

# Limits to arbitrage: Empirical evidence from Euro area sovereign bond markets

Stefano Corradin  
European Central Bank

Maria Rodriguez-Moreno\*  
Universidad de Navarra

First version: 15 February 2013

This version: 16 May 2014

## Abstract

We document that the yield-to-maturity of an USD-denominated bond, once the foreign exchange rate risk is hedged in the USD-EUR currency swap market, and a comparable EUR-denominated bond issued by the same Euro area country could differ by more than 150 basis points between 2008 – 2013. USD-denominated bonds became always cheaper (higher yield-to-maturity) than those denominated in Euro. We find that the European Central Bank (ECB) liquidity facilities and non-standard monetary policy measures play a key role in explaining the differential yield, using ECB proprietary data on all sovereign bond purchases and all sovereign collateral pledged in the euro area during this period. Because EUR-denominated bonds could be used as collateral for liquidity operations with the ECB at lower haircuts, a monetary funding premium is embedded in these bonds yields. Moreover, this funding premium might also vary over time, depending on the credit spreads of the sovereign issuer, on the one hand, and the general liquidity supply conditions partly determined by the ECB policy stance, on the other.

**JEL classification:** G01, G12

**Keywords:** Limits to Arbitrage, Market Anomalies, Central Banks Interventions

---

\*The views expressed herein are those of authors only and do not represent the position of the European Central Bank or the Eurosystem. We are grateful for comments from Geert Bekaert, Frederic Boissay, Simone Manganelli and Manfred Kremer. We benefited from discussions with Cristina Arellano, Alessandro Beber, Andrea Buraschi, John Campbell, Giancarlo Corsetti, Luca Dedola, Michael Ehrmann, Emmanuel Farhi, Marie Hoer-ova, Peter Hoffman, Sergio Mayordomo, James McAndrews, Augustine Landier, David Lando, Enrico Perotti, Frank Smets, Cristina Sommacampagna, Oreste Tristani and Harald Uhlig. Email contacts: stefano.corradin@ecb.europa.eu and mrodriguez@unav.es.

# 1 Introduction

The absence of arbitrage opportunities is a central tenet of asset pricing theory: asset that generate the same identical cash flows must command the same price. Nevertheless, there are instances in which the no-arbitrage condition breaks down for non-negligible periods of time. Recent theory such as Brunnermeier and Pedersen (2009) and Garleanu and Pedersen (2011) stresses the role that funding constraints, the limited ability of financial institutions to borrow against their securities, may play a key role in propagating mis-pricing in financial markets. At times of crisis, central banks can affect the funding liquidity varying the haircuts (or margin requirements) on securities, expanding the liquidity and extending the maturity of secured loans offered. As a result, security prices may increase significantly, especially for securities with low haircuts.

This paper provides support for the implications of these recent friction-based theories, studying the euro area sovereign market between 2008 – 2013. We document the occurrence of a large pricing anomaly developed between USD- and EUR-denominated comparable bonds issued by the same euro area country. Using European Central Bank (ECB) proprietary data on all all sovereign collateral pledged, the main contribution of our paper to the previous literature is to document the existence of a monetary funding premium. This premium is embedded in the EUR-denominated bonds because these bonds could be used as collateral for liquidity operations with the ECB at lower haircuts than comparable USD-denominated bonds during a period of market distress for the euro area. Moreover, this monetary funding premium is time varying and substantial when the ECB changed its collateral policy varying the haircuts and offered loans at longer maturities than otherwise available in the repo market and when the sovereign issuer experienced periods of market stress.

The pricing anomaly consists in a large yield spread, a basis, developed between EUR- and USD-denominated comparable bonds issued by the same euro area country. USD-denominated bonds became substantially cheaper (higher yield-to-maturity) than those denominated in euro, once the foreign exchange rate risk is hedged in the USD-EUR currency swap market. We document that the pricing anomaly is a feature of bonds issued by Austria, Belgium, Finland, Italy and Spain for whom USD-denominated bonds are available. Figure 1 depicts the weekly average basis across the bond pairs analyzed for each euro area sovereign country for the period January 2008 to February 2013.

[INSERT FIGURE 1 HERE]

Before September 2008, the basis for each country is negligible. Over the period September 2008 - April 2010, the size of the anomaly was large, persistent and similar across the countries considered. The finding is consistent with Buraschi, Sener and Menguturk (2014), who find that USD-denominated bonds issued by Turkey traded at a cheaper level

than the EUR-denominated bonds over the same time period. In May 2010 the intensification of the euro area sovereign debt crisis impacted further on the size of the basis and significant differences emerged across the countries. The basis that we document widened (i.e., became more positive) in the second half of 2010 for countries whose sustainability of fiscal positions became a concern for market investors. Over this period, the weekly average basis across the bond pairs for Austria reached 93 bps, while the basis for Belgium, Italy and Spain reached 199 bps, 152 bps and 402 bps.

Our empirical investigation seeks to identify what the main drivers of the basis were. We conduct panel regression analysis considering specific bond factors, such as market liquidity, lending activity, differential governing law, macro-financial and country specific factors, political and policy uncertainty factors in the euro area, and other factors. Although, these factors affect the basis, they are not able to provide a fully satisfactory explanation of the existence of these arbitrage opportunities. In particular, these factors play a limited role during the euro area sovereign debt crisis period, when the size of the basis on average widens and significant differences emerged across the countries.

Thus, we focus our attention on the ECB's role and specifically on the ECB liquidity facilities and collateral policy. The ECB liquidity operations mirror private repos: the ECB provides funds to the counter-parties against eligible collateral where the amount of funding equals to the market price of the collateral multiplied by one minus the haircut. To explore how these factors may be driving the basis, we study how (i) changes in eligibility criteria, (ii) the amount of the sovereign debt collateral pledged at the ECB in exchange of liquidity, and (iii) the introduction of long-term refinancing operations had an impact on the basis. To explore how these factors may be driving the basis, we use ECB proprietary data and we conduct our panel regression analysis using as control variables the bond and market risk factors previously mentioned. In addition, we study the reaction of the basis around the introduction of the ECB policy interventions to isolate the effect of such interventions using an event study analysis.

In the context of changes to the rules relating to eligibility of collateral, the ECB announced the admission of marketable debt instruments denominated in USD and other currencies to be eligible collateral in ECB credit operations on 23 October 2008, subject to an additional haircut for the exchange rate risk. This temporal change was in place until the 31 December 2010. Subsequently, the ECB announced the reintroduction of this decision on 6 September 2012. Interestingly, only some of the USD-denominated bonds in our sample were eligible because they fulfilled all the eligibility criteria and such eligibility was unpredictable by market participants.<sup>1</sup> We find that the response to the change in the eligibility criteria is a statistically significant and persistent decrease by over 20 bps in the basis of bond pairs that include eligible USD-denominated bonds, while we don't find any effect on the pairs that include rejected USD-denominated bonds. The

---

<sup>1</sup>The ECB publishes the list of eligible assets on a daily basis.

impact on the basis is substantial when compared with Ashcraft, Garleanu and Pedersen (2010) who examine empirically the impact of the introduction of the Term Asset-Backed Securities Loan Facility (TALF) lending facility, studying the reaction of market prices by considering the price response to unpredictable bond rejection from the TALF programme. They measure a temporary decrease of 5 bps in the yield spread for the eligible TALF securities, but a statistically significant rise in the yield spread by over 20 bps for the rejection.

Second, we study the effect of the sovereign debt collateral pledged at the ECB in exchange of liquidity using information on the nominal value of all sovereign bonds pledged to the ECB for the countries under study. We find that the size of the basis of a country significantly widens when the same country experiences periods of market stress. The size of the basis for a country is strongly positively related to the amount of sovereign bonds pledged to the ECB, when the credit default swap (CDS) of the same country reaches extreme levels. This is the case for Italy and Spain over the period August 2011 - May 2012. We find that an increase of a 1% of the sovereign debt collateral pledged at the ECB divided by the total outstanding nominal amount of the sovereign debt during distress periods widens the basis approximately by 3.18 bps. Thus, our results suggest that the ECB liquidity facility was priced widening the basis for these countries in times of increased sovereign credit spreads.

Third, we focus on the effect of the sovereign debt collateral pledged at the ECB in exchange of liquidity during the 3-year LTROs that consist of 3-year collateralized loan. We find that the size of the basis is strongly positively related to the amount of sovereign bonds pledged to the ECB in the context of 3-year operations. Specifically, we find that an increase of a 1% of the sovereign debt collateral pledged at the ECB during 3-year LTROs divided by the total outstanding nominal amount of the sovereign debt widens the basis approximately by 2.66 bps. Since only EUR-denominated bonds could be pledged to the ECB in exchange of liquidity for a very long horizon that was not available in private repo market, our results indicate that the widening of the basis reflects the funding premium that EUR-denominated bonds embedded during this non-standard measure. Consistent with these findings, when we study the reaction of the basis at the announcement of the 3-year LTROs, we find a statistically significant increase in the basis by over 60 bps.

As a robustness check, we use the basis based on USD- and EUR-denominated bonds issued by Turkey as a control group to further assess the impact of the ECB liquidity facilities on the basis of the euro area countries under study. Since Turkish bonds could not be pledged to the ECB in exchange of liquidity, we use the Turkey's weekly average basis across the bond pairs to control for factors that affected all bond markets at the same time. Our results are not affected by this exercise.

Finally, we also evaluate the impact of the Security Market Programme (SMP) activated by the ECB to intervene in the secondary markets of public and private EUR-

denominated debt securities markets. The creation of the SMP is related to the Greek debt crisis, which triggered later the sovereign debt crisis in the rest of the continent. Since the SMP targeted public and private EUR-denominated debt securities, we expect a widening of the basis around purchases. The main innovation of our paper is to analyze ECB bond purchases at the level of daily individual bonds purchases instead of focusing on benchmark yields (see Ghysels, Idier, Manganelli and Vergote (2013) and Eser and Schwaab (2013)). Moreover, our empirical design based on pairs of EUR- and USD-denominated bonds helps us to clearly identify the impact of purchases because the USD-denominated bonds were explicitly not targeted by the ECB. We focus our attention on the reactivation of the SMP in August 2011 for the Italian and Spanish sovereign debt markets. When we use information on individual bond purchases, we find that, over time, a Euro 1 billion of individual bond purchases on average widens the basis by 27.24 bps. The results indicate that SMP purchases of the targeted EUR-denominated sovereign bonds significantly widen the basis, in particular when the targeted EUR-denominated bonds belong to bond pairs of our analysis. Our event study findings suggest that the interventions had a large but temporary impact on the price of individual sovereign bonds of the targeted countries, Italy and Spain.

This paper contributes to two streams of literature. The first stream relates to “limits to arbitrage” theories (see Shleifer and Vishny (1997)) who study the economic determinants for observed deviations of the law of one price.<sup>2</sup> Within this literature, there are several recent empirical papers, to whom our paper is related, that document large price anomalies: the CDS-bond basis by Bai and Collin-Dufresne (2013), the US TIPS-Treasury bond puzzle by Fleckenstein, Longstaff and Lustig (2013), the impact of FX market liquidity on arbitrage trading by Mancini, Ranaldo and Wrampelmeyer (2013), and the relative mis-pricing of pairs of emerging market sovereign bonds issued in both dollars and euros by Buraschi, Sener and Menguturk (2014). Our paper is more directly related to the latter one. However, the crucial difference between Buraschi, Sener and Menguturk (2014) paper and our paper is the main findings. While our findings are consistent with their results in the *pre* euro area sovereign debt crisis period, we document that the intensification of the euro area sovereign debt crisis impacted further on the size of the basis and significant differences emerged across the countries. Thus, our unique and novel data allow us to directly link the basis evolution with the amount of the sovereign debt collateral pledged to the ECB in exchange of liquidity.

We also contribute to the recent literature on the role played by the non-standard monetary policy measures implemented by the central banks through the lending facil-

---

<sup>2</sup>Shleifer and Vishny (1997) discuss how limited availability of risk capital by arbitrageurs leads to persistent deviations of the law of one price when an initial price shock occurs. There are several lines of research, that depart from this seminal paper, who study different sources of frictions that can cause these deviations as (i) short selling restrictions; (ii) funding cost and collateral margins; (iii) institutional and regulatory frictions; and (iv) trading liquidity.

ities.<sup>3</sup> Ashcraft, Garleanu and Pedersen (2010) discuss how the central bank’s lending facilities lowering margin requirements can increase asset prices in crises by offering loans and easing funding constraints in the banking sector. The results are consistent with the theoretical predictions of Garleanu and Pedersen (2011) who show that margin differences lead to basis between securities with (nearly) identical cash flows during times of funding illiquidity. Drechsler, Drechsel, Marques-Ibanez and Schnabl (2013) document that European banks, which borrowed heavily, also pledged increasingly risky collateral to the ECB suggesting that the ECB’s liquidity facility was used for risk-shifting due to the lower haircuts. Acharya and Steffen (2013) document that under-capitalized banks in the peripheral countries used the ECB’s LTRO to increase their exposure to risky domestic bonds, thus tightening the feedback loop between banks and sovereigns. Finally, Nagel, Krishnamurthy and Vissing-Jorgensen (2013) find that ECB actions have been successful in lowering government bond yields, in particular in reducing the solvency risk and in mitigating market segmentation, but they abstract from the role the ECB liquidity facilities and collateral policy played during the euro area sovereign debt crisis.

The paper is organized as follows. In Section 2, we describe the euro area sovereign pricing anomaly that is the focus of our paper. Section 3 describes the data. Section 4 discusses the empirical strategy, while we study the determinants of the basis and investigates the effects of ECB’s policy interventions on the basis in Section 5. Section 6 concludes.

## 2 Pricing Anomaly

### 2.1 The Arbitrage Strategy

We proceed by first describing the USD- and EUR-denominated bond arbitrage strategy. We study deviations between the yield to maturity of bonds issued by the same Euro area sovereign countries in EUR and in a foreign currency. As foreign-currency bonds issued in USD are relatively common among Euro area countries and are also in general relatively actively traded, we restrict our analysis to USD-denominated bonds exclusively.

---

<sup>3</sup>We also shed light on the impact of central banks purchases on the markets for sovereign bonds contributing to a recent and growing literature that has analyzed the effects of SMP on sovereign bond yields. De Pooter, Martin and Pruitt (2013) find that weekly ECB purchases had the desired effect of lowering liquidity premia, but such reduction was mainly temporary. Eser and Schwaab (2013) find that SMP purchases have contributed effectively in lowering yields bonds and the impact is stronger in markets which are smaller, less liquid, and where risk premia were higher. Ghysels, Idier, Manganelli and Vergote (2013) analyze the high-frequency dynamics of bond yields and purchases. Their empirical investigation reveals that SMP purchases have contributed to reducing the volatility of targeted bond yields. Trebesch and Zettelmeyer (2013) back out the ECB’s purchases of Greek bonds in the SMP in 2010, using the fact that the ECB did not participate in the Greek debt exchange of March 2012. They find that bonds bought by the ECB show a much larger drop in yields after the start of the SMP. Overall, their findings support the view that the interventions had a large local impact on the price of individual sovereign bonds.

We select five euro area sovereign countries: Austria, Belgium, Finland, Italy, and Spain. We focus on fixed-rate coupon bonds denominated in USD, issued after 1999 and traded on a daily basis. Next, for every single USD-denominated bond we select a comparable EUR-denominated bond in terms of issuer, issue date and maturity and create a list of pair bonds.

In order to exploit the pricing anomaly, we assume traders convert the USD-denominated bond into a synthetic EUR-denominated bond by means of a cross-currency asset swap. Baba and Sakurai (2011) note that due to the long term horizon in bond cash-flows, cross-currency basis swaps have been used as a tool for converting currencies of the liabilities, particularly by issuers of bonds denominated in foreign currencies. Nevertheless, there are alternative ways to convert cash-flows from USD to EUR. One possibility is to use the forward market to hedge each cash-flow. Because forward contracts become less liquid beyond one year, the use of forward market does not result appropriate due to the length of the cash-flows we are interested in. This is also reinforced by the largely documented fact that the covered interest parity (CIP) that equates the return on domestic currency with a full hedged foreign currency return holds under short term maturities. For longer maturities, the CIP is violated. As a result, the difference in the term structure of the credit spreads of two different countries and the currency basis swap are needed in order to hedge foreign currency denominated cash-flows. Alternatively, Tuckman and Porfidio (2003) propose a strategy to create an adjusted forward rate that takes into account violations of the CIP in the long run on the basis of the spot exchange rate, the local and foreign LIBOR and the cross-currency basis.<sup>4</sup>

Figure 2 depicts the trading strategy to convert the bond denominated in USD into a synthetic bond denominated in EUR. This strategy involves buying a cross currency asset swap package to exchange the fixed coupons of the USD-denominated bond at the Euribor rate plus a spread, the cross currency spread or cross currency basis, and getting into a floating-fixed interest rate swap to exchange the EUR-denominated stream of floating inflow into a fixed coupon rate. At initiation, the buyer receives the USD-denominated bond in exchange of its cash price valued in EUR at the spot price. Additionally, the trader has to pay/receive an upfront payment to compensate for any premium or discount paid for the USD-denominated bond. This upfront payment ensures that the net position created by the cross currency asset swap package is the same as a USD-denominated bond issued at par. On coupon dates, the buyer pays the coupon of the USD-denominated bond ( $C_t^{USD}$ ) and receives the Euribor rate plus the cross currency spread. By means of the floating-fixed interest rate swap, this floating cash-flow is exchanged at a fixed-rate EUR-denominated coupon ( $C_t^{EUR}$ ). On maturity date, the buyer pays the redemption amount

---

<sup>4</sup>This strategy presents a lot of similarities with the one implemented in this paper, in the sense that both are based on a combination of a currency swap and an interest rate swap. However, this strategy is very costly to implement in our context because we need to enter in a combination of currency swaps and interest rate swap to discount every single cash-flow of a bond.

of the USD-denominated bond and receives the swapped redemption amount in EUR at the spot price. By getting into this strategy, we create a synthetic fixed-rate coupon EUR-denominated bond. We estimate the yield to maturity by applying standard bond valuation techniques.

[INSERT FIGURE 2 HERE]

Subsequently, we estimate the yield to maturity ( $\widehat{Y}_{i,t}^{USD \rightarrow EUR}$ ) of that synthetic bond for the pair  $i$  at time  $t$ . To conclude, we define the basis for every matched-pair bond as the difference between the yield to maturity of the synthetic bond and the yield to maturity of the bond denominated in EUR ( $Y_{i,t}^{EUR}$ ):

$$Basis_{i,t} = \widehat{Y}_{i,t}^{USD \rightarrow EUR} - Y_{i,t}^{EUR}. \quad (1)$$

One contribution of this paper is to deal with the mismatch in coupon rates and payment dates between bonds and swaps and to document that other less precise alternatives have a substantial impact on the calculation of the basis affecting the level and the dynamics of the basis itself (see Appendix A).<sup>5</sup>

## 2.2 The Evolution of the Pricing Anomaly

Figure 3 depicts the weekly average basis, the yield to maturity of the EUR-denominated ( $Y_t^{EUR}$ ) and of the synthetic EUR-denominated ( $\widehat{Y}_{i,t}^{USD \rightarrow EUR}$ ) bond across the bond pairs at country level from January 2006 to February 2013. Apart from the five European countries, the last panel refers to Turkey in order to highlight the similarities and differences in the behavior of both yields across sub-periods. At the first glance, we observe a large and persistent difference between both yields that is common across all countries, where the yield of the synthetic EUR-denominated bond is almost systematically higher than the yield of EUR-denominated bond. And hence, for most of the sample period we observe that the USD-denominated bonds trade cheaper than the comparable bond denominated in Euro.

[INSERT FIGURE 3 HERE]

At the beginning of the sample period we observe tiny differences between both yields being the average basis close to zero. Between the Lehman Brothers collapse and March 2009, we observe a generalized increase of the basis that is common across the five European countries and Turkey. The finding is consistent with Buraschi, Sener and Menguturk (2014), who find that USD-denominated bonds issued by Turkey traded at a cheaper level than the EUR-denominated bonds over the same time period. Over this period, the weekly

---

<sup>5</sup>The existing literature that applies cross currency swap directly subtracts par swap rates from yields on coupon bearing bonds not necessarily traded at par.

average basis across the bond pairs for Italy reached 152 bps, while the basis for Austria, Belgium and Spain reached 68 bps, 56 bps and 67 bps.

There are several reasons why one might expect the basis to be positive and to become even more positive during strongly distressed periods. Because natural buyers of euro area sovereign bonds are the European banks, three main factors make holding USD-denominated euro area sovereign bonds unattractive for them. First, at the beginning of the financial crisis, USD-denominated bonds were not accepted as eligible collateral under the terms of the ECB liquidity facilities. On 23 October 2008, in the context of the non-standard monetary policy measures, the list of assets accepted as eligible collateral was extended to further ease access to ECB operations in an attempt to reduce asset-side constraints on banks' balance-sheets. The ECB announced the admission of marketable debt instruments denominated in USD, the pound sterling and the Japanese yen, and issued and held in the Euro area, to be eligible collateral in ECB credit operations. This temporal change was in place until the 31 December 2010.<sup>6</sup> However, USD-denominated bonds have an additional haircut in comparison to the EUR-denominated and USD-denominated bonds do not systematically fulfill other eligibility criteria as the one related to area to be held and settled. Second, under Basel rules, EUR-denominated domestic sovereign bonds have zero capital weightings for domestic banks, while the USD-denominated domestic sovereign bonds do not, so holding these bonds would incur capital charges (see Acharya, Engle and Pierret (2013)). Third, an additional margin is required in a repo operation, when an European bank finances holdings of USD-denominated bonds.

After that period both yields depict a downward trend and the basis drops but its level is above the observed at the beginning of the sample period. At the beginning of 2010, the activation of the Security Market Programme (SMP) by the ECB is seen as the official start of the sovereign debt crisis in the euro area with the Greek debt crisis, which triggered the sovereign debt crisis for Ireland and Portugal and later for Italy and Spain in August 2011. The program was designed to intervene in the secondary markets of public and private EUR-denominated debt securities markets. This period is also characterized by the activation of a set of non-standard measures by the ECB such as the first 3-year LTRO on December 2011 and the second one on February 2012, whose objective was to provide liquidity for a very long horizon that was not available in the private repo market. However, only EUR-denominated bonds could be pledged as collateral to the ECB in exchange for this liquidity.

During this period, both sovereign yields skyrocket mainly in Italy and Spain reaching a peak in December 2011. Hereafter, the yields perform a constant downward trend. We observe a large and persistent basis in all European countries, in particular the basis widened for countries whose sustainability of fiscal positions became a concern for market

---

<sup>6</sup>Subsequently, the ECB announced the reintroduction of this decision on 6 September 2012 in order to maintain the access to the ECB liquidity-providing operations.

investors. Over the period December 2011 - March 2012 the weekly average basis across the bond pairs for Austria reached 93 bps, while the basis for Belgium, Italy and Spain reached 199 bps, 152 bps and 402 bps. Interestingly, the basis of Turkey remains unaffected by this turmoil. Overall, this supports the idea that will be tested in the following sections that the ECB interventions generated asymmetries between those ex-ante comparable bonds and explain these large and persistent pricing anomalies.

## 3 Data and Variables

The datasets for this paper consist of daily sovereign bond prices collected from Bloomberg and ECB proprietary data on all sovereign bond purchases made by the ECB under the SMP programme and all euro area sovereign collateral pledged to the ECB from 2008 to 2013. Additionally, following the more recent “limits to arbitrage” literature we include in the analysis information on the lending activity and market and political risk factors collected from Data Explorers and Datastream, respectively.

### 3.1 Bond and Pair Characteristics

We focus on all European Monetary Union (EMU) countries that issue fixed-rate coupon bonds denominated in US Dollars (USD). Using information from Dealogic database we select all bonds issued in USD before 1999 and with maturity after 2008. For those bonds we find a comparable bond denominated in euro in terms of the same issuer, similar issue date and maturity. We rule out those USD-denominated bonds for which we do not find a comparable EUR-denominated bond.

#### 3.1.1 Bond Data

Bond level information is gathered from Bloomberg. We retrieve daily bid, mid and ask prices and yields as weighted averages based on the number of sources who price at 2nd and 3rd best pricing levels among the qualifying deals (Bloomberg CBBT).<sup>7</sup> When these prices are not available, we use the Bloomberg BGN, a weighted average of the quotes contributed to Bloomberg by a minimum of five brokers and dealers, and as a last source, we use Bloomberg BVAL prices which provide a theoretical price of the bond. The sample covers information about five EMU countries: Austria, Belgium, Finland, Italy, and Spain for which we use 47 fixed-rate coupon bonds of which 25 are USD- and 22 EUR-denominated. The Appendix B reports the information about the 55 specific bonds. As a robustness check, we also construct the basis for the Turkish sovereign bonds using 8 fixed-rate coupon bonds (4 USD- and 4 EUR-denominated).

---

<sup>7</sup>CBBT requires at least three executable pricing sources with prices and size on both sides on the market. Prices must be within five minutes.

To control for the liquidity of the bonds, we define the  $Bid - Ask Spread_{i,j,t}$  as difference between the bid-ask spread in the USD- and EUR-denominated bonds and proxies the relative illiquidity of the EUR-denominated bond.

### 3.1.2 Pair Characteristics

Our sample is composed of 25 different pairs belonging to the five countries under analysis. Table 1 reports the main characteristics of these pairs. The first two columns report the starting and the last day in the sample. In order to avoid systematic convergence in the basis around the maturity date due to the convergence of the price to the face value, we rule out the last year of the bond life. Therefore, a bond that matures in May 2012 is only considered in the sample until May 2011.

[INSERT TABLE 1 HERE]

The third column reports the country that issued the pair under study. The most active country is Italy with 10 out of the 25 pairs in sample and thus represents a large part of our sample. Spain and Austria have 5 pairs each, followed by Belgium (3) and Finland (2).

The fourth column reports the average basis, which is consistently positive for all pairs and over the whole sample period. Focusing on those pairs that cover most of the sample we observe that on average Italy, Spain and to lower extent Belgium have larger deviations than in Austria and Finland, but these bases are on average higher than 25 bps for all pairs. We also report the relative size of the USD-denominated bond to its EUR-denominated comparable bond in the fifth column. We observe that the outstanding amount of the EUR-denominated bond is significantly larger, ranging from the 5% to the 22%. However, the minimum size we observe in the sample for a USD-denominated bond is above 600 million which means that although smaller, USD-denominated bonds are sizable.

The last column refers to the governing law of the USD-denominated bonds given that all EUR-denominated bonds are issued under the local law. We observe that Austria, Finland and Spain issue USD-denominated debt under English law and Belgium under local law. Italy is the only country issuing under different regimes. It issues most of the USD-denominated bonds under the New York legislation as well as issuing under local and English law. We also control by other bond specific covenants such as *negative pledge* and *cross default clauses* which could potentially explain differences across comparable bonds.

### 3.1.3 Lending Activity

Bond level information is complemented with information about lending activity provided by Data Explorers. Although security lending activity is not a direct measure of

short selling activity, it is a proxy commonly used in the limits to arbitrage literature. To short a bond, an investor must first borrow the bond through a secured loan where the owner of the bond lends the bond to the investor at some market determined rate.

We explore the effect of two variables: *No. of Transactions* and *Fees*. The *No. of Transactions* refers to the number of open securities lending transactions on a specific bond. On average, we observe 21 and 14 daily open lending transactions on the EUR- and USD-denominated bonds respectively. The *Fees* denotes the daily average fee for borrowing a specific bond. We observe that the average fee is around 43 (48) basis points for EUR-denominated (USD-denominated) bonds during our sample.

## 3.2 Currency Swaps

## 3.3 Risk Factors

In order to control for the potential impact of risk factors on the basis we include a set of global and country-specific market risk factors and a news-based policy uncertainty index on the euro area.

Quanto Credit Default Swaps (*Quanto CDS<sub>j,t</sub>*) refers to the differential of CDSs on the same underlying, but quoted in different currencies. According to Ehlers and Shönbucher (2006), the *Quanto CDS<sub>j,t</sub>* is defined as one minus the ratio between the average EUR-denominated CDS spread and the average USD-denominated CDS spread capturing the expected devaluation of the Euro relative to the USD conditional on the country's default. We consider EUR- and USD-denominated CDS spreads with maturities of 6m, 1y, 2y, 3y, 4y, 5y, 7y, 10y, 20y and 30y to compute the *Quanto CDS<sub>j,t</sub>*. Thus, the *Quanto CDS* captures the correlation between creditworthiness of the euro area sovereign  $j$  and the value of euro currency against the dollar.

We use the spread between the sovereign specific Eurepo general collateral rate 3-month and the OIS both EUR-denominated (*Eurepo<sub>j,t</sub> - OIS*) to control for the funding risk, since eurozone funding markets are increasingly dependent on collateralized rather than unsecured loans.<sup>8</sup> Due to the increased riskiness of its sovereign collateral, the repo rates of Italian and Spanish collateral have been diverging from the ones of Germany and France since July 2011. On the other hand, OIS is equivalent to the average of the overnight interest rates expected until maturity and is almost riskless. Thus, the *Eurepo - OIS* spread over the same term quantifies the premium that banks pay when borrowing collateralized funds for a pre-determined period relative to the expected interest cost from a repeatedly rolling over funding in the overnight market.<sup>9</sup>

Information referring to global risk is represented by the implied volatility index

---

<sup>8</sup>A repo is a sale of a security coupled with an agreement to repurchase the same security at a specified price in exchange of liquidity that is remunerated at the general collateral rate.

<sup>9</sup>Information on the country specific Eurepo general collateral rate is collected from the European Banking Association (EBA).

( $VIX_t$ ) from the Chicago Board Options Exchange (CBOE) which is obtained from Datastream. This index captures the expected volatility and volatility risk premium (Bai and Collin-Dufresne (2013)) and it is a good proxy for the global risk factor (Lustig, Roussanov and Verdelhan (2011)).

To proxy the economic uncertainty at European level we use the Economic Policy Uncertainty index proposed by Baker, Bloom and Davis (2013) ( $EPI_t$ ). To measure European policy-related economic uncertainty, the authors construct an index from two types of underlying components: newspaper coverage of policy-related economic uncertainty and disagreement among economic forecasters uncertainty.<sup>10</sup>

### 3.4 ECB Data

#### 3.4.1 *ECB Liquidity Facility and Collateral Management*

In line with central bank practice, the ECB requires counterparties to pledge collateral in exchange of liquidity. The collateral has to satisfy eligibility criteria regarding the type of assets, credit standards, place of issue, type of issuer, currency, asset marketability and other characteristics which are applied uniformly across the Euro area.

USD- and EUR-denominated bonds from the same issuer are treated differently. Differences can be summarized as follows: (i) USD-denominated bonds are not eligible during the whole sample period of our study;<sup>11</sup> (ii) USD-denominated bonds are subject to an additional haircut of 8% due to the currency risk; and (iii) USD-denominated bonds do not systematically fulfill the eligibility criteria as the ones related to area to be held and settled.

The ECB collateral management procedure collects with a weekly frequency information at bond level from the National Central Banks (NCBs), who are also responsible for submitting information to the ECB on eligible assets listed in their respective national markets. Our data contains the nominal amount and the market value before and after the application of the haircuts of all individual sovereign bonds pledged to the ECB. We compute the total nominal amount of sovereign bonds held by the ECB at country level. We scale these amounts by the total nominal sovereign debt outstanding by each country ( $Sov. Collateral_{j,t}$  to  $Tot. Sov. Debt_{j,t}$ ) in order to account for the proportion of the total debt that is actually pledged to the ECB.

#### 3.4.2 *Securities Market Programme (SMP)*

The ECB launched the securities market programme (SMP) in May 2010. This programme consisted in purchasing debt securities in the open market and remaining them

---

<sup>10</sup>This variable is available available at <http://www.policyuncertainty.com/index.html>.

<sup>11</sup>The ECB admitted US dollars, pounds sterling or Japanese yen as eligible collateral subject to the fulfillment of the relevant eligibility criteria from the 25th of October 2008 to the 31st of December 2009 and from the 9th of November 2012 onwards.

on the balance sheet of the ECB up to the payment of all the cash flows of the securities (hold-to-maturity strategy). Some distinctive features of this programme are related in particular to the disclosure of the composition of the portfolio. The ECB did not disclose the total amounts which would be spent, the time frame over which the program would be active, or the set of securities that would be targeted. Data on the outstanding value of the holding portfolio were only published weekly without any reference to the time during the week when the securities had been bought. Moreover, the ECB did not provide a breakdown describing the composition of assets by national origin of issuance. On 21 February 2013, the ECB provided details on securities holdings acquired under the programme revealing a country-by-country breakdown. Italian debt accounts for roughly half of the total: 103 billion Euros (\$136 billion) out of 218 billion Euros.<sup>12</sup>

Figure 5 plots the accumulated book value over time. Clearly, purchases are not evenly spread out over time. The largest purchases occurred after the introduction of the SMP on 10 May 2010 in the context of the central bank reactions to the Greek debt crisis and after its reactivation on 8 August 2011 for the Italian and Spanish sovereign bond market. The chart also suggests that there have been long periods during which the SMP has been open but inactive. From the week ending in 25 March 2011 until 8 August 2011 the SMP was inactive for 19 weeks. Purchases stopped on January 2012.

[INSERT FIGURE 4 HERE]

We include the SMP information in three different ways: we use data on (i) weekly public available purchases ( $SMP_t$ ); (ii) weekly purchases at country level ( $SMP_{j,t}$ ); and (iii) weekly purchases at pair level ( $SMP_{i,j,t}$ ). Purchases at pair level refer to the weekly purchases of the EUR-denominated bonds given that only EUR-denominated bonds were targeted.

## 4 Empirical Strategy

Our empirical strategy seeks to identify the main drivers of the basis. We first evaluate to what extent factors established in the “limit to arbitrage” literature help to explain the previously documented basis on Section 2.2 by means of the following panel regression analysis:

$$\text{Basis}_{i,j,t} = \alpha + \delta_j + \beta_1 \times \text{Bond Factors} + \beta_2 \times \text{Risk Factors} + \varepsilon_{i,j,t}, \quad (2)$$

where the dependent variable is the estimated basis for each pair  $i$  and  $j$  refers to the issuer country. *Bond Factors* is a matrix that contains pair-specific information about the bond liquidity, lending activity and bond covenants. Following the definition of the

---

<sup>12</sup>Spain ranks second, with 44 billion euros of its debt purchased by the Euro area’s central bank, followed by Greece (34 billion Euros), Portugal (23 billion Euros) and Ireland (14 billion Euros).

basis, we construct pair-specific information as the difference between the USD- and the EUR-related variables. *Risk Factors* is matrix that contains country and global market risk factors and the euro area Economic Policy Uncertainty index. We employ a Prais-Winsten regression with country fixed-effects  $\delta_j$ , correlated panels, corrected standard errors (PCSEs) and robust to heteroskedasticity, contemporaneous correlation across panels and serial autocorrelation within panels. The correlation within panels is treated as a first-order autocorrelation AR(1) and the coefficient of this process is common to all the panels.

We divide the period January 2008 - February 2013 into two main subsamples: a *pre* euro area sovereign debt crisis period that starts on January 1, 2008 and ends on May 9, 2010, and a euro area sovereign debt crisis period starting on May 10, 2010. The beginning of the later period coincides with the activation of the SMP.

To assess the impact of the ECB policy actions on the basis we employ information relative to the ECB liquidity facility and collateral management and to the SMP. Figure 5 depicts a time line of the main ECB policy actions understudy in this paper.

[INSERT FIGURE 5 HERE]

First, we study to what extent the ECB liquidity facility and collateral management policy explain the time-varying evolution of the basis in the context of the European sovereign debt crisis. We study the impact of those factors individually through the following weekly panel regression analysis:

$$\begin{aligned} \text{Basis}_{i,j,t} = & \alpha + \delta_j + \beta_1 \times \text{Bond Factors} + \beta_2 \times \text{Risk Factors} \\ & + \beta_3 \times \text{ECB Collateral Factors} + \varepsilon_{i,j,t}, \end{aligned} \quad (3)$$

where *ECB Collateral Factors* account for three different factors: (i) changes in eligibility criteria; (ii) the amount of sovereign collateral pledged to the ECB in exchange of liquidity; and (iii) the introduction of the 3-year long term refinancing operations.

Besides panel data estimation, we also use an event study methodology to test for the effect of the ECB intervention over a window of 56 (8 weeks) days before and 56 after the intervention date. Compared to panel data estimation, this method has the advantage of focusing on a time interval in which the effects of the intervention should be less clouded by confounding factors. Thus, we conduct the following daily panel regression analysis

$$\text{Basis}_{i,j,t} = \alpha + \delta_i + \delta_j + \delta_t + \beta \times \text{Dum. After} + \varepsilon_{i,j,t}, \quad (4)$$

including pair, country and time fixed-effects. *Dum. After* is a matrix that contains four dummy variables. The first one is 1 for a window of two weeks after the event under study and zero otherwise, the second one is 1 from the third to the fourth week and zero otherwise and so on. This decomposition of the after event period allows us to evaluate the size and the persistence of the policy action on the basis.

Finally, we evaluate the impact of the SMP on the basis by means of a panel regression analysis as in Equation (3) and an event study analysis around the reactivation of the SMP for the Italian and Spanish sovereign market in August 2011.

## 5 What Drives the Pricing Anomaly?

### 5.1 Bond Information and Market Factors

Table 2 reports the estimates of Equation (2). The first column contains the result for the whole sample period while columns (2) and (3) report the results for the *pre* euro area sovereign debt and euro area sovereign debt crisis sub-periods.

[INSERT TABLE 2 HERE]

In general terms, USD-denominated bonds present wider bid-ask spreads (i.e., they are generally more illiquid) and hence, the *Bid – Ask Spread* $_{i,j,t}$  is most of the time positive. We document that as the illiquidity of the EUR-denominated bonds gets closer to illiquidity of the USD-denominated bond, the basis decreases by 3.887 bps. Thus, differences in the relative illiquidity explain the widening of the basis: the larger the differences in the relative illiquidity, the wider the basis. Additionally, this effect is only significant during the euro area sovereign debt crisis period.

We next study the role of the lending activities on the basis by means of the *No. Transactions* $_{i,j,t}$  and *Fees* $_{i,j,t}$  variables. We systematically observe that EUR-denominated bonds are expensive in comparison to the comparable USD-denominated bond, which is consistent with Buraschi, Sener and Menguturk (2014). In order to exploit this anomaly, we expect traders to buy cheap (USD-denominated) and short-sell expensive (EUR-denominated) in such a way that relative increases of the number of transactions or of the lending cost of the EUR-denominated bonds should decrease the basis. However, the empirical results do not support this possible explanation. On the contrary, we find that an increase in the relative number of transactions of the EUR-denominated bonds (i.e., *No. Transactions* $_{i,j,t}$  becomes more negative) significantly widens the basis. Additionally, we observe that this effect is only significant during the euro area sovereign debt crisis period. Interestingly, we were advised in private conversations with practitioners that the increase of lending activity of EUR-denominated bonds is likely to be related to the increasing demand of collateral securities that could be pledged by banks to the ECB in exchange of liquidity. This would support the existence of a monetary funding premium in the EUR-denominated bonds that will be discussed in the next section.

Then, we study whether the bond covenants could explain the pricing anomaly. We consider two dummies related to the law jurisdictions: *England Law* $_{i,j}$  takes 1 when a USD-denominated bond is issued under that the UK law and *NY Law* $_{i,j}$  takes 1 when a USD-denominated bond is issued under the New York law. In addition, we control

for additional covenants in the USD-denominated bond in the dummy called *Additional Clauses*.<sup>13</sup> We expect to have a larger basis for those pairs issued under the local law than in those pairs issued under international laws, because the sovereign bond issued under international laws should guarantee a higher recovery rate in case of sovereign default. In fact, we find that the basis is on average smaller when the USD-denominated bond is issued under the New York law, in both sub-periods, suggesting that a USD-denominated bond issued under New York law is more attractive than a comparable USD-denominated bond issued under the local law.<sup>14</sup> However, this effect is not supported across jurisdictions by the data due to the fact that countries tend to issue under the same law jurisdiction and so it is very hard to disentangle the law and country effect.

We then address the impact of the country and global market factors. The *Quanto CDS* has been used as a proxy of the expected devaluation of the Euro relative to the USD, conditional on the country's default (see Ehlers and Shönbucher (2006)). Thus, buying EUR-denominated CDS is a less attractive hedge, as the value of that protection is likely to diminish as the referenced sovereign approaches default. According to this definition, we would expect that the *Quanto CDS* has a negative impact on the basis because, as the expected devaluation increases, USD-denominated bonds should become more attractive than EUR-denominated bonds. Nevertheless, we do not find empirical support to this economic intuition. On the contrary, we find a positive and significant effect of the *Quanto CDS*<sub>*j,t*</sub>. Buraschi, Sener and Menguturk (2014) argue that the Quanto CDS contracts gained great popularity during the 2010 euro area sovereign debt crisis, as market participants feared a substantial devaluation of the euro as a consequence of the default of one of its member countries. Before 2010, however, expected devaluation values were close to zero and the Quanto CDS prices were then trading at only a few basis points. Interestingly, we were advised in private conversations with practitioners that the liquidity in Quanto CDS has been fairly limited and investors' demand for Quanto CDS was the defining factor in Quanto CDS pricing. In particular, the main source of supply stemmed from credit-linked notes, where investors buy government bonds and sell the relevant CDS to enhance the yield. In this instance, having an exact profile match between the currency of the bond and the CDS was preferable for investors.

The development of the secured market funding has dramatically changed during the crisis. According to Hördahl and King (2008), during the first part of the crisis, the Eurepo-OIS spread was marginally affected in the Euro area, and subsequently moved upwards as the crisis progressed due to a combination of factors. In the *pre* euro area

---

<sup>13</sup>*Negative pledge* and *cross default clauses* are two covenants that appear simultaneously in some of the USD-denominated bonds so we control by them in one variable called "Additional Clauses" that takes 1 when the USD-denominated bond is issued under those covenants.

<sup>14</sup>Choi, Gulati and Posner (2011) document that the yield premium of the Greek sovereign debt governed by local law versus foreign law was discernible before November 2009 but then increased, reaching a peak of 400 bps, as the news about Greece's financial state emerged and the probability of a restructuring increased.

sovereign debt crisis period, we observe that increases in the  $Eurepo - OIS Spread_{j,t}$  significantly widen the basis, suggesting that the shift from unsecured to secured funding made EUR-denominated bonds more attractive than USD denominated bonds, because the latter ones are subject to an additional haircut in repo transactions due to the currency risk. Instead, in the euro area sovereign debt crisis period, we observe that decreases in the Eurepo activity significantly increase the basis. In this period, secured funding in the Euro area was affected by several factors. Large increases were observed of the interest rates on repos, general collateral rates, for countries under market stress affecting the bank funding. In addition, the repo market experienced a large decline in its activity due to the effect of the ECB's 3-year LTROs (see Mancini, Ranaldo and Wrampelmeyer (2013b)).

We also control by a global risk factor proxies by the  $VIX_t$ . We find that increases in the global risk significantly tighten the basis during the second period while it is not significant during the first one. This finding suggests that increases in the basis are due to the country or regional specific situations and global shocks affect both bonds in a similar way do not increasing the asymmetry between them. Finally, we find that the increase of the policy uncertainty index ( $EPI_t$ ) in the Euro area significantly widens the basis.

Overall, the bond and risk factors affect the basis, but they are not able to provide a fully satisfactory explanation of the existence of these arbitrage opportunities. In particular, these factors play a limited role during the euro area sovereign debt crisis period, when the size of the basis on average widens and significant differences emerged across the countries. In fact, the  $R^2$  of our regressions fairly drops from 33.8% (*pre* euro area sovereign debt crisis ) to 10.5% (euro area sovereign debt crisis).

## 5.2 The role of the ECB

In the previous sub-section, we document that the relative illiquidity, the lending activities and the market and political risk factors significantly affect the basis. Moreover, these results also support the idea that the ECB interventions might have played a role to explain the relation between USD- and EUR-denominated comparable sovereign bonds. In this section we explore this impact according to the empirical strategy discussed in Section 4.

### 5.2.1 ECB Liquidity Facility and Collateral Management

In this subsection, we study the impact of the liquidity facilities provided by the ECB in exchange of liquidity. In order to disentangle this effect we focus on three different aspects: (i) changes in the eligibility criteria; (ii) the amount of sovereign debt collateral pledged at the ECB; and (iii) the introduction of the 3y-LTROs.

Table 3 reports the results for the changes in the eligibility criteria. Panel A shows

the results of Equation (3) where we introduce two dummies that is 1 during the first and the second eligibility windows (*1st Eligibility Window<sub>t</sub>* and *2nd Eligibility Window<sub>t</sub>*, respectively). The *1st Eligibility Window* refers to the changes to the rules announced on 23 October 2008 and implemented on 14 November 2008. This temporal change was in place until the 31 December 2010. Subsequently, the ECB announced the reintroduction of this decision on 6 September 2012 (*2nd Eligibility Window*) with effect on 9 November 2012. Additionally, we interact these variables with a dummy that is 1 for those pairs where the USD-denominated bonds fulfill all the eligibility criteria that were unpredictable by market participants on the announcement of the intervention.

[INSERT TABLE 3 HERE]

We find that the basis of those eligible pairs is statistically lower than the ones of non-eligible pairs by 11 and 23 bps during the first and the second eligibility windows, respectively. In addition, Panel B reports the results of Equation (4) in which we conduct the event study analysis around the implementation date of the changes in the eligibility criteria. Consistently with the previous findings, we document that the basis of those eligible pairs is statistically lower than the one of non-eligible pairs after the introduction of the first eligibility window (column (1)), and the impact is persistent over time.

Figure 6 shows the estimated response of the basis to being the USD-denominated bond eligible or rejected around the introduction of the changes in the eligibility criteria on 14 November 2008. This figure illustrates our event study estimates by plotting the cross-sectional averages for the eligible USD-denominated pair group (blue line) and the no eligible USD-denominated pair group (green line) minus their respective pre-event average mean over time. The dashed lines indicate the sub-period averages for pre event, 2 weeks after the event, 4 weeks after the event, 6 weeks after the event and 8 weeks after the event. The initial response of the basis is reduced to 3 bps over the first 2 weeks, but it is not significant (see Table 3). The larger effect is registered after the third week and is persistent. It could be due to price pressure associated with selling of no-eligible USD-denominated bonds by investors who would only hold the bonds if they could pledge the bond to the ECB.

[INSERT FIGURE 6 HERE]

However, the impact of the second change of the eligible criteria (column (2)) seems to be weaker and non-persistent, probably due to an anticipation effect from the market. The announcement was made on September 2012 but with effect on 9 November 2012. Overall, these findings support the idea that the possibility of being pledged to the ECB in exchange of liquidity is priced on the eligible bonds by the market. So, the fact that only EUR-denominated bonds can be pledged to the ECB in exchange of liquidity generates

an asymmetry between EUR- and USD-bond represented on the basis, that is mitigated after the expansion of the list of eligible assets to the USD-denominated bonds.

We next investigate the effect of the sovereign debt collateral pledge at the ECB in exchange of liquidity and how this effect varies depending on the country default risk. To that aim we run the Equation (3) including the variable  $Sov. Collateral_{j,t}$  to  $Tot. Sov. Debt_{j,t}$  that captures the proportion of the total sovereign debt that is actually pledged at the ECB. Results are reported in Table 4. We find that during non-distress periods the level of sovereign collateral pledged at the ECB does not play a significant role. To investigate the effect during distress periods, we interact this variable with a dummy that takes 1 when the CDS of the same country reaches extreme levels (i.e., the CDS is above the 90th percentile). We find that an increase of a 1% of the sovereign debt collateral pledged at the ECB divided by the nominal total outstanding amount of the sovereign debt during distress periods widens the basis approximately by 3.89 bps. The fact that the  $Sov. Collateral_{j,t}$  to  $Tot. Sov. Debt_{j,t} \times Dum. High CDS_{j,t}$  variable obtains a positive and significant effect supports the idea that the ECB liquidity facility was priced on the EUR-denominated bonds widening the basis for these countries in strong distress.

[INSERT TABLE 4 HERE]

Finally, we study the impact of the 3-year LTROs. As we described in section 3.3, in the context of exceptional circumstances the ECB launched the 3-year long term refinancing operations (3-year LTROs) in order to provide longer-term refinancing to the banking sector. Concretely, the 3-year LTROs provided EUR 489 billion on 21 December 2011 in three years loans and EUR 523 billion on 29 February 2012, aiming in supporting the provision of bank lending to the economy and reducing banks' funding risk. In line with the findings on the eligibility criteria we expect the 3-year LTRO to have an impact on the basis because of the unique opportunity provided by the ECB to get liquidity under better conditions than those that prevail on the market.

Panel A of Table 5 reports the estimation of Equation (3), where in order to capture the difference in the spirit of the regular operations and the 3-year LTRO, we interact the  $Sov. Collateral$  to  $Tot. Sov. Debt_{j,t}$  variable with a dummy variable that is 1 in the implementation weeks of the 3-year LTROs. We find that an increase of a 1% of the sovereign debt collateral pledged at the ECB during 3-year LTROs divided by the nominal total outstanding amount of the sovereign debt widens the basis approximately by 3.14 bps. The fact that the  $Sov. Collateral_{j,t}$  to  $Tot. Sov. Debt_{j,t} \times Dum. 3y - LTRO_t$  variable obtains a positive and significant effect reflects the funding premium that the EUR-denominated bonds embedded during the implementation of the non-standard measures. Additionally, Panel B reports the results of the event study analysis around the announcement date of the 3-year LTROs. In line with the previous findings, we document

a positive and significant effect of the announcement of the 3–year LTRO which persists over time.

[INSERT TABLE 5 HERE]

### 5.2.2 Securities Market Programme (SMP)

As discussed in section 3.3.2, we consider the SMP information in three different ways: we use data on (1) weekly public available purchases ( $SMP_t$ ); (2) weekly purchases at country level ( $SMP_{j,t}$ ); and (3) weekly purchases at pair level ( $SMP_{i,j,t}$ ). The sample starts in May 2010 coinciding with the launch of the programme. Since the SMP targeted public and private EUR-denominated debt securities, we expect a widening of the basis around purchases.

Panel A of Table 6 reports the estimation of Equation (3) using the SMP information at different disaggregate levels. We find that over time a Euro 1 billion of bond purchases on average widens the basis of 2.55 bps (see column (2)). Interestingly, when we estimate the same specification using information on individual bond purchases, we find that over time a Euro 1 billion of individual bond purchases on average widens the basis of 27.24 bps (see column (3)). Our results indicate that SMP purchases of the targeted EUR-denominated sovereign bonds significantly widen the basis, in particular when the EUR-denominated bonds targeted by the program belong to the bond pairs of our analysis. This finding suggests that the interventions had a large impact on the price of individual sovereign bonds.

[INSERT TABLE 6 HERE]

In addition we conduct an event study analysis around the reactivation of the SMP in August 2011 in order to disentangle the impact on the targeted countries. The announcement date is 7 August 2011 when an ECBs press release stated “*The Governing Council of the European Central Bank (ECB) welcomes the announcements made by the governments of Italy and Spain concerning new measures and reforms in the areas of fiscal and structural policies. ... It is on the basis of the above assessments that the ECB will actively implement its Securities Markets Programme. This programme has been designed to help restoring a better transmission of our monetary policy decisions - taking account of dysfunctional market segments - and therefore to ensure price stability in the euro area.*”

We estimate the event study Equation (4) adding the dummy variable Dum. Target Countries that is 1 when the country  $j$  is Italy or Spain. In line with the previous findings (see Panel B of Table 6), we document a positive and significant impact of the SMP on the basis of the targeted countries which persists over time during the subsequent purchases in the following weeks.

### 5.2.3 A Robustness Check

Finally, in order to highlight the impact of the ECB liquidity facilities on the basis we estimate Equation (3) using as dependent variable the difference between the estimated basis of each pair and the average basis of Turkey  $\text{Basis}_{i,j,t} - \overline{\text{Basis Turkey}}_t$ . Since sovereign bonds issued by Turkey cannot be pledged to the ECB in exchange of liquidity, this difference allows us to control for factors that affected all bonds at the same time. Table 7 reports the results. Column (1) reports the estimates on the collateral eligibility, column (2) on the amounts of sovereign collateral pledged to the ECB and column (3) reports the impact of the 3-year LTROs. The results are consistent with the ones reported in the baseline specification. So, our findings support the existence of the funding liquidity premium that is priced during period of special distress.

[INSERT TABLE 7 HERE]

## 6 Conclusions

In this paper, we document the occurrence of a large pricing anomaly in the euro area sovereign bond market between 2008 – 2013. A large yield spread, a basis, developed between EUR- and USD-denominated comparable bonds issued by the same country. USD-denominated bonds became substantially cheaper (higher yield-to-maturity) than those denominated in euro, once the foreign exchange rate risk is hedged in the USD-EUR currency swap market.

The existence of these large and persistent pricing anomalies are not fully explained by the traditional channels used in the limits-to arbitrage literature such as time-varying funding costs affecting capital, short selling constraints and liquidity risk. Apart from these factors, we find that country specific factors help to explain cross-sectional differences in the basis.

Overall, our results suggest that the ECB liquidity facilities and non-standard monetary policy measures play a key role in explaining the basis. Because EUR-denominated bonds could be used as collateral for liquidity operations with the ECB at lower haircuts, a monetary funding premium is embedded in these bonds yields. Moreover, this funding premium might also vary over time, depending on credit spreads of sovereign issuer, on the one hand, and the collateral policy and the liquidity supply conditions determined by the ECB policy stance, on the other.

Further investigation is needed to shed light on the role played by the ECB liquidity facilities and non-standard monetary policy measures. A thorough analysis of the impact of these actions would also require detailed information on banks' collateral policy. In fact, the monetary funding premium might also depend on banks' funding needs. We plan to address these issues in the next version of this paper.

## References

- Acharya, V., R. Engle, and D. Pierret, (2013). Testing macroprudential stress tests: The risk of regulatory risk weights. NBER Working Paper No. 18968.
- Acharya, V., and S. Steffen (2013). The “Greatest” Carry trade ever? Understanding Eurozone bank risks. NBER Working Paper No. 19039.
- Aschcraft, A., N. B. Garleanu, and L.H. Pedersen (2010). Two monetary tools: Interest rates and haircuts. NBER Macroeconomics Annual.
- Baba, N., and Y. Sakurai (2011). When and how US dollar shortages evolved into the full crisis? Evidence from the cross-currency swap market. *Journal of Banking & Finance* 35, 1450–1463.
- Bai, J., and P. Collin-Dufresne (2013). The Determinants of the CDS-bond basis during the financial crisis of 2007-2009. Working paper, Federal Reserve Bank of New York.
- Baker, S.R., N. Bloom, and S.J. Davis (2013). Measuring economic policy uncertainty. Chicago Booth Research Paper No. 13-02.
- Brunnermeier, M., and L., Pedersen (2013). Market liquidity and funding liquidity. Review of Financial Studies, vol. 22, No. 6, pp. 2201-2238.
- Buraschi, A., E. Sener and M. Mengütürk (2014). The geography of risk capital and limits to arbitrage. Fama-Miller Center Papers, N. 13-44.
- Choi, S.J., M. Gulati, and E.A. Posner (2011). Pricing terms in sovereign debt contracts: a Greek case study with implications for the European crisis resolution mechanism. *Capital Markets Law Journal* 6, 163–187.
- Darracq-Paries, M., and R. De Santis (2013). A non-standard monetary policy shock: The ECB’s 3-Year LTROs and the shift in credit supply. Working paper, European Central Bank No. 1508.
- De Pooter, M., R. F., Martin, and S. Pruitt (2013). The effects of official bond market intervention in Europe. Federal Reserve Board, Working paper.
- Drechsler, I., T. Drechsel, D. Marques-Ibanez, P. Schnabl (2013). Who borrows from the Lender of Last Resort? University of New York, Working paper.
- Ehlers P., and P. Schönbucher (2006). The influence of FX risk on credit spreads. ETZ Zurich, Working paper.
- Eser F., and B. Schwaab (2013). Assessing asset purchases within ECB’s Securities Markets Programme. ECB Working Paper No. 1587.
- Fleckenstein, M., A. Longstaff and H. Lustig (2013). The TIPS-Treasury bond puzzle. Forthcoming Journal of Finance.

- Garleanu, N. B., and L.H. Pedersen (2011). Margin-based asset pricing and the law of one price. *Review of Financial Studies*, vol. 24, no. 6, pp. 1980-2022.
- Ghysels E., J. Idier, S. Manganelli, O. Vergote (2013). A high frequency assessment of the ECB Securities Markets Programme. CEPR Discussion Paper No. DP9778.
- Habib, M. M and M. Joy (2010) Foreign-currency bonds: currency choice and the role of uncovered and covered interest parity. *Applied Financial Economics*, 20, 601–626.
- Hördahl, P., and M. King (2008). Developments in repo markets during the financial turmoil. *Bank for International Settlements Quarterly Review* (December), 37–53.
- Lustig, H., N. Roussanov, and A. Verdelhan (2011). Common risk factors in currency markets. *Review of Financial Studies*, 24, 3731–3777.
- Mancini, L., A. Ranaldo, and J. Wrampelmeyer (2013). Liquidity in the foreign exchange market: measurement, commonality, and risk premiums. Forthcoming in *Journal of Finance*.
- Mancini, L., A. Ranaldo, and J. Wrampelmeyer (2013b). The Euro interbank repo market. University of St. Gallen, Working paper.
- Nagel, S., A., Krishnamurthy, and A., Vissing-Jorgensen (2013). ECB policies involving government bond purchases: Impact and channels. Haas Business School, University of California, Working paper.
- Sheifer, A., and R., Vishny (1997). The limits of arbitrage. *Journal of Finance*, Vol. 52, No. 1, pp.35-55.
- Trebesch, C., and J., Zettelmeyer (2013). ECB interventions in distressed sovereign debt markets: The case of Greek bonds. University of Munich, Working paper.
- Tuckman B., and P. Porfidio (2003). Interest rate parity, money market basis swaps, and cross-currency basis swaps. *Fixed Income Research, Lehman Brothers*.

# Figures

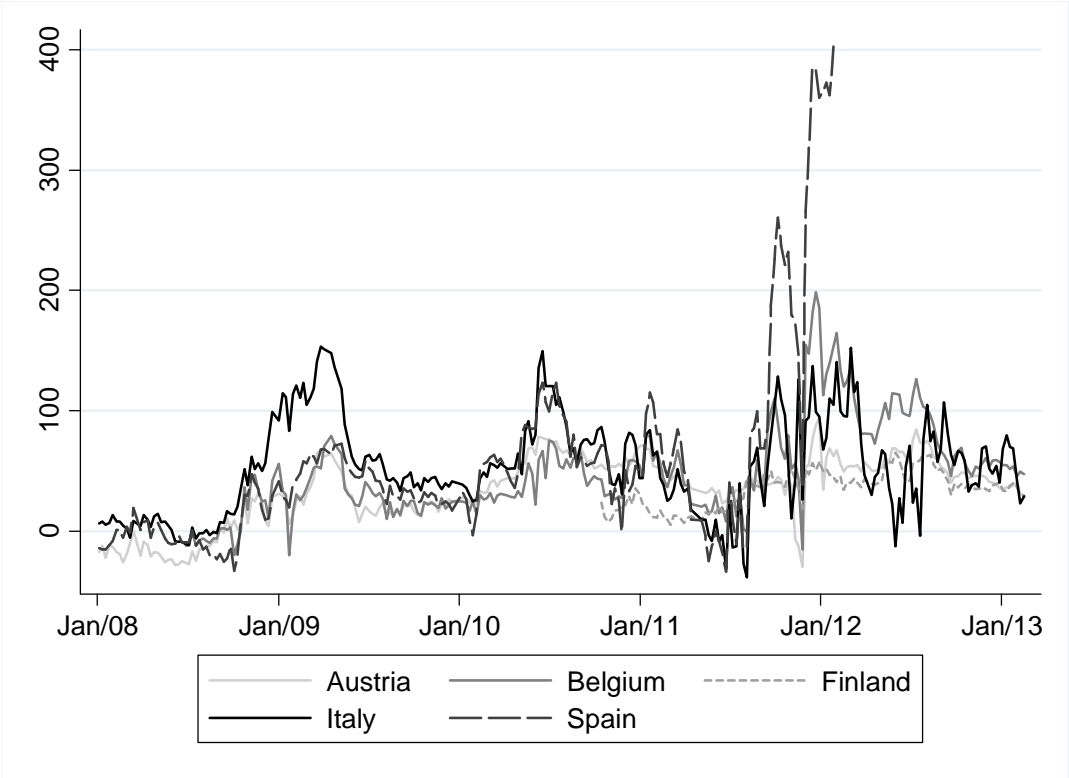


Figure 1: This figure depicts the average basis across pair bonds of the five considered countries: Austria, Belgium, Finland, Italy and Spain. For every bond pair, the basis is defined as the difference between the yield to maturity of the USD-denominated bond after the conversion of the bond cash flows from US-Dollar to Euro ( $\hat{Y}_{i,t}^{USD \rightarrow EUR}$ ) and the EUR-denominated bond ( $Y_{i,t}^{EUR}$ ). The sample spans from January 2008 to February 2013. Bases are reported on weekly basis and measured on basis points.

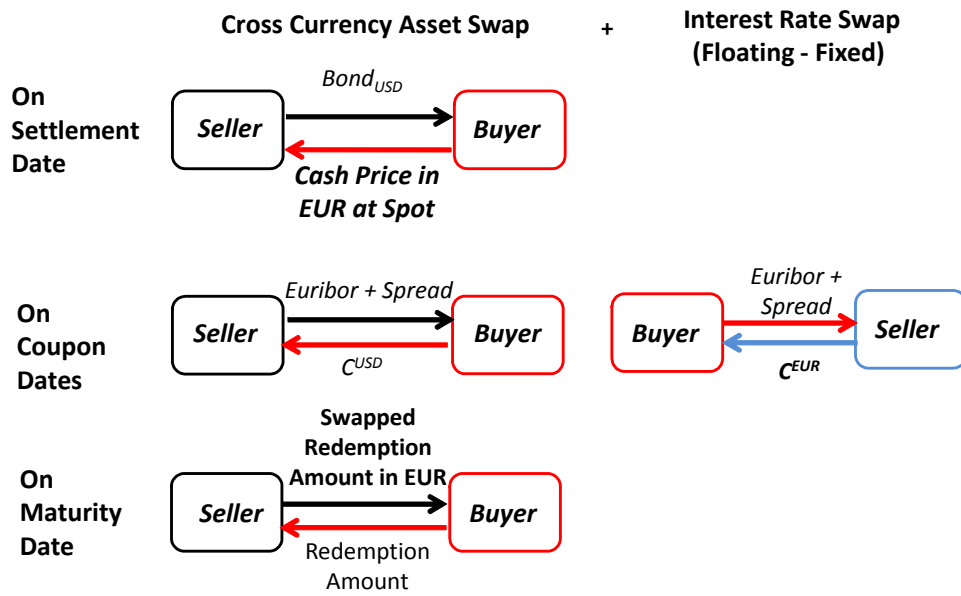


Figure 2: This figure depicts the trading strategy to convert the bond denominated in USD into a synthetic bond denominated in EUR. This strategy involves buying a cross currency asset swap package to exchange the fixed coupons of the USD-denominated bond at the Euribor rate plus a spread and getting into a floating-fixed interest rate swap to exchange that EUR-denominated stream of floating inflow into a fixed coupon rate.

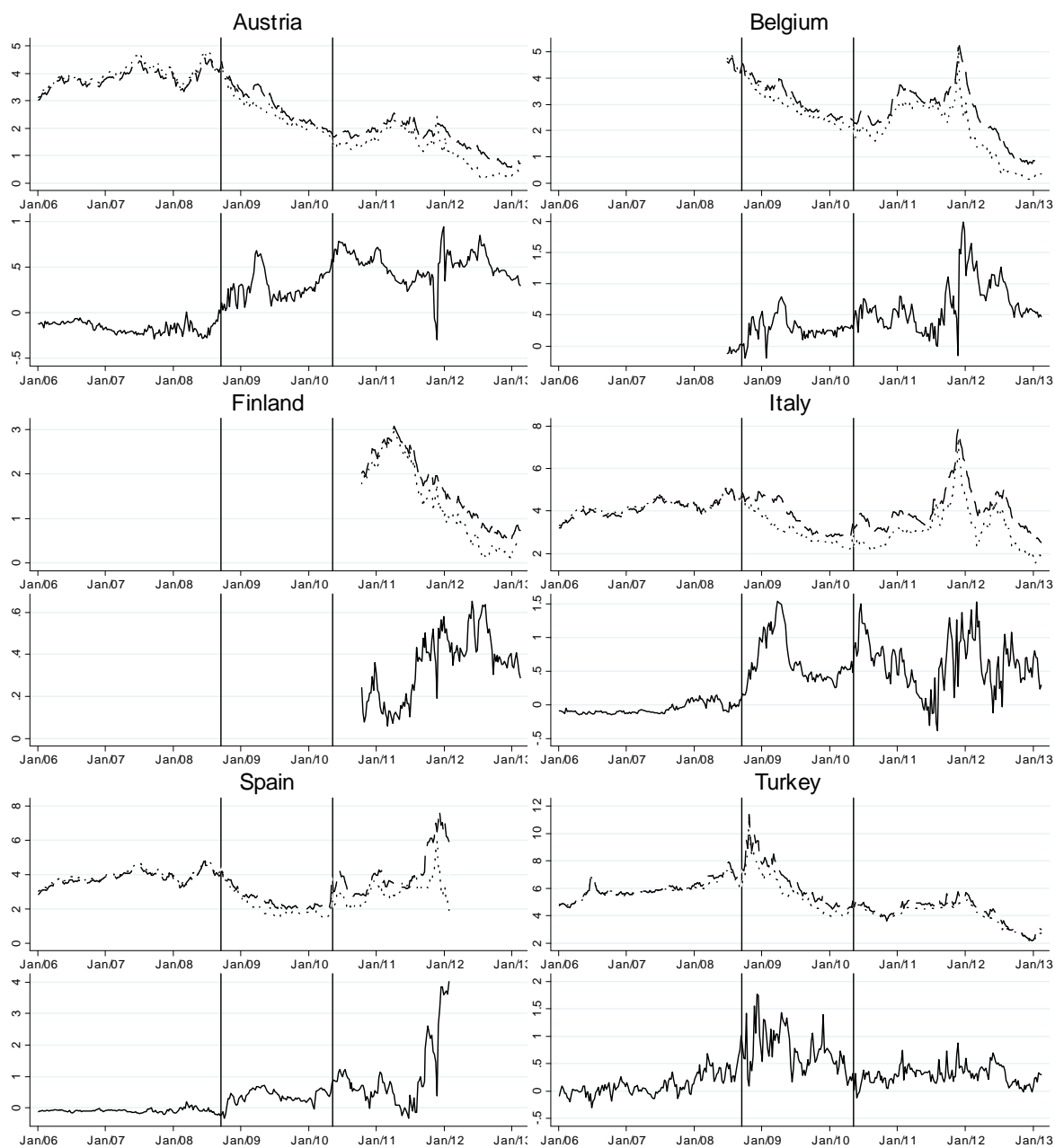


Figure 3: This figure shows the average yield to maturity of the USD-denominated bonds ( $\hat{Y}_{i,t}^{USD \rightarrow EUR}$ ), the EUR-denominated ( $Y^{EUR}$ ) and the average basis, defined as the difference between those yields. For every country in the sample, the upper panel contains the average yield of the EUR-denominated bonds (dot line) and the average yield of the USD-denominated bonds after converting the cash flows in EUR (dashed line). The bottom panel contains the average basis, which is the dependent variable in our analysis. The sample spans from January 2006 to February 2013 and the y-axis is measured in percentage. Vertical lines refer to the Lehman Brothers collapse (September 2008) and the starting date of the Securities Market Programme (May 2010).

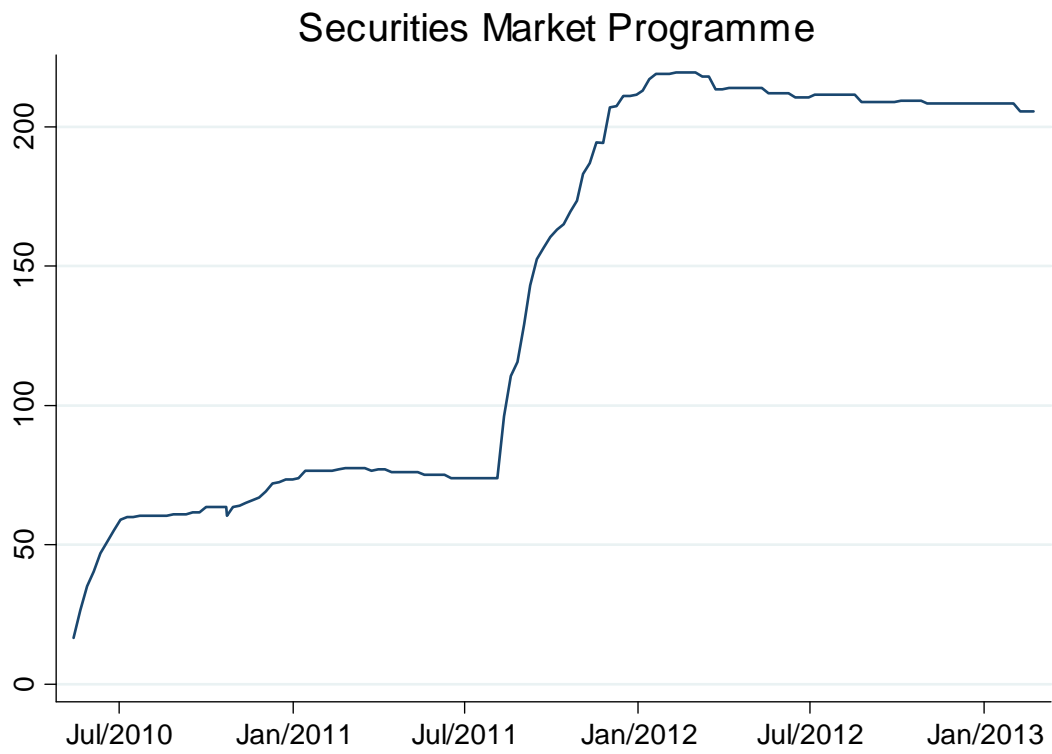


Figure 4: This figure depicts the publicly available information of the Securities Market Programme (SMP). It contains the accumulated book value in EUR billion corresponding to the SMP.

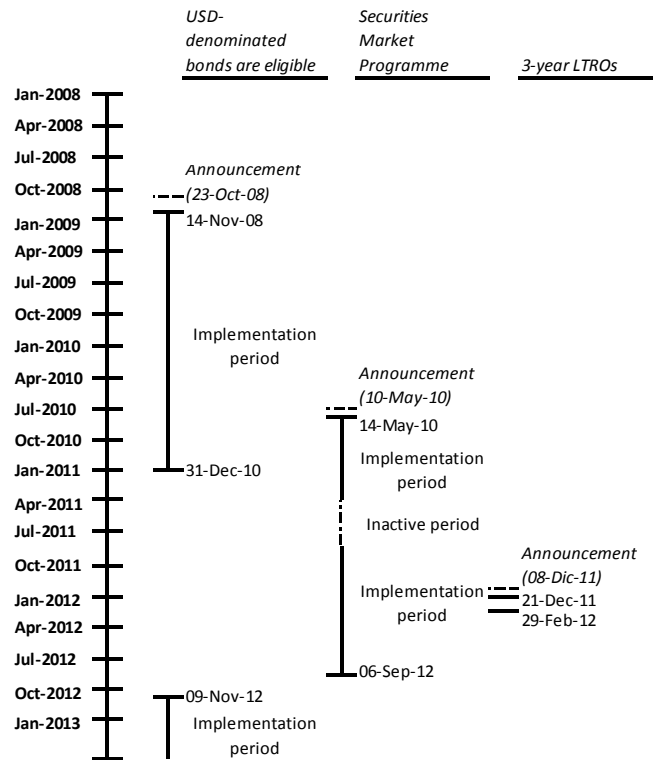


Figure 5: This figure depicts a time line of the ECB interventions under study. The first column refers to the windows during which USD-denominated bonds were eligible as collateral at the ECB; Columns (2) reports the Securities Market Programme (SMP); Column (3) presents the 3-year Long Term Refinancing Operations (3y-LTROs).

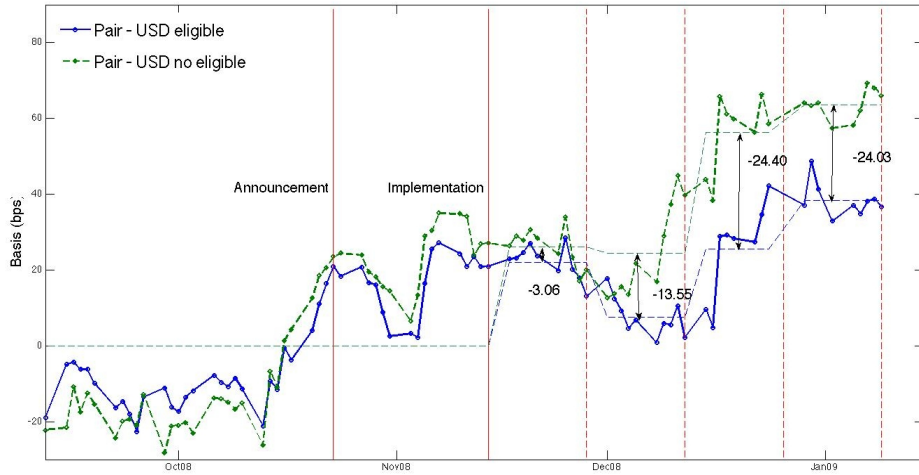


Figure 6: This figure illustrates our event study estimates by plotting the cross-sectional averages for the eligible USD-denominated pair group (blue line) and the no eligible USD-denominated pair group (green line) minus their respective pre-event average mean over time. The dashed lines indicate the sub-period averages for pre event, 2 weeks after the event, 4 weeks after the event, 6 weeks after the event and 8 weeks after the event. We report the coefficient estimates “Dum. After<sub>t</sub> x Eligible Pairs<sub>i,j</sub>” in the graph.

## Tables

Table 1: This table reports the main descriptive statistics at pair bond level. We report the starting and ending date in sample, country, mean basis during the sample period, the ratio between the amount outstanding in USD- and EUR-denominated bonds and the governing law of the USD-denominated (bonds EUR-denominated are issued under the local law).

<i>Starting</i>	<i>End</i>	<i>Country</i>	<i>Mean Basis</i>	<i>Ration Am. Out</i>	<i>Gov. Law USD</i>
11/Jul/08	31/Aug/12	Belgium	39.07	0.10	Local
18/Sep/09	15/Feb/13	Belgium	96.38	0.05	Local
9/Apr/10	15/Feb/13	Belgium	37.43	0.15	Local
18/May/07	17/Jul/09	Spain	18.35	0.05	England
16/May/08	27/Jan/12	Spain	79.84	0.09	England
22/May/09	30/Apr/10	Spain	41.28	0.08	England
13/Mar/09	4/Mar/11	Spain	53.34	0.07	England
8/Jan/10	16/Sep/11	Spain	8.59	0.11	England
18/May/07	22/Jun/12	Austria	25.76	0.20	England
18/May/07	15/Feb/13	Austria	31.34	0.10	England
18/May/07	25/Mar/11	Austria	21.81	0.09	England
25/Sep/09	15/Jul/11	Austria	50.98	0.10	England
24/Jun/11	15/Feb/13	Austria	24.17	0.07	England
22/Oct/10	15/Feb/13	Finland	33.90	0.22	England
18/Mar/11	15/Feb/13	Finland	40.14	0.22	England
3/Sep/10	4/Feb/11	Italy	100.95	0.12	New York
18/May/07	15/Jun/12	Italy	27.32	0.08	New York
18/May/07	15/Feb/13	Italy	37.21	0.14	New York
18/May/07	15/Feb/13	Italy	73.05	0.06	New York
18/May/07	15/Feb/13	Italy	60.72	0.09	Local
15/Jun/07	15/Feb/13	Italy	75.85	0.06	England
12/Sep/08	16/Jul/10	Italy	37.46	0.09	New York
22/Jan/10	7/Oct/11	Italy	30.56	0.09	New York
5/Feb/10	15/Feb/13	Italy	26.35	0.09	New York
26/Nov/10	14/Sep/12	Italy	4.89	0.09	New York

Table 2: This table reports the estimation of Equation (2) in which we study the impact of the Bond Information and Market Factors on the basis. We employ a Prais-Winsten regression with country fixed-effects, correlated panel, corrected standard errors and robust to heterokedasticity and contemporaneous correlation across panels and serial autocorrelation within panels. The correlation within panels is treated as a first-order autocorrelation AR(1) and the coefficient of this process ( $\rho$ ) is common to all the panels. Bond Information refers pair-specific information about the bond liquidity (Bid-Ask Spread), lending activity (Fees and No. Transaction) and bond covenants (Dum. England Law, Dum. NY Law and Dum. Additional Clauses). Following the definition of the basis, we construct pair-specific information as the difference between the USD- and the EUR-related variables. Market Factors refers to the Quanto CDS, Euro-OIS Spread, VIX and the European Policy Uncertainty (EPI). The sample spans from January 2008 to February 2013 and it is composed of 25 pairs of bonds that belong to 5 European countries. Column (1) refers to the whole sample. Columns (2) and (3) refer to the "Pre European Sovereign Debt" and "European Sovereign Debt" crisis period, respectively.  $j$  denotes country specific variable and  $i, j$  denotes bond specific variable. The regression is conducted on weekly basis.

	(1)	(2)	(3)
Bid-Ask Spread $_{i,j,t}$	3.887*** (1.459)	13.543*** (3.303)	2.880 (1.804)
Fees $_{i,j,t}$	-42.427 (128.488)	110.725 (101.342)	-22.218 (174.239)
No. Transactions $_{i,j,t}$	-0.187*** (0.057)	-0.022 (0.053)	-0.271*** (0.083)
Dum. England Law $_{i,j}$	19.387* (10.119)	12.064 (8.616)	26.718* (14.437)
Dum. NY Law $_{i,j}$	-24.539*** (8.432)	-18.294*** (6.837)	-23.972** (11.712)
Dum. Additional Clauses $_{i,j}$	1.549 (7.408)	-1.522 (5.377)	-1.077 (10.509)
Quanto CDS $_{j,t}$	75.978*** (6.803)	68.460*** (8.471)	69.439*** (9.742)
Eurepo-OIS $_{j,t}$	6.805 (9.136)	56.012*** (8.320)	-73.102*** (15.106)
VIX $_t$	-0.368*** (0.079)	-0.044 (0.069)	-0.982*** (0.145)
EPI $_t$	0.527*** (0.040)	0.539*** (0.039)	0.510*** (0.057)
Constant	-69.442*** (12.026)	-69.803*** (10.565)	-64.606*** (17.705)
$\rho$	0.836	0.829	0.807
Num. Obs.	3763	1470	2293
$R^2$	0.110	0.338	0.105

$t$  statistics in parentheses  
\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Table 3: This table shows the impact of changes in the eligibility criteria. Panel A reports the estimation of Equation (3) where we conduct a panel regression analysis using the whole sample period on weekly basis. 1st Eligibility Window and 2nd Eligibility Window are two dummies that take 1 during the first and the second eligibility windows. Eligible Pair is a dummy that takes 1 for those pairs where the USD bonds are eligible. Panel B report the estimation of Equation (4) where we conduct an event study around the first and second implementation dates of the changes in the eligibility (reported in columns (1) and (2), respectively). We consider a window of 8 weeks before and after the event. We break down the after period in four dummies that takes 1 in windows of two weeks. The regression is conducted on daily basis. In the estimations we employ a Prais-Winsten regression correlated panel, corrected standard errors and robust to heterokedasticity and contemporaneous correlation across panels and serial autocorrelation within panels. The correlation within panels is treated as AR(1) and the coefficient of this process ( $\rho$ ) is common to all the panels.  $i,j$  denotes bond specific variable.

Panel A		(1)	
1st Eligibility Window $_t$		21.758*** (4.001)	
2nd Eligibility Window $_t$		18.859*** (6.497)	
Eligible Pair $_{i,j}$		24.586*** (7.842)	
1st Eligibility Window $_t$ x Eligible Pair $_{i,j}$		-11.484** (4.862)	
2nd Eligibility Window $_t$ x Eligible Pair $_{i,j}$		-22.786** (9.403)	
Constant		-100.338*** (13.817)	
Country FE		Yes	
Other Control Variables		Yes	
$\rho$		0.823	
Num. Obs.		3763	
$R^2$		0.128	
Panel B		(1)	(2)
Dum. After 1w-2w $_t$		1.058 (5.508)	-11.179*** (4.287)
Dum. After 3w-4w $_t$		-1.497 (5.572)	5.346 (4.305)
Dum. After 5w-6w $_t$		31.776*** (5.638)	-3.846 (4.308)
Dum. After 7w-8w $_t$		43.187*** (5.738)	5.401 (4.303)
Dum. After 1w-2w $_t$ x Eligible Pair $_{i,j}$		-3.066 (3.116)	4.895* (2.641)
Dum. After 3w-4w $_t$ x Eligible Pair $_{i,j}$		-13.351*** (3.472)	-4.932* (2.778)
Dum. After 5w-6w $_t$ x Eligible Pair $_{i,j}$		-24.406*** (3.806)	-3.349 (2.798)
Dum. After 7w-8w $_t$ x Eligible Pair $_{i,j}$		-24.038*** (4.268)	-2.856 (2.764)
Eligible Pair $_{i,j}$		45.447*** (4.540)	10.488*** (1.943)
Constant		-8.719 (6.199)	40.842*** (3.106)
Time FE		Yes	Yes
Country FE		Yes	Yes
Pair FE		Yes	Yes
$\rho$		0.791	0.639
Num. Obs.		1078	850
$R^2$		0.726	0.861

$t$  statistics in parentheses  
\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Table 4: This table shows the impact of the amount of sovereign debt collateral pledge at the ECB in exchange of liquidity. We report the estimation of Equation (3) where we conduct a panel regression analysis using the whole sample period on weekly basis. Sov. Collateral to Tot Sov. refers to the of the sovereign debt collateral pledged over the total nominal sovereign debt outstanding by each country. Dum. High CDS is a dummy that takes 1 when the CDS of the same country reaches extreme levels (i.e., the CDS is above the 90th percentile). The analysis is conducted on weekly basis using a Prais-Winsten regression correlated panel, corrected standard errors and robust to heterokedasticity and contemporaneous correlation across panels and serial autocorrelation within panels. The correlation within panels is treated as AR(1) and the coefficient of this process ( $\rho$ ) is common to all the panels.  $j$  denotes country specific variable.

	(1)
Sov. Collateral to Tot. Sov Debt $_{j,t}$	-48.435 (68.020)
Sov. Collateral to Tot. Sov Debt $_{j,t}$ x Dum. High CDS $_{j,t}$	289.624** (122.452)
Dum. High CDS $_{j,t}$	-32.672*** (6.198)
Constant	-72.651*** (11.782)
Country FE	Yes
Other Control Variables	Yes
$\rho$	0.829
Num. Obs.	3763
$R^2$	0.128

$t$  statistics in parentheses

\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Table 5: This table shows the impact of the 3y-LTRO. Panel A reports the estimation of Equation (3) where we conduct a panel regression analysis using the whole sample period on weekly basis. Sov. Collateral to Tot. Sov. refers to the of the sovereign debt collateral pledged over the total nominal sovereign debt outstanding by each country. Dum. 3y-LTROs is a dummy variable that takes value 1 in the implementation dates of the 3y-LTROs. Panel B report the estimation of Equation (4) where we conduct an event study around the announcement date of the 3y-LTROs. We consider a window of 8 weeks before and after the event. We break down the after period in four dummies that takes 1 in windows of two weeks. The regression is conducted on daily basis. In the estimations we employ a Prais-Winsten regression correlated panel, corrected standard errors and robust to heterokedasticity and contemporaneous correlation across panels and serial autocorrelation within panels. The correlation within panels is treated as AR(1) and the coefficient of this process ( $\rho$ ) is common to all the panels.  $j$  denotes country specific variable.

Panel A	(1)
Sov. Collateral to Tot. Sov Debt $_{j,t}$	-82.963 (67.164)
Sov. Collateral to Tot. Sov Debt $_{j,t}$ x Dum. 3y-LTROs $_{j,t}$	314.022** (131.503)
Dum. 3y-LTROs $_{j,t}$	-0.267 (4.734)
Constant	-71.566*** (11.529)
Country FE	Yes
Control Variables	Yes
$\rho$	0.826
Num. Obs.	3763
$R^2$	0.121
Panel B	(1)
Dum. After 1w-2w $_t$	28.127** (12.379)
Dum. After 3w-4w $_t$	45.728*** (12.379)
Dum. After 5w-6w $_t$	5.985 (12.379)
Dum. After 7w-8w $_t$	39.376*** (12.379)
Constant	-9.356 (9.739)
Time FE	Yes
Country FE	Yes
Pair FE	Yes
$\rho$	0.796
Num. Obs.	1231
$R^2$	0.708

$t$  statistics in parentheses  
\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Table 6: This table reports the impact of the Securities Market Programme (SMP). Panel A reports the estimation of Equation (3) where we conduct a panel regression analysis using the "European Sovereign Crisis" subsample (from May 2010 to February 2013). Column (1) reports the results using the weekly public available SMP purchases; column (2) reports the results using weekly purchases at country level; and column (3) reports the results using weekly purchases at pair level. Panel B report the estimation of Equation (4) where we conduct an event study around the reactivation of the SMP in August 2011. We consider a window of 8 weeks before and after the event. We break down the after period in four dummies that takes 1 in windows of two weeks. Target Countries is a dummy that takes 1 for Italy and Spain and zero otherwise. The regression is conducted on daily basis. In the estimations we employ a Prais-Winsten regression correlated panel, corrected standard errors and robust to heterokedasticity and contemporaneous correlation across panels and serial autocorrelation within panels. The correlation within panels is treated as AR(1) and the coefficient of this process ( $\rho$ ) is common to all the panels.  $j$  denotes country specific variable and  $i,j$  denotes bond specific variable.

Panel A	(1)	(2)	(3)
SMP <sub>t</sub>	1.926*** (0.168)		
SMP <sub>j,t</sub>		2.550*** (0.367)	
SMP <sub>i,j,t</sub>			27.245** (11.296)
Constant	-52.673*** (17.501)	-65.929*** (17.177)	-64.949*** (17.671)
Country FE	Yes	Yes	Yes
Control Variables	Yes	Yes	Yes
$\rho$	0.813	0.805	0.807
Num. Obs.	2293	2293	2293
$R^2$	0.156	0.132	0.109
Panel B	(1)		
Dum. After 1w-2w <sub>t</sub>	37.413*** (5.930)		
Dum. After 3w-4w <sub>t</sub>	36.177*** (5.944)		
Dum. After 5w-6w <sub>t</sub>	20.458*** (5.930)		
Dum. After 7w-8w <sub>t</sub>	56.019*** (5.980)		
Dum. After 1w-2w <sub>t</sub> x Target Countries <sub>j</sub>	49.266*** (4.955)		
Dum. After 3w-4w <sub>t</sub> x Target Countries <sub>j</sub>	55.745*** (5.040)		
Dum. After 5w-6w <sub>t</sub> x Target Countries <sub>j</sub>	20.388*** (4.955)		
Dum. After 7w-8w <sub>t</sub> x Target Countries <sub>j</sub>	56.727*** (5.111)		
Target Countries <sub>j</sub>	-99.275*** (6.111)		
Constant	18.668*** (6.391)		
Time FE	Yes		
Country FE	Yes		
Pair FE	Yes		
$\rho$	0.780		
Num. Obs.	1436		
$R^2$	0.768		

*t* statistics in parentheses  
\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Table 7: This table reports the estimation of Equation (5) in which we study the ECB facilities and collateral management on the new basis defined as the difference between the estimated basis of each pair and the average basis of Turkey. We employ a Prais-Winsten regression with country fixed-effects, correlated panel, corrected standard errors and robust to heterokedasticity and contemporaneous correlation across panels and serial autocorrelation within panels. The correlation within panels is treated as a first-order autocorrelation AR(1) and the coefficient of this process ( $\rho$ ) is common to all the panels. The sample spans from January 2008 to February 2013 and it is composed of 25 pairs of bonds that belong to 5 European countries. Column (1) reports the impact of changes in the eligibility criteria. 1st Eligibility Window and 2nd Eligibility Window are two dummies that take 1 during the first and the second eligibility windows. Eligible Pair is a dummy that takes 1 for those pairs where the USD bonds are eligible. Column (2) reports the effect of the sovereign debt collateral pledged at the ECB. Sov. Collateral to Tot Sov. refers to the of the sovereign debt collateral pledged over the total nominal sovereign debt outstanding by each country. Dum. High CDS is a dummy that takes 1 when the CDS of the same country reaches extreme levels (i.e., the CDS is above the 90th percentile). Column (3) reports the effect of the 3y-LTRO. Dum. 3y-LTROs is a dummy variable that takes value 1 in the implementation dates of the 3y-LTROs.  $j$  denotes country specific variable and  $i,j$  denotes bond specific variable. The regression is conducted on weekly basis.

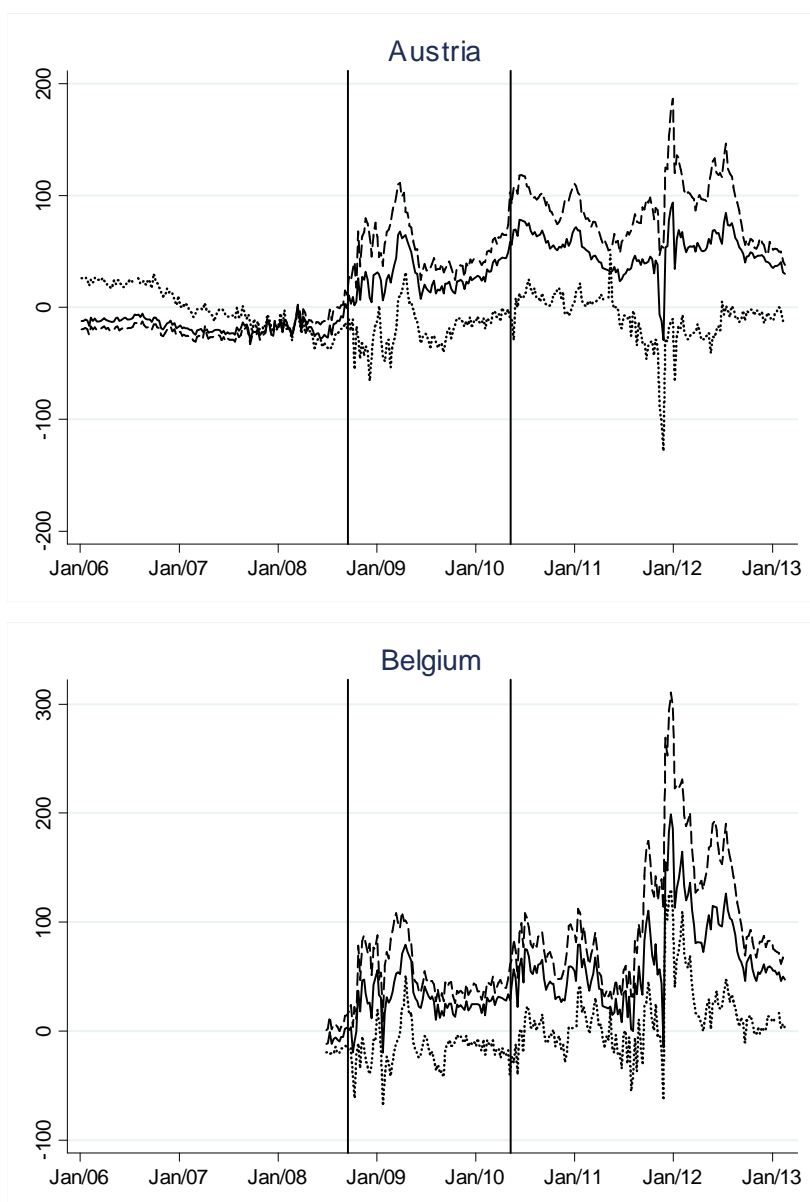
	(1)	(2)	(3)
1st Eligibility Window $_t$	11.286*** (4.366)		
2nd Eligibility Window $_t$	26.602*** (6.953)		
Eligible Pair $_{i,j}$	13.180 (10.807)		
1st Eligibility Window $_t$ x Eligible Pair $_{i,j}$	-10.957* (5.861)		
2nd Eligibility Window $_t$ x Eligible Pair $_{i,j}$	-23.668** (10.648)		
Sov. Collateral to Tot. Sov Debt $_{j,t}$		-141.717* (80.043)	-159.235** (78.683)
Sov. Collateral to Tot. Sov Debt $_{j,t}$ x Dum. High CDS $_{j,t}$		405.487*** (131.656)	
Dum. High CDS $_{j,t}$		-39.891*** (6.665)	
Sov. Collateral to Tot. Sov Debt $_{j,t}$ x Dum. 3y-LTRO $_t$			297.494** (146.528)
Dum. 3y-LTROs $_{j,t}$			-3.348 (5.759)
Constant	-151.062*** (16.556)	-135.501*** (13.325)	-133.845*** (13.073)
Country FE	Yes	Yes	Yes
Control Variables	Yes	Yes	Yes
$\rho$	0.818	0.832	0.829
Num. Obs.	3763	3763	3763
$R^2$	0.115	0.118	0.108

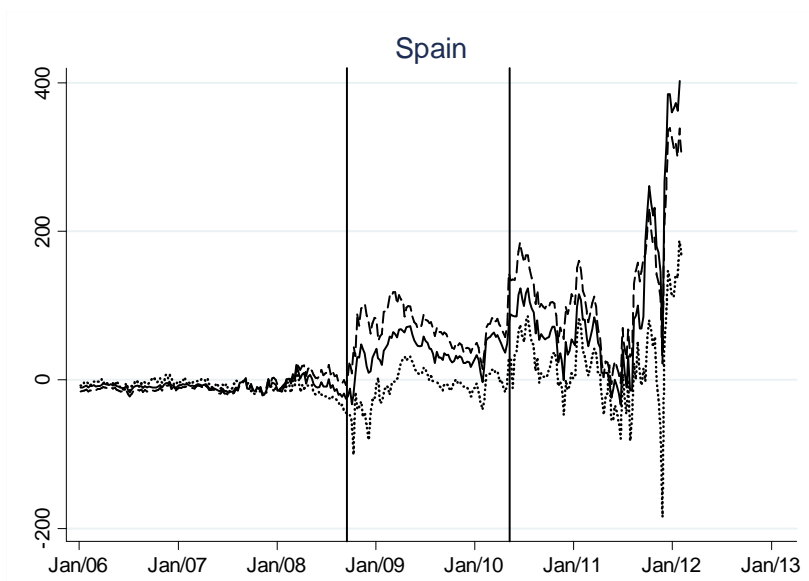
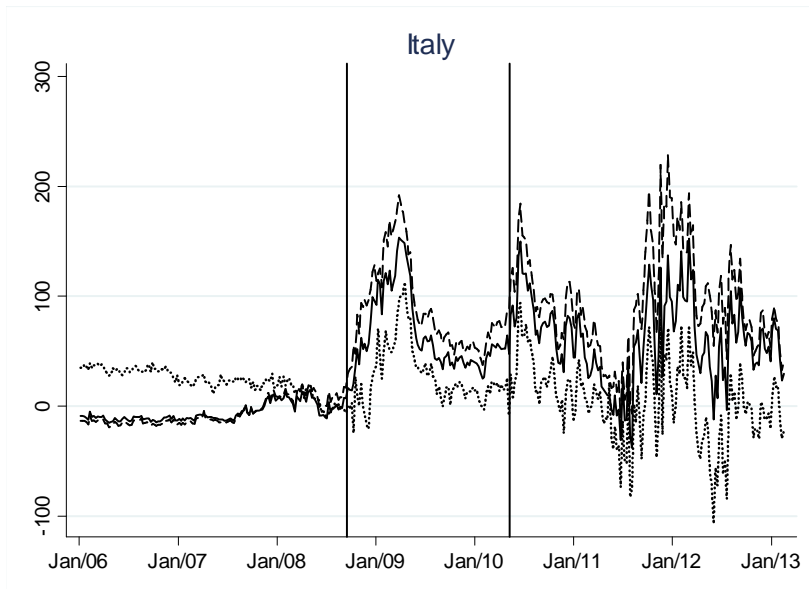
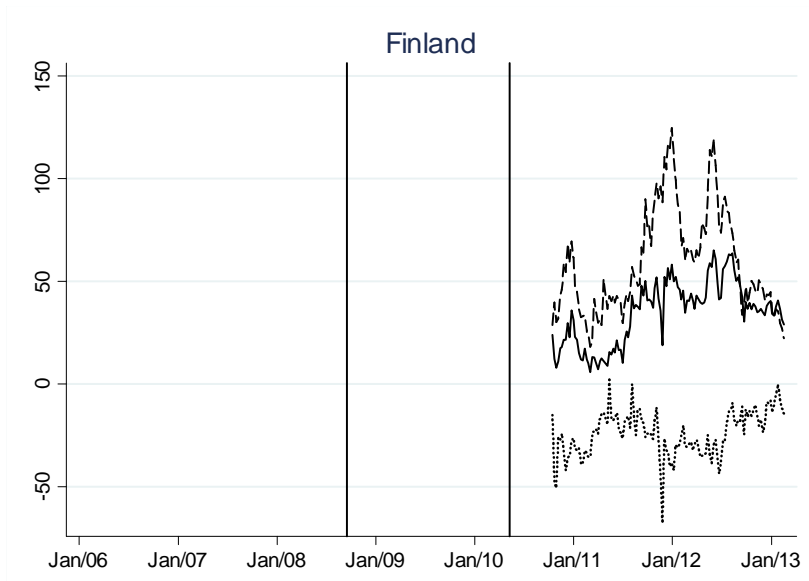
$t$  statistics in parentheses

\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

## Appendix A

These figures show the average basis using three different approaches to convert the USD-denominated cash flows in EUR. The solid line depicts the trading strategy considered in the paper. It involves buying a cross currency asset swap package to exchange the fixed coupon of the USD-denominated bond at the Euribor rate plus a spread and getting into a floating-fixed interest rate swap to exchange that EUR-denominated stream of floating inflow into a fixed coupon rate. The dashed line depicts the Tuckman and Porfidio's (2003) strategy to create an adjusted forward rate that takes into account violations of the covered interest parity in the long run. The dotted line depicts the trading strategy that involves the use of forward contracts to convert the USD-denominated cash flows. The sample spans from January 2006 to February 2013 and the y-axis in measure in basis points. Vertical lines refer to the Lehman Brothers collapse (September 2008) and the starting date of the Securities Market Programme (May 2010)





## Appendix B

Table 8: Bond descriptive statistics. This table reports the main descriptive statistics at bond level. We report the ISIN, issuer country, settlement and maturity dates, coupon (all bonds are fixed rate), currency, and outstanding amount in millions of EUR (for those bonds USD-denominated we apply the spot exchange rate of the settlement date).

<i>ISIN</i>	<i>Country</i>	<i>Settlement Date</i>	<i>Maturity Date</i>	<i>Coupon</i>	<i>Currency</i>	<i>Amount Out.</i>
AT0000385356	Austria	15/Jan/02	15/Jul/12	5	EUR	10000
AT0000385992	Austria	28/May/03	20/Oct/13	3.8	EUR	13127
XS0170724479	Austria	25/Jun/03	25/Jun/13	3.25	USD	2687
AT0000386073	Austria	15/Jan/04	15/Jul/14	4.3	EUR	9560
XS0192781150	Austria	19/May/04	19/May/14	5	USD	998
XS0211055891	Austria	26/Jan/05	30/Mar/12	4	USD	918
XS0453795824	Austria	23/Sep/09	15/Nov/12	2	USD	1018
AT0000A0GLY4	Austria	15/Jan/10	20/Feb/17	3.2	EUR	9877
XS0638878461	Austria	17/Jun/11	17/Jun/16	1.75	USD	699
BE0000314238	Belgium	24/Apr/08	28/Mar/14	4	EUR	13000
BE0934531337	Belgium	1/Jul/08	3/Sep/13	4.25	USD	1266
BE6000356335	Belgium	15/Sep/09	15/Sep/14	2.875	USD	682
BE6000673598	Belgium	5/Mar/10	5/Mar/15	2.75	USD	1468
BE0000319286	Belgium	16/Mar/10	28/Mar/16	2.75	EUR	9594
FI4000018049	Finland	21/Sep/10	15/Apr/16	1.75	EUR	6500
XS0550739535	Finland	19/Oct/10	19/Oct/15	1.25	USD	1448
XS0605995561	Finland	17/Mar/11	17/Mar/16	2.25	USD	1426
IT0003190912	Italy	1/Feb/02	1/Feb/12	5	EUR	28303
XS0144129649	Italy	1/Mar/02	15/Jun/12	5.625	USD	3467
US465410BF43	Italy	27/Feb/03	15/Jun/13	4.375	USD	1861
IT0003472336	Italy	2/May/03	1/Aug/13	4.25	EUR	24696
IT0003719918	Italy	1/Sep/04	1/Feb/15	4.25	EUR	21350
US465410BN76	Italy	21/Jan/05	21/Jan/15	4.5	USD	3075
IT0003844534	Italy	2/May/05	1/Aug/15	3.75	EUR	25809
US465410BQ08	Italy	25/Jan/06	25/Jan/16	4.75	USD	1634
IT0004019581	Italy	1/Mar/06	1/Aug/16	3.75	EUR	26738
US465410BR80	Italy	20/Sep/06	20/Sep/16	5.25	USD	2364
IT0004164775	Italy	2/Jan/07	1/Feb/17	4	EUR	25598
US465410BS63	Italy	12/Jun/07	12/Jun/17	5.375	USD	1503
US465410BT47	Italy	4/Jun/08	15/Jul/11	3.5	USD	1621
IT0004404973	Italy	1/Sep/08	1/Sep/11	4.25	EUR	18199
US465410BU10	Italy	5/Oct/09	5/Oct/12	2.125	USD	1706
IT0004564636	Italy	4/Jan/10	15/Dec/12	2	EUR	18686
IT0004568272	Italy	15/Jan/10	15/Apr/15	3	EUR	20404
US465410BV92	Italy	26/Jan/10	26/Jan/15	3.125	USD	1776
US465410BW75	Italy	16/Sep/10	16/Sep/13	2.125	USD	1530
IT0004653108	Italy	1/Nov/10	1/Nov/13	2.25	EUR	17819
ES00000120E9	Spain	12/Apr/05	30/Jul/10	3.25	EUR	16183
XS0225226710	Spain	20/Jul/05	20/Jul/10	4.125	USD	823
ES00000120Z4	Spain	15/Jan/08	30/Apr/11	4.1	EUR	15542
ES0000011660	Spain	8/Apr/08	31/Jan/13	6.15	EUR	13606
XS0363874081	Spain	14/May/08	17/Jun/13	3.625	USD	1292
XS0376589288	Spain	16/Jul/08	18/Jul/11	3.375	USD	1264
ES00000121I8	Spain	13/Jan/09	30/Apr/12	2.75	EUR	11939
XS0416150950	Spain	5/Mar/09	5/Mar/12	2.75	USD	797
XS0452149072	Spain	17/Sep/09	17/Sep/12	2	USD	1696
ES00000121T5	Spain	6/Oct/09	30/Apr/13	2.3	EUR	14894
US900123AS92	Turkey	24/Sep/03	15/Jan/14	9.5	USD	1523
DE000A0AU933	Turkey	10/Feb/04	10/Feb/14	6.5	EUR	788
XS0245387450	Turkey	1/Mar/06	1/Mar/16	5	EUR	629
US900123AZ36	Turkey	26/Sep/06	26/Sep/16	7	USD	1577
XS0285127329	Turkey	2/Feb/07	2/Apr/19	5.875	EUR	965
US900123BA75	Turkey	3/Oct/07	3/Apr/18	6.75	USD	1597
US900123BH29	Turkey	18/Mar/10	30/Mar/21	5.625	USD	1470
XS0503454166	Turkey	22/Apr/10	18/May/20	5.125	EUR	1505