonds as underlying on average of € 0.03 for several months. This mispricing is statistically significant at the 1% level and is significantly positive taking into account the bid-ask spreads of both the cash bond and the futures contract. Even in this case, we find that the basis is still positive for a substantial amount of time in the second half of the sample. Furthermore, we investigate whether the liquidity of the BTP cash market, or the lack thereof, resulting from the ECB intervention was, in fact, transmitted to the BTP futures market. We show that the bid-ask spreads of both the cash bond and the futures contract increase after the PSPP implementation: The ECB Intervention is a relevant source of the future bond-basis indicating that the PSPP induced a reduction in liquidity in the cash bond market and also had an impact on the arbitrage activities, causing an increase of the bid-ask spread of the futures contract. The ECB intervention increased the liquidity co-movement between the cash and the bond market. The opposite happens to the volume. The volume of trades in the cash bond market reduces significantly during the PSPP implementation, and instead the volume of trade in the futures market increases significantly reducing the co-movement between the volume of trade in the bond and that of the futures contract, by approximately one half. This effect could be explained by the fact that the ECB interventions are implemented by the national central banks (for the Italian bonds by the Bank of Italy) in the over-the-counter cash bond markets and, therefore, a significant fraction of the volume of trades in the cash market has been developed outside the MTS market. Instead, the future market is an exchange market and if arbitrageurs, speculators or hedgers would like to perform their trading strategies have no other alternative to this market that indeed observed an increase in the volume of trade.

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Tables

Table I
Cheapest-to-deliver Bonds

This table reports, per each delivery in our sample, the bond we consider the cheapest to deliver. The bond is identified by its ISIN. We report the frequency, in percentage terms of trading minutes per contract, for which the bond was the actual cheapest-to-deliver. We report the percentage of contracts that were physically delivered ("Of outstanding"), and the fraction of these that were settled with the bond we identify as the cheapest-to-deliver ("Of delivered"). We also report the coupon rate, issue date, and maturity date of each bond. The data are obtained from the website of the Eurex market.

Delivery	Bond ISIN	Frequency	Of outstanding	Of delivered	Coupon Rate	Issue Date	Maturity Date
201309	IT0004848831	98.535	1.000%	100.000%	5.500%	30/08/2012	01/11/2022
201312	IT0004848831	89.416	4.000%	77.664%	5.500%	30/08/2012	01/11/2022
201403	IT0004848831	99.800	8.000%	100.000%	5.500%	30/08/2012	01/11/2022
201406	IT0004898034	99.867	9.000%	98.753%	4.500%	27/02/2013	01/05/2023
201409	IT0004898034	99.896	3.000%	100.000%	4.500%	27/02/2013	01/05/2023
201412	IT0004356843	99.877	6.000%	100.000%	4.750%	01/02/2008	01/08/2023
201503	IT0004953417	99.597	2.000%	100.000%	4.500%	30/07/2013	01/03/2024
201506	IT0004953417	99.282	10.000%	100.000%	4.500%	30/07/2013	01/03/2024
201509	IT0004513641	98.789	1.000%	100.000%	5.000%	01/03/2009	01/03/2025
201512	IT0004513641	75.768			5.000%	01/03/2009	01/03/2025
201603	IT0004513641	99.202	1.900%	100.000%	5.000%	01/03/2009	01/03/2025

Table II
Descriptive Statistics

This table shows the distribution bond- and futures contract–specific variables, together with a cohort of macro variables. Variables derived from the bond and futures markets are shown in Panel A. Panel B presents the system variables used in the regression analysis. The sample consists of the quotes from 581 days in our sample for the bond and futures markets data and end-of-day quotes for the other measures. On day t, $Yield_t$ is the yield of the cheapest-to-deliver, TtM_t is its time to maturity, OM_t its original maturity, $Duration_t$ its duration, $Coupon_t$ its coupon, CF its conversion factor, and BA_t^B its bid-ask spread, sampled at a one-minute frequency and averaged at a daily frequency. BA_t^F is the bid-ask spread for the futures contract, on day t. The volume traded in the Italian sovereign bond market (total for all bonds) in billions of euros of face values is $Volume_t^B$, and the volume traded on the futures market is $Futures_t^F$, in millions of contracts. The global systemic variables are the three-month Euro Interbank Offered Rate ($Euribor_t$), the VIX index (Vix_t), and the cross-currency basis swap spread ($CCBSS_t$). We also report the five year CDS spread for the Italian government debt (CDS_t) and the value of an index for the repo-rate of an italian bond on special, r_t . Bond-based data are obtained from the Mercato dei Titoli di Stato (MTS), while the futures data are obtained from Eurex, and cover the sample from June, 2013 to December 31, 2015. All other data were obtained from Bloomberg.

Panel A: Bond Market Variables							
Variable	Mean	Std	P5	P25	Median	P75	P95
$Yield_t$	2.663	1.064	1.270	1.703	2.484	3.662	4.373
TtM_t	9.093	0.276	8.715	8.871	9.053	9.293	9.630
OM_b	11.845	2.543	10.178	10.178	10.178	15.507	16.011
$Duration_t$	7.500	0.235	7.106	7.323	7.492	7.669	7.877
$Coupon_b$	4.952	0.425	4.500	4.500	5.000	5.500	5.500
CF_b	0.934	0.029	0.903	0.905	0.934	0.971	0.972
BA_t^B	0.086	0.035	0.043	0.062	0.078	0.100	0.152
BA_t^F	0.014	0.002	0.012	0.013	0.014	0.015	0.017
$Volume_t^B$	4.695	1.813	1.922	3.321	4.617	5.924	8.071
$Volume_t^F$	0.066	0.036	0.021	0.037	0.059	0.087	0.136
Panel B: Funding liquidity and credit risk Variables							
Variable	Mean	Std	P5	P25	Median	P75	P95
$Euribor_t$	0.129	0.141	−0.091	−0.013	0.202	0.228	0.319
Vix_t	0.152	0.035	0.117	0.130	0.142	0.162	0.221
$CCBSS_t$	0.143	0.102	0.017	0.064	0.118	0.208	0.327
CDS_t	1.436	0.544	0.914	1.070	1.178	1.677	2.617
r_t	0.020	0.172	−0.200	−0.154	0.040	0.149	0.282

Table III
Futures-Bond Basis

This table shows the time series distribution of the variables defined in Section V. We report the distribution characteristics of a cohort of mispricing measures, sampled at a one-minute frequency and averaged to obtain daily measures. $Basis_t$ measures the profit an arbitrageurs would lock in shorting the bond and going long a futures contract and is calculated using mid-quotes. $Basis_t^B$ ($Basis_t^S$) is a profit measure of the same (opposite) strategy, using appropriate bid- and ask-prices. $Freq_t$ measure the fraction of minutes, in day t when $Basis_t$ was positive. $Freq_t^B$ and $Freq_t^S$ are calculated similarly. Our bond-based data are obtained from the Mercato dei Titoli di Stato (MTS), while the futures data are obtained from Eurex, and cover the sample from June, 2013 to December 31, 2015. All other data were obtained from Bloomberg.

Variable	Mean	Std	P5	P25	Median	P75	P95
$Basis_t$	−0.001	0.030	−0.039	−0.021	−0.006	0.013	0.062
$Basis_t^B$	−0.052	0.032	−0.105	−0.074	−0.050	−0.032	0.002
$Basis_t^S$	−0.049	0.038	−0.133	−0.062	−0.039	−0.024	−0.008
$Freq_t$	0.404	0.428	0.000	0.000	0.189	0.924	1.000
$Freq_t^B$	0.068	0.204	0.000	0.000	0.000	0.003	0.622
$Freq_t^S$	0.036	0.106	0.000	0.000	0.000	0.010	0.270

Table IV
Futures-Bond Basis and ECB Intervention

This table presents the averages of a cohort of variables before and during the ECB intervention. Panel A presents the mispricing measures, while Panel B present the liquidity measures. The average measure before (during) the intervention is indicated under $ECB_t = 0$ ($ECB_t = 1$). We report the difference between the average basis before and during the ECB intervention and the t-test for its difference from zero. The mispricing variables in Panel A are: $Basis_t$, measuring the profit an arbitrageurs would lock in shorting the bond and going long a futures contract and is calculated using mid-quotes; $Basis_t^B$ ($Basis_t^S$), measuring of the same (opposite) strategy, using appropriate bid- and ask-prices; $Freq_t$, measuring the fraction of minutes, in day t when $Basis_t$ was positive; $Freq_t^B$ and $Freq_t^S$ are calculated similarly to $Freq_t$, using a straightforward notation. The liquidity variables in Panel B are: BA_t^B, the bid-ask spread of the bond market; and BA_t^F, the bid-ask spread for the futures contract. The volume traded in the Italian sovereign bond market (total for all bonds) in billions of euros of face values is $Volume_t^B$, and the volume traded on the futures market is $Futures_t^F$, in millions of contracts. All variables are sampled at a one-minute frequency and averaged through day t to obtain a daily series. Our data set spans from June 2013 to December 2015, and was obtained from the Mercato dei Titoli di Stato (MTS) and the Eurex market. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

Panel A: Basis Measures				
	$ECB_t = 0$	$ECB_t = 1$	Difference	$t-$test
$Basis_t$	−0.013	0.020	0.032***	12.406
$Basis_t^B$	−0.058	−0.041	0.017***	5.536
$Basis_t^S$	−0.032	−0.079	−0.047***	−14.479
$Freq_t$	0.256	0.668	0.412***	11.918
$Freq_t^B$	0.004	0.182	0.178***	8.331
$Freq_t^S$	0.047	0.016	−0.031***	−3.971
Panel B: Liquidity Measures				
	$ECB_t = 0$	$ECB_t = 1$	Diff	$t-$test
BA_t^B	0.075	0.105	0.029***	9.558
BA_t^F	0.014	0.014	0.000*	1.887
$Volume_t^B$	4.846	4.426	−0.420***	−2.649
$Volume_t^F$	0.052	0.091	0.039***	13.468
Panel C: Funding Liquidity and Credit Risk Measures				
	$ECB_t = 0$	$ECB_t = 1$	Diff	$t-$test
$Euribor_t$	0.221	−0.034	−0.255***	−49.775
Vix_t	0.144	0.166	0.022***	6.289
$CCBSS_t$	0.084	0.249	0.165***	26.867
CDS_t	1.611	1.125	−0.486***	−14.911
r_t	0.121	−0.161	−0.282***	−36.994

Table V
Futures-Bond Basis Determinants

This table presents the results for the regression of the mispricing between the futures contract and the underlying cheapest-to-deliver bond on day t, $Basis_t$, on a dummy that equals one when the QE intervention by the ECB is in place, and 0 otherwise, ECB_t. Alternatively, we capture the central bank intervention by ΔECB_t^Q, the monthly net purchases of Italian sovereign bonds by central banks. Other co-variates include the days to delivery, DtD_t, the liquidity of the bond and futures market, BA_t^B and BA_t^F, respectively, the volatility index, Vix_t, the Euribor rate, $Euribor_t$, and the EUR/USD cross-currency basis swap spread, $CCBSS_t$. The dependent variable $Basis_t$ is defined as the profit an arbitrageurs would lock in shorting the bond and going long a futures contract and is calculated using mid-quotes. Heteroskedasticity-robust t-tests are reported in parentheses. Our data set consists of 578 days from June 2013 to December 2015. The data are obtained from the Mercato dei Titoli di Stato (MTS) Global Market bond trading system and the Eurex market. All macro variables were obtained from Bloomberg. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
	$Basis_t$	$Basis_t$	$Basis_t$	$Basis_t$	$Basis_t$	$Basis_t$
ECB_t	0.032***	0.032***	0.034***	0.037***	0.005***	
	(12.413)	(12.661)	(11.696)	(8.295)	(3.098)	
ΔECB_t^Q						0.005***
						(7.764)
DtD_t		0.012***	0.011***	0.012***	0.003	0.009**
		(3.083)	(2.877)	(2.924)	(1.154)	(2.247)
$Volume_t^B$			0.002**	0.001**		0.001*
			(2.579)	(2.187)		(1.868)
$Volume_t^F$			−0.043	−0.034		−0.038
			(−1.016)	(−0.747)		(−0.822)
$Euribor_t$				0.022		−0.005
				(1.246)		(−0.325)
$CCBSS_t$				0.016		0.005
				(0.875)		(0.281)
$Basis_{t-1}$					0.798***	
					(19.956)	
$ECB \cdot Basis_{t-1}$					0.063	
					(1.104)	
Constant	−0.013***	−0.019***	−0.025***	−0.031***	−0.004**	−0.021***
	(−13.429)	(−8.421)	(−6.672)	(−4.930)	(−2.560)	(−3.448)
Adj. R^2	0.270	0.282	0.289	0.287	0.792	0.274
Obs	578	578	578	578	576	578

Table VI
Liquidity-adjusted Futures-Bond Basis Determinants

This table presents the results for the regression of the market liquidity-adjusted mispricing between the futures contract and the underlying cheapest-to-deliver bond on day t, $Basis_t^B$, on a dummy that equals one when the QE intervention by the ECB is in place, and 0 otherwise, ECB_t. Alternatively, we capture the central bank intervention by ΔECB_t^Q, the monthly net purchases of Italian sovereign bonds by central banks. Other co-variates include the days to delivery, DtD_t, the liquidity of the bond and futures market, BA_t^B and BA_t^F, respectively, the volatility index, Vix_t, the Euribor rate, $Euribor_t$, and the EUR/USD cross-currency basis swap spread, $CCBSS_t$. The dependent variable $Basis_t^B$ is defined as the profit an arbitrageurs would lock in shorting the bond and going long a futures contract and is calculated using the bid-price for the bond transaction and the ask-price for the transaction in the futures contract. Heteroskedasticity-robust t-tests are reported in parentheses. Our data set consists of 578 days from June 2013 to December 2015. The data are obtained from the Mercato dei Titoli di Stato (MTS) Global Market bond trading system and the Eurex market. All macro variables were obtained from Bloomberg. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

	(1) $Basis_t^B$	(2) $Basis_t^B$	(3) $Basis_t^B$	(4) $Basis_t^B$	(5) $Basis_t^B$
ECB_t	0.017***	0.016***	0.026***	0.038***	
	(5.539)	(5.568)	(7.651)	(7.098)	
ΔECB_t^Q					0.005***
					(6.218)
DtD_t		0.010**	0.007*	0.010**	0.007
		(2.188)	(1.678)	(2.130)	(1.565)
$Volume_t^B$			0.006***	0.006***	0.005***
			(9.017)	(7.447)	(7.126)
$Volume_t^F$			−0.189***	−0.149***	−0.151***
			(−4.019)	(−3.058)	(−3.084)
$Euribor_t$				0.098***	0.067***
				(4.539)	(3.259)
$CCBSS_t$				0.071***	0.061**
				(3.102)	(2.546)
Constant	−0.058***	−0.063***	−0.083***	−0.110***	−0.100***
	(−42.406)	(−23.813)	(−20.108)	(−14.649)	(−13.612)
Adj. R^2	0.060	0.066	0.178	0.196	0.178
Obs	578	578	578	578	578

Table VII
Futures-Bond Basis Determinants

This table presents the results for the regression of the mispricing between the futures contract and the underlying cheapest-to-deliver bond on day t, $Freq_t$, on a dummy that equals one when the QE intervention by the ECB is in place, and 0 otherwise, ECB_t. Alternatively, we capture the central bank intervention by ΔECB_t^Q, the monthly net purchases of Italian sovereign bonds by central banks. Other co-variates include the days to delivery, DtD_t, the liquidity of the bond and futures market, BA_t^B and BA_t^F, respectively, the volatility index, Vix_t, the Euribor rate, $Euribor_t$, and the EUR/USD cross-currency basis swap spread, $CCBSS_t$. The dependent variable $Freq_t$ measure the fraction of minutes, in day t when $Basis_t$ was positive. $Basis_t$ is defined as the profit an arbitrageurs would lock in shorting the bond and going long a futures contract and is calculated using mid-quotes. Heteroskedasticity-robust t-tests are reported in parentheses. Our data set consists of 578 days from June 2013 to December 2015. The data are obtained from the Mercato dei Titoli di Stato (MTS) Global Market bond trading system and the Eurex market. All macro variables were obtained from Bloomberg. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

	(1) $Freq_t$	(2) $Freq_t$	(3) $Freq_t$	(4) $Freq_t$	(5) $Freq_t$	(6) $Freq_t$
ECB_t	0.412***	0.411***	0.487***	0.439***	1.064***	
	(11.923)	(11.927)	(12.332)	(6.591)	(6.297)	
ΔECB_t^Q						0.047***
						(5.235)
DtD_t		0.068	0.046	0.088	0.246*	0.066
		(1.266)	(0.845)	(1.589)	(1.724)	(1.172)
$Volume_t^B$			0.043***	0.035***	0.093***	0.032***
			(4.596)	(3.672)	(3.729)	(3.365)
$Volume_t^F$			−1.491***	−1.529***	−1.938	−1.487***
			(−2.723)	(−2.729)	(−1.340)	(−2.644)
$Euribor_t$				0.679**	1.532**	0.197
				(2.359)	(2.067)	(0.729)
$CCBSS_t$				1.324***	2.805***	1.238***
				(5.035)	(3.429)	(4.541)
Constant	0.256***	0.219***	0.102*	−0.143	−1.149***	−0.002
	(13.924)	(6.394)	(1.771)	(−1.483)	(−4.210)	(−0.026)
Adj. R^2	0.213	0.214	0.240	0.257	0.139	0.231
Obs	578	578	578	578	578	578

Table VIII
Futures-Bond Basis Determinants

This table presents the results for the regression of the mispricing between the futures contract and the underlying cheapest-to-deliver bond on day t, $Freq_t^B$, on a dummy that equals one when the QE intervention by the ECB is in place, and 0 otherwise, ECB_t. Alternatively, we capture the central bank intervention by ΔECB_t^Q, the monthly net purchases of Italian sovereign bonds by central banks. Other co-variates include the days to delivery, DtD_t, the liquidity of the bond and futures market, BA_t^B and BA_t^F, respectively, the volatility index, Vix_t, the Euribor rate, $Euribor_t$, and the EUR/USD cross-currency basis swap spread, $CCBSS_t$. The dependent variable $Freq_t^B$ measure the fraction of minutes, in day t when $Basis_t^B$ was positive. $Basis_t^B$ is defined as the profit an arbitrageurs would lock in shorting the bond and going long a futures contract and is calculated using bid- and ask-quotes. Heteroskedasticity-robust t-tests are reported in parentheses. Our data set consists of 578 days from June 2013 to December 2015. The data are obtained from the Mercato dei Titoli di Stato (MTS) Global Market bond trading system and the Eurex market. All macro variables were obtained from Bloomberg. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

	(1) $Freq_t^B$	(2) $Freq_t^B$	(3) $Freq_t^B$	(4) $Freq_t^B$	(5) $Freq_t^B$	(6) $Freq_t^B$
ECB_t	0.178***	0.176***	0.180***	0.150***	0.485***	
	(8.336)	(8.645)	(7.365)	(6.402)	(5.410)	
ΔECB_t^Q						0.026***
						(6.504)
DtD_t		0.142***	0.141***	0.134***	0.240***	0.116***
		(4.951)	(4.786)	(4.612)	(3.183)	(4.235)
$Volume_t^B$			0.001	0.003	0.029**	0.003
			(0.256)	(0.679)	(2.280)	(0.538)
$Volume_t^F$			−0.095	−0.200	−0.362	−0.263
			(−0.343)	(−0.639)	(−0.506)	(−0.839)
$Euribor_t$				−0.263**	−0.137	−0.278**
				(−2.270)	(−0.345)	(−2.469)
$CCBSS_t$				−0.193	0.169	−0.257
				(−1.268)	(0.536)	(−1.631)
Constant	0.004***	−0.074***	−0.074***	−0.001	−0.696***	0.019
	(3.926)	(−4.684)	(−3.166)	(−0.025)	(−5.265)	(0.457)
Adj. R^2	0.175	0.215	0.213	0.214	0.294	0.228
Obs	578	578	578	578	578	578

Table IX
Futures and Bond Liquidity Determinants

This table presents the results for the regression of a measure of the bond and futures market liquidity, the bid-ask spread BA_t^B and BA_t^F, respectively, on a dummy that equals one when the QE intervention by the ECB is in place, and 0 otherwise, ECB_t. Alternatively, we capture the central bank intervention by ΔECB_t^Q, the monthly net purchases of Italian sovereign bonds by central banks. Other co-variates include the days to delivery, DtD_t, the liquidity of the bond and futures market, BA_t^B and BA_t^F, respectively, the volatility index, Vix_t, the Euribor rate, $Euribor_t$, and the EUR/USD cross-currency basis swap spread, $CCBSS_t$. Heteroskedasticity-robust t-tests are reported in parentheses. Our data set consists of 578 days from June 2013 to December 2015. The data are obtained from the Mercato dei Titoli di Stato (MTS) Global Market bond trading system and the Eurex market. All macro variables were obtained from Bloomberg. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

	(1) BA_t^B	(2) BA_t^B	(3) BA_t^B	(4) BA_t^F	(5) BA_t^F	(6) BA_t^F
ECB_t	0.029***	0.018***		0.000*	0.001***	
	(9.563)	(4.281)		(1.888)	(5.508)	
ΔECB_t^Q			0.002***			0.000***
			(3.162)			(5.128)
$CCBSS_t$		0.025	0.041**		−0.001	0.000
		(1.607)	(2.583)		(−0.849)	(−0.492)
CDS_t		0.007***	0.006***		0.002***	0.002***
		(3.907)	(3.221)		(17.859)	(17.582)
$\sigma_t^{2,B}$		387.841***	396.006***			
		(14.316)	(14.599)			
$\sigma_t^{2,F}$					17.794***	17.891***
					(19.049)	(19.263)
Constant	0.075***	0.019***	0.019***	0.014***	0.009***	0.009***
	(56.401)	(5.279)	(5.204)	(144.612)	(47.933)	(48.171)
Adj. R^2	0.166	0.497	0.487	0.004	0.692	0.690
Obs	578	578	578	578	578	578

Table X
Commonality in Liquidity

This table presents the results for the regression of the traded volume on the futures and bond market and a measure of the bond and futures market liquidity, the bid-ask spread BA_t^B and BA_t^F, respectively, on a dummy that equals one when the QE intervention by the ECB is in place, and 0 otherwise, ECB_t. Other co-variates include the days to delivery, DtD_t, the liquidity of the bond and futures market, BA_t^B and BA_t^F, respectively, the volatility index, Vix_t, the Euribor rate, $Euribor_t$, and the EUR/USD cross-currency basis swap spread, $CCBSS_t$. Heteroskedasticity-robust t-tests are reported in parentheses. Our data set consists of 578 days from June 2013 to December 2015. The data are obtained from the Mercato dei Titoli di Stato (MTS) Global Market bond trading system and the Eurex market. All macro variables were obtained from Bloomberg. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

	(1) $Volume_t^F$	(2) $Volume_t^F$	(3) $Volume_t^B$	(4) $Volume_t^B$	(5) BA_t^B	(6) BA_t^F
ECB_t	0.041***	0.051***	−1.238***	−0.270	−0.097***	0.001***
	(15.223)	(7.614)	(−7.409)	(−0.705)	(−4.066)	(3.758)
$Volume_t^B$	0.006***	0.007***				
	(9.897)	(10.458)				
$Volume_t^B \cdot ECB_t$		−0.002				
		(−1.522)				
$Volume_t^F$			21.245***	27.284***		
			(8.990)	(9.344)		
$Volume_t^F \cdot ECB_t$				−13.245***		
				(−2.846)		
BA_t^F					8.731***	
					(14.157)	
$BA_t^F \cdot ECB_t$					8.903***	
					(5.023)	
BA_t^B						0.044***
						(9.593)
$BA_t^B \cdot ECB_t$						−0.024***
						(−4.678)
Constant	0.021***	0.017***	3.739***	3.424***	−0.044***	0.010***
	(6.827)	(5.519)	(24.824)	(19.962)	(−5.317)	(34.003)
Adj. R^2	0.358	0.360	0.143	0.154	0.473	0.379
Obs	578	578	578	578	578	578

Table XI
Correlation between Bid-Ask Spreads and Volumes

This table presents the correlation between traded volume on the futures and bond market and a measure of the bond and futures market liquidity, the bid-ask spread BA_t^B and BA_t^F. The correlation is computed separately before and during the ECB intervention and is presented in Panel A and B, respectively. Our data set consists of 578 days from June 2013 to December 2015. The data are obtained from the Mercato dei Titoli di Stato (MTS) Global Market bond trading system and the Eurex market. *, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

Panel A: Correlations Before QE				
	BA_t^B	BA_t^F	$Volume_t^B$	$Volume_t^F$
BA_t^B	1.000			
BA_t^F	0.620***	1.000		
$Volume_t^B$	−0.381***	−0.584***	1.000	
$Volume_t^F$	0.149**	−0.280***	0.443***	1.000
Panel B: Correlations During QE				
	BA_t^B	BA_t^F	$Volume_t^B$	$Volume_t^F$
BA_t^B	1.000			
BA_t^F	0.600***	1.000		
$Volume_t^B$	−0.449***	−0.437***	1.000	
$Volume_t^F$	−0.042	0.168*	0.266***	1.000

Figures

Figure 1
Central Bank Holdings of Italian Sovereign Bonds

This figure shows the time series of the amount of Italian bonds held at the central banks and its changes. In red we plot the level of bond holdings by central banks, in billions (right-hand side axis), while we plot the changes in blue (left-hand side axis), also in billions of euro. The data have a monthly frequency and are obtained from the bank of Italy. The period when the ECB was active is shaded in gray.

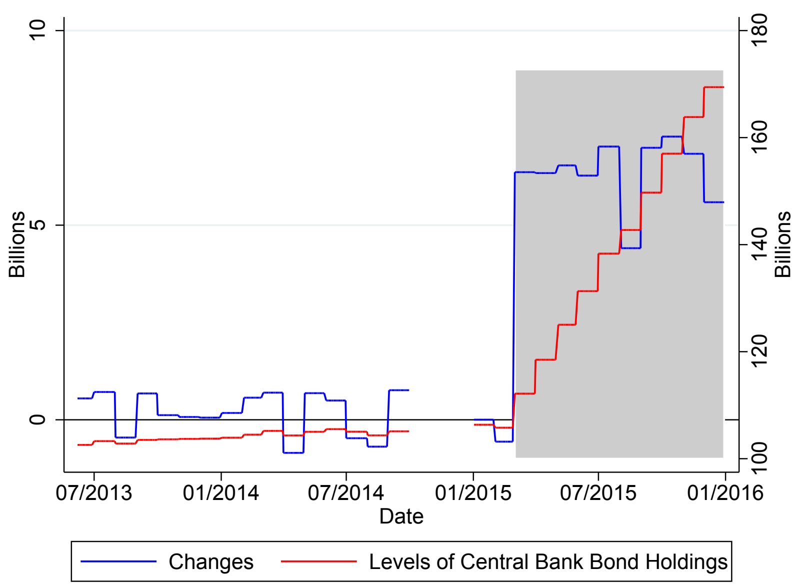
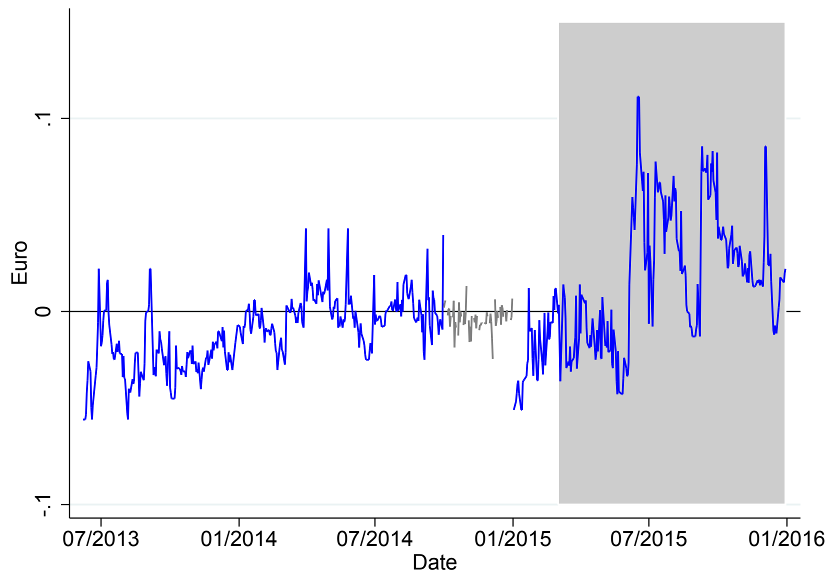


Figure 2
Futures-Bond Basis and ECB Intervention

This figure shows the daily time series of the mispricing between the futures contract and the underlying cheapest-to-deliver bond. The mispricing is calculated as the profit locked in by an arbitrageurs shorting the bond and going long the futures contract, as per Equation 1, taking into account the cost of carry for the bond position. The basis is calculated for each minute in our sample and aggregated at a daily frequency. The mispricing is calculated in euros per 100 euros of face value. Panel A (B) shows the mispricing when the prices of the bond and futures market are calculated using midquotes (the appropriate bid- and ask-prices). The time-period when the ECB is active on the market is shaded in gray. Our dataset consists of quotes for Italian sovereign bonds and futures contract with those bonds as underlying. They are obtained from the MTS market and Eurex, respectively, and cover the period between June, 2013, and December, 2015.

A: $Basis_t$



B: $Basis_t^B$

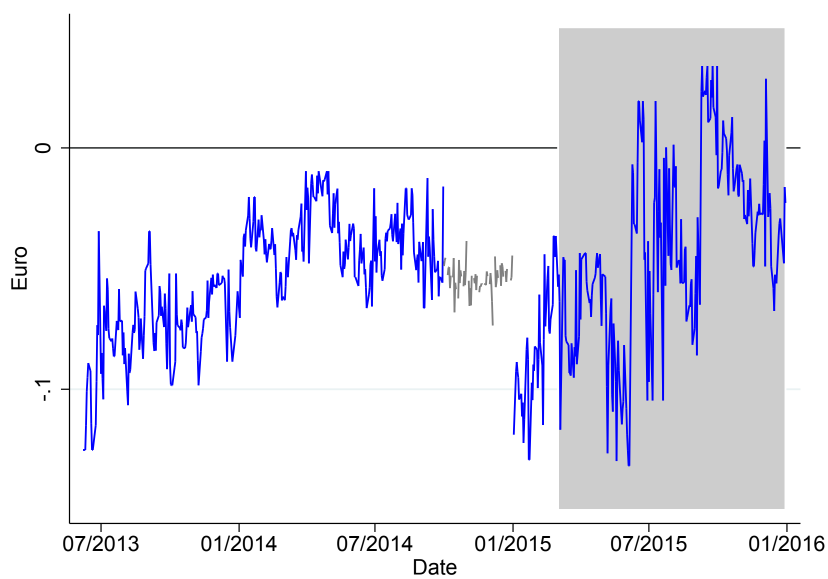
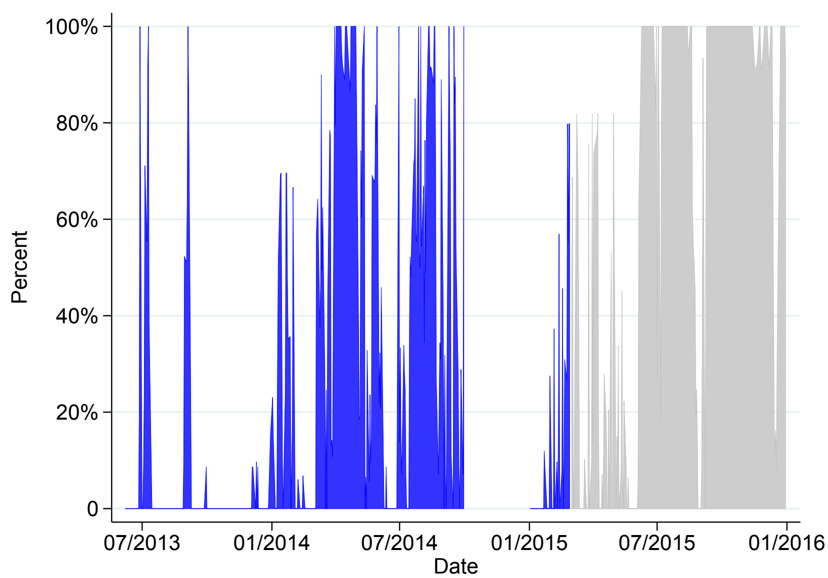


Figure 3
Frequency of Positive Basis and ECB Intervention

This figure shows the daily time series of the frequency of positive mispricing between the futures contract and the underlying cheapest-to-deliver bond. The mispricing is calculated as the profit locked in by an arbitrageurs shorting the bond and going long the futures contract, as per Equation 1, taking into account the cost of carry for the bond position. This figure reports the percentage of minutes when the basis is positive, for each day in our sample. Panel A (B) shows the frequency of positive mispricing when the prices of the bond and futures market are calculated using midquotes (the appropriate bid- and ask-prices). The period when the ECB is active on the market is shaded in gray. Our dataset consists of quotes for Italian sovereign bonds and futures contract with those bonds as underlying. They are obtained from the MTS market and Eurex, respectively, and cover the period between June, 2013, and December, 2015.

A: $Freq_t$



B: $Freq_t^B$

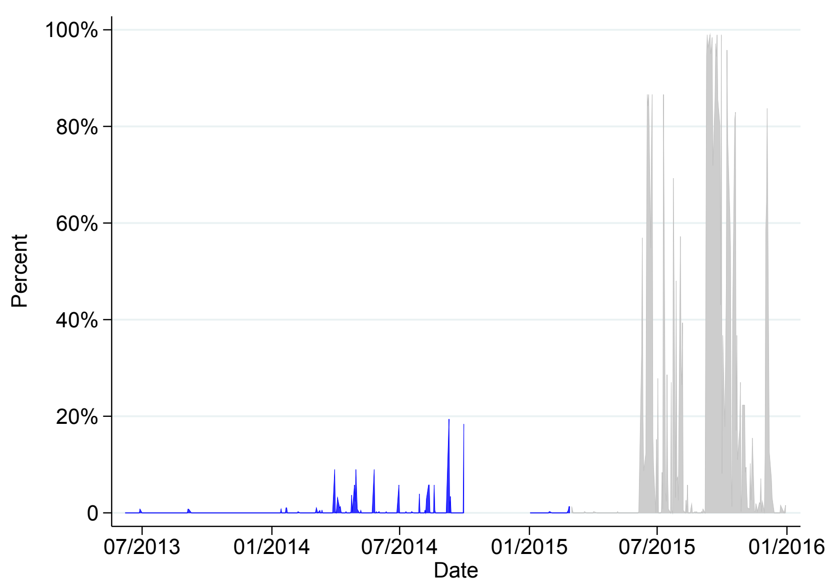
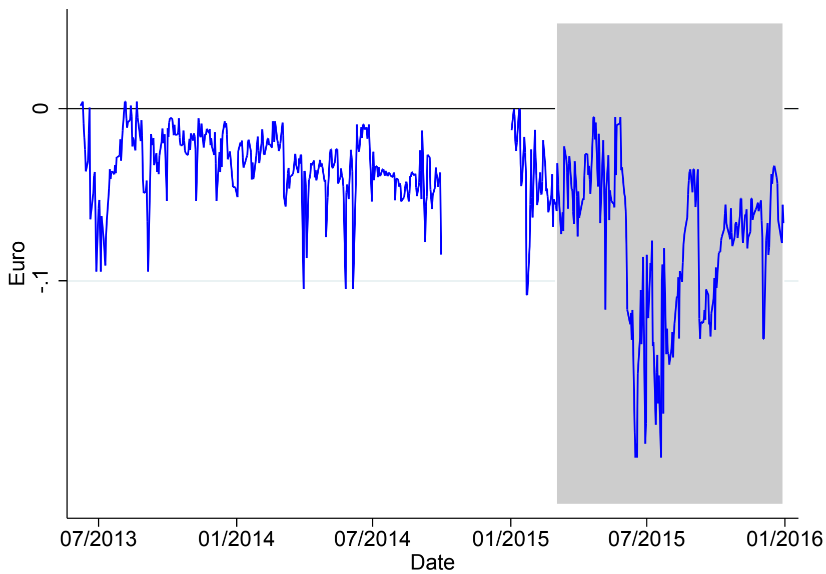


Figure 4
Frequency of Positive Basis when Shorting the Futures Contract and ECB Intervention

This figure shows the daily time series of the average and frequency of positive mispricing between the futures contract and the underlying cheapest-to-deliver bond, when the mispricing is calculated as the profit locked in by an arbitrageurs shorting the futures contract and going long the bond. Our calculations take into account the cost of carry for the bond position and the transaction costs of the two trades. The basis is calculated for each minute in our sample and aggregated at a daily frequency. The mispricing is calculated in euros per 100 euros of face value. Panel A shows the average size of the mispricing, while Panel B shows the frequency with which the positive mispricing take place. The period when the ECB is active on the market is shaded in gray. Our dataset consists of quotes for Italian sovereign bonds and futures contract with those bonds as underlying. They are obtained from the MTS market and Eurex, respectively, and cover the period between June, 2013, and December, 2015.

A: $Basis_t^S$



B: $Freq_t^S$

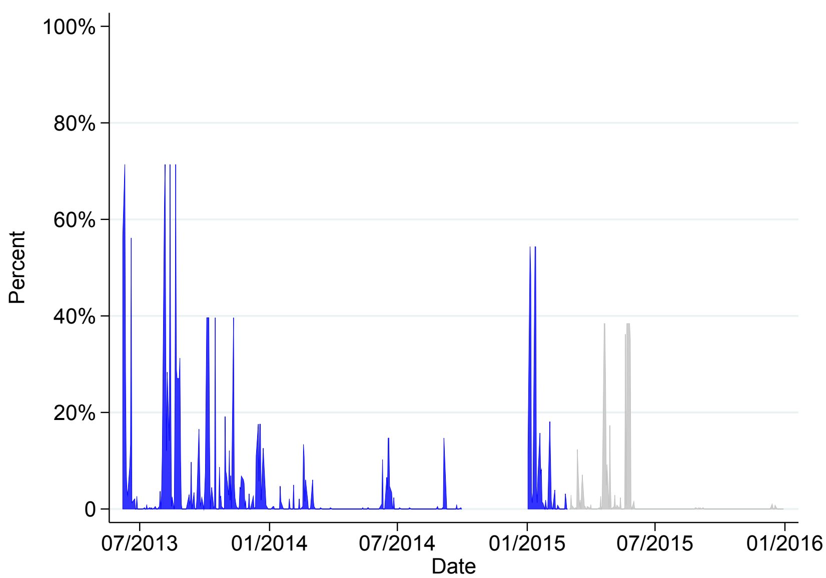
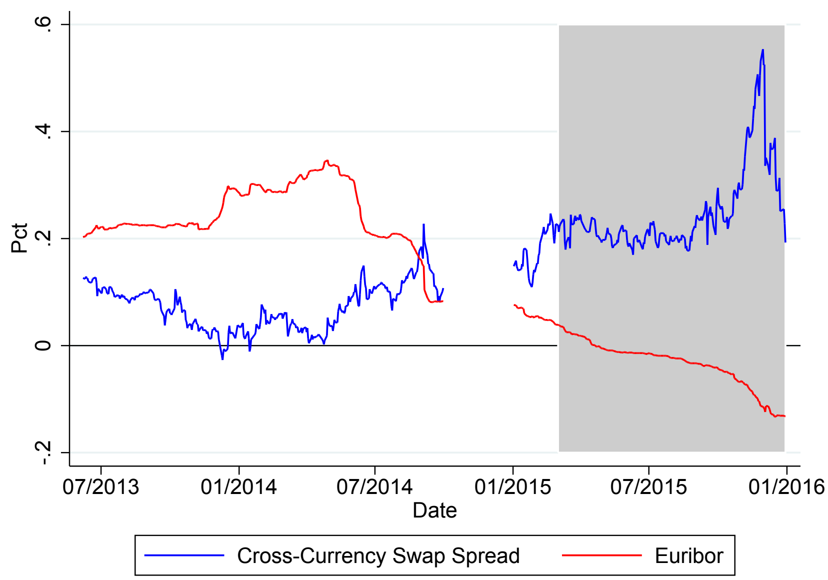


Figure 5
Macro Variables

This figure shows the time series of system variables we use in the regression analysis. Panel A shows the evolution of the EUR/USD cross-currency basis swap spread, and the Euribor rate, both in percentage points. Panel B shows the evolution of the volatility index (left-hand side axis), the credit default swap spread for a five-year contract (right-hand side axis), and the yield of the cheapest-to-deliver bond (right-hand side axis), from June 2013 to December 2015. All daily data were obtained from Bloomberg.

A: Cross Currency Basis Swap and Euribor



B: Vix, Bond Yield, and CDS Spread

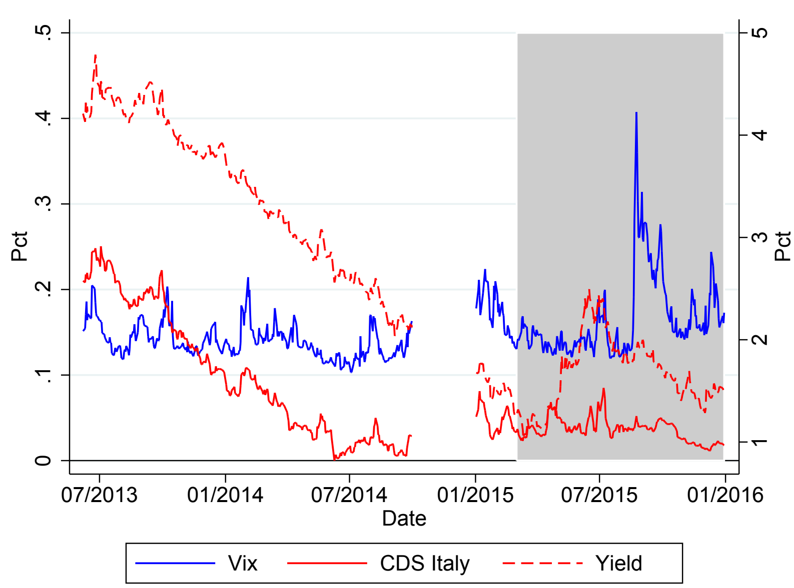
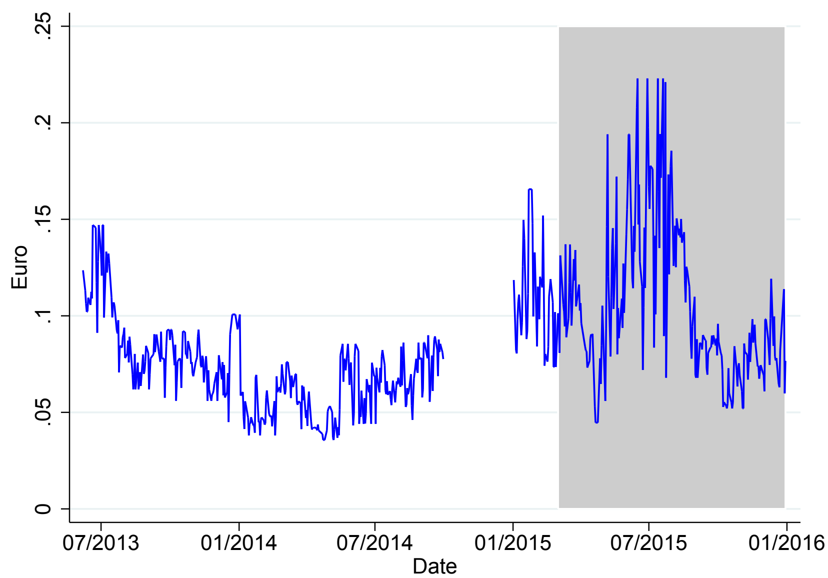


Figure 6
Futures and Bond Market Liquidity

This figure shows the time series of the the bid-ask spread of the bond market, in Panel A, and futures market, in Panel B. For the bond (futures) market, the bid-ask spread is calculated for the cheapest-to-deliver bond (next delivery contract) at a one-minute frequency and aggregated at a daily level. The grey area represents the period when the ECB purchased bonds as part of the QE intervention. Our dataset consists of quotes for Italian sovereign bonds and futures contract with those bonds as underlying. They are obtained from the MTS market and Eurex, respectively, and cover the period between June, 2013, and December, 2015.

A: The Bond Market



B: The Futures Market