Information shares and market quality before and during the European sovereign debt crisis

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Abstract

We investigate information shares in the price discovery process in the euro-area sovereign bond market across the yield curve, during both calm and crisis periods. We employ a rich high-frequency dataset from the MTS platform. We find that price discovery is enhanced, on average, especially for periphery countries during the European sovereign debt crisis however, increases in information shares are not uniform across the yield curve. We further show that no particular market leads the price formation process across all maturity segments. We find a clear improvement in market quality for core countries (Germany and the Netherlands) but mixed results for periphery countries (Italy and Spain) in the crisis period.

Keywords: Price discovery, Information shares, Sovereign bond markets, European debt crisis, High-frequency data, Market quality

JEL Classification: C5; G01; G10; G15

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1. Introduction

Price discovery is defined by Schreiber and Schwartz (1986) as the process that incorporates new information into the efficient price. The direction and extent of price discovery is of paramount importance especially when the process of market fragmentation accelerates. Understanding the price discovery process is also important to market participants who are interested in exploiting profitable arbitrage opportunities that may arise in the marketplace. Moreover, this information is useful to policymakers who design and implement financial regulations. It is crucial for regulators to be able to identify the markets that spread credit risk related information more quickly and lead the price discovery process especially during periods of stress. Such information can provide prompt reactions to systemic crises that affect many markets simultaneously and can lead to dramatic contagious episodes. Credit risk is particularly relevant in the sovereign bond market. The longer term debt sustainability of various countries was questioned a number of times, due to sovereign credit rating downgrades by Fitch, Moody's and Standard & Poor's during the recent European debt crisis. One of the lessons learned from the European and other recent crises is that the more efficient the price discovery process is for distressed markets, the more stable and less vulnerable is the financial system.

In this paper we strive to determine the location at which price discovery takes place for euro-denominated sovereign bonds using benchmark securities from core and periphery countries. We also investigate whether price discovery is enhanced for euro-area sovereign bonds during the sovereign debt crisis period compared to the calm period that preceded it. Previous studies have shown that financial shocks are likely to be transmitted more strongly during crisis periods affecting the way prices are formed in the marketplace (Didier et al., 2010; Grammatikos and Vermeulen, 2012).

The European bond market was a market under stress during the debt crisis period. Financially distressed eurozone member states (Greece, Ireland, Portugal, Spain, and Italy to a lesser extent) resorted to the European Troika and the International Monetary Fund (IMF) for financial assistance. During the crisis, risk aversion was elevated to unprecedented levels from the part of investors and adversely affected segments of the economy of the European Union.

Although eurozone sovereign bond markets are integrated, mainly due to their EMU membership, they can also be regarded as separate financial markets as they share different credit risk characteristics. Thus liquidity is dispersed. Price discovery not only applies to identical assets that are cross-listed on multiple trading venues, but also to securities such as sovereign bonds that, although are technically distinct, are very closely linked to each other by arbitrage arguments (an interesting discussion is provided by Blanco et al., 2005). In the long term, eurozone sovereign bonds are correlated as they share the same fundamental macroeconomic drivers and a common interest rate (Dufour and Nguyen, 2013). As Mizrach and Neely (2008) argue, neither the Hasbrouck (1995) model nor the price discovery framework requires the securities to be identical, we only need the prices to be cointegrated. This relationship exists theoretically as a result of arbitrage arguments and we can confirm the cointegration link empirically in the analysis that follows. Issuers of euro-denominated sovereign debt compete for international becnhmark status, high credit quality, enhanced liquidity and other technical considerations, such as homogeneity and regularity of bond issues (Galati and Tsatsaronis, 2001). In that sense, this study can offer new and useful insights on the specifics of the eurozone sovereign bond markets.

In financial markets, including the bond market, market frictions such as transaction costs and information asymmetries act as barriers to impounding new information into the efficient price instantly, thereby prices reflect all new information gradually over time and price discovery is nowhere near efficient. In such a setting it is important to know which market reflects the new information first, that is, which market is the dominant market in the price formation process and which is the "satellite" market, a term popularized by Garbade and Silber (1983).

The current analysis is different from previous studies on price formation in European sovereign bond markets in the following ways. First, we employ a high-frequency dataset from the MTS markets in contrast to previous studies that have relied on lower frequency data, such as that of Caporale and Girardi (2013). The use of high-frequency data has many advantages such as a high number of observations along with statistical gains (Gargano et al., 2019). Moreover, high-frequency data has enabled us to get into the skin of those markets and analyse their distinct characteristics and behavior at every "tick" of price information. Also, the use of high-frequency data enables the construction of more accurate and model-free *ex-post* volatility measurements via the summation of squared intraday returns (Andersen and Bollerslev, 1998; Andersen et al., 2001). Tick-by-tick data also allow the construction of microstructure-based liquidity measures that are able to capture multiple liquidity dimensions.

Second, we investigate the price discovery process between and within core (Germany and the Netherlands) and periphery (Italy and Spain) euro-zone bond markets during both tranquil and crisis periods. We condition for time-to-maturity because price discovery may differ across the various segments of the bond market. Earlier studies have focused on single markets (Girardi and Impenna, 2013) and on sample periods of tranquillity (Dufour and Nguyen, 2013). Studies like those of Furfine and Remolona (2005) and Upper and Werner (2007) which deal with markets under stress, also focus on single market segments and do not take into account the interrelationships across markets and asset classes. In this study, we highlight the importance of considering relationships between separate but at the same time interrelated markets.

Third, this paper adds to the literature by testing whether pricing relationships in the European bond market that prevail under tranquil periods carry over to periods of market turbulence. In previous periods such as the 1998 financial market turbulence, the pricing relationships that were taken as granted broke down and led to market failures such as the collapse of Long-Term Capital Management (LTCM). The euro-area sovereign debt crisis enables the investigation of changes in price discovery under totally different market conditions.

Finally, a fourth goal of this paper is to understand the mechanisms of market quality across the yield curve. Price discovery as an element of market efficiency is one of the cornerstones of market quality. Man et al. (2013) show that the price discovery process is important to policymakers and regulators who have a genuine interest in market quality. Actually, an enhancement in market quality such as lower transaction costs and higher trading activity has a positive causal effect on price discovery. Alan and Schwartz (2013) highlight the fact that price discovery is an essential function of an exchange as it provides confidence to investors and ensures the efficient functioning of the secondary market for capital, thus good-quality price discovery must be a regulatory priority. It follows that the efficiency with which prices are formed in the marketplace plays an important role in measuring market quality.

Risk aversion differs substantially between tranquil and crisis periods. During periods of stress flight to quality episodes take place in global financial markets as investors rebalance their portfolios towards highly liquid and less risky assets. Generally speaking, trading costs as measured by the quoted or relative spread, increase during crisis periods even in "safe heavens" such as the German government bond market indicating a deterioration of liquidity (see Upper, 2000 for a discussion). However, although spreads increase, a market might be able to handle a significantly large number of transactions and turnover, i.e. a larger market depth. This means that the net effect on market quality may be favourable when quoted depth increases outweigh the corresponding spread increases. When market makers and traders differ in their risk aversion, the same information affects market makers' quotes and traders' valuations differently, so clearly risk aversion affects market quality (Decamps and Lovo, 2006).

In the analysis that follows, we document a number of interesting findings. The percentage changes in information shares between pre-crisis and crisis for Italy and Spain reveal increases and decreases of roughly the same magnitude across the maturity spectrum. It follows that there is no clear pattern within periphery markets and results are mixed in terms of price discovery improvements in the crisis period. Within core countries, Germany leads the price discovery process pre-crisis but becomes a satellite market in the crisis, as Netherlands takes the lead with large positive percentage changes in information shares. We note a clear improvement in the price discovery process for the Dutch market and a deterioration for Germany.

Results are more clear cut regarding information shares between core and periphery countries. It is evident that, on average, there is an improvement in the price discovery process during the sovereign debt crisis period and is more pronounced for the periphery than the core eurozone countries. This finding indicates that market specific information is impounded into prices more rapidly during periods of stress compared to periods of normal market conditions. However, we show that there is no particular market that dominates across all maturity segments and that increases in information shares are not uniform across the yield curve.

Using a short and a long event window we find that liquidity in the European bond market was impaired during the crisis, as spreads increased due to liquidity dry-ups. The short-term effect of the crisis on the European bond market quality was positive due to the fact that quoted depth liquidity increases overwhelmed the increase in spread-based liquidity. The longer-term effect of the crisis on the German and Dutch liquidity was positive with significant spread drops and depth increases. Market quality improved for Italy and Spain at the longer end of the yield curve but deteriorated at shorter maturities. Along these lines we calculate and collect four bond attributes (i.e. euro trading volume, average midquote price, realized volatility, and credit default swap (CDS) spreads) that are known to explain time-series variations in the spread. Price volatility is positively related to spread measures whilst trading volume, on average, is negatively associated with spreads. That is, lower price volatility leads to higher liquidity in the form of narrower speads, and an increase in volume is associated with an improvement in liquidity, as expected from theory and previous empirical evidence. Under normal market conditions, prices should be negatively related to liquidity, however, we find that this relationship breaks down in various instances in the crisis and the price appears to correlate positively with spread changes. We also show that sovereign credit risk as represented by CDS spreads, exhibits a positive and statistically significant relationship with liquidity across both periphery and core countries in most cases, although statistical significance is mainly manifested in the periphery countries of Italy and Spain. This makes perfect economic sense as their long term debt sustainability was challenged a number of times in the crisis.

The rest of the paper is organised as follows. Section 2 presents a literature review. Section 3 describes the methodology and the dataset. Section 4 discusses the empirical results. Finally, Section 5 offers some concluding observations and takeaways for policy making.

2. Related literature

There are a few studies on price discovery in foreign exchange markets (Batten and Hogan, 2001; D'Souza, 2007; Osler et al., 2011; Chaboud et al., 2020) however, the majority of studies on price discovery focus on the U.S. equity markets. Hasbrouck (1995) and Harris et al. (1995) study the price discovery of U.S. stocks cross-listed on the NYSE and regional exchanges and find that the NYSE leads the price formation process. Evidence on non-

U.S. stocks is provided by Werner and Kleidon (1996), Biais et al. (1999), Hupperets and Menkveld (2002), Eun and Sabherwal (2003), Grammig et al. (2005), Korczak and Phylaktis (2010), Ngene et al. (2014), Papavassiliou (2015), to name a few.

More recent articles on stock markets and stock index futures markets include the following. Cespa and Foucault (2014) propose a theoretical model that studies how the joint pricing of trading services and price information affects price discovery and the distribution of gains from trading in financial markets. Ye (2016) studies the impact of dark pools on price discovery under a noisy information framework and finds that when a dark pool is added to a traditional exchange price discovery is amplified, provided that the information has a high precision. Whereas, price discovery is impaired when information exhibits low precision. Kryzanowski et al. (2017) compare the price discovery contributions of equity and credit default swap (CDS) markets for U.S. firms and provide evidence that the CDS market's contribution increases for after-hours OTC trading and for negative earnings surprises. Brogaard et al. (2019) analyse the contribution to price discovery of market and limit orders by high-frequency traders and non-high-frequency traders and show that as limit orders are more numerous price discovery mainly takes place through limit orders.

Hasbrouck (2019) uses U.S. equity high-frequency data time stamped to nanosecond precision along with long distributed lag models and finds that the information shares of listing exchanges dominate those of their volume shares and moreover, quotes dominate trades in the price formation process. Kakhbod and Song (2020) introduce a discrete-time, dynamic trading game between an informed trader and a number of uninformed, single-period risk-averse hedgers and show that post-trade price transparency delays the price formation. He et al. (2020) study the price discovery process in the Chinese stock index futures market following a change in market regulation. The authors find that the futures market becomes more sensitive to the release of new information shortly after the change in regulation and takes the leading role in price discovery. However, as the new regulation negatively affects liquidity in the longer term, price discovery weakens compared to its previous levels. Patel et al. (2020) show that new information is reflected in options prices first before being transmitted to stock prices especially around important information events. Cepoi et al. (2021) study the drivers of price discovery using an unconditional quantile model and provide evidence that price discovery responds asymmetrically to the different drivers and proves to be quite sensitive to country-level risk and financial market stability.

Due to the popularity of cryptocurrencies in recent years a number of studies on price discovery have emerged. Ghysels and Nguyen (2019) examine price discovery and liquidity provision in the secondary market for bitcoin and find that order informativeness increases with order aggressiveness and aggressive orders are more attractive to informed agents when volatility levels increase. Baur and Dimpfl (2019) find that price discovery is led by the spot bitcoin market and not by the futures bitcoin market, contradicting previous evidence from traditional asset markets. Alexander and Heck (2020) analyse information flows in the bitcoin market and document that unregulated derivatives products dominate the regulated futures products of CME and Bakkt. Alexander et al. (2020) analyse the microstructure of ether trading on BitMEX derivative exchange and on a number of spot exchanges, including Coinbase and show that BitMEX trading leads the price discovery process and exhibits larger trading volumes than major ether spot cryptocurrency exchanges.

The majority of studies from the sovereign bond markets focus on the U.S. Treasury markets. Fleming and Remolona (1999) analyse price formation and liquidity in the U.S. Treasury market by examining the response of prices, volumes, and bid-ask spreads to macroeconomic announcements. The authors conclude that prices adjust sharply to announcements whilst trading volume and liquidity decline as a result. Brandt and Kavajecz (2004) examine the role of price discovery in the U.S. Treasury market and find that order flow imbalances account for up to a quarter of the daily variation in yields on days without major macroeconomic news announcements. The authors demonstrate that liquidity plays a pervasive role in the price discovery process and as liquidity deteriorates the price discovery process is magnified. They also show that price discovery is mainly focused on the on-the-run segment of the U.S. market. Brandt et al. (2007) examine the U.S. Treasury cash and futures markets and highlight illiquidity's important role in enhancing price discovery in the cash market due to increased asymmetric information. Mizrach and Neely (2008) study the price discovery process in the U.S. bond market across a range of maturities in both spot and futures markets. The authors highlight the importance of the futures market in the price formation process and find that liquidity and volatility are able to explain daily bond-market information shares in a statistically significant fashion.

Fricke and Menkhoff (2011) examine the relative information shares of the 10-year euro bond future contract on German sovereign debt and find that, although the futures contract is quite important it does not dominate price discovery. Moreover, the authors show that when order flow is included in the analysis the future market's information share increases. Palladini and Portes (2011) study the price discovery relationship between sovereign CDS premia and bond yield spreads using daily data from six euro-area countries over the period 2004-2011. Their analysis suggests that the CDS market contributes more to the price discovery process than the bond market. Their findings are in line with those of Blanco et al. (2005) and Zhu (2006) but contradict those of Ammer and Cai (2011), suggesting that eurozone sovereign credit risk is not strongly related to that of developing countries but rather to corporate credit risk of more economically advanced countries.

Valseth (2013) compares the informational content of interdealer order flow to that of customer order flow in the Norwegian government bond market and shows that aggregate interdealer order flow contributes more to the price discovery process. Dufour and Nguyen (2013) study the price discovery process in the euro-area government bond markets. They find that the French market dominates the short end of the yield curve, the German market is more influencial at the medium and longer maturities, while the Italian market seems to be more informative at the longest end of the yield curve. Caporale and Girardi (2013) investigate the role of trade segmentation in the process of price discovery in the eurozone bond market and find that the level of trading activity crucially affects a market's contribution to price discovery. Gyntelberg et al. (2018) use intraday data on sovereign CDS and bonds across a number of euro area countries and investigate the effect the ban on naked CDS trading has had on the price discovery process of sovereign credit risk. The authors find that the CDS market dominates the bond market in terms of price discovery and that the ban on short-selling did not alter the price discovery dynamics of the market. Fleming and Nguyen (2019) study the U.S. Treasury market and find that price discovery is enhanced in the case of lit order flow as opposed to dark order flow especially during periods when private information is released more strongly. Guidolin et al. (2021) analyse time-variation of the price discovery process in sovereign debt markets and show that when cointegration fails to hold, none of the markets leads price discovery.

Our analysis is also related to the literature on the relation between market quality and price discovery. Bessembinder et al. (2011) argue that lower spreads as a result of the presence of liquidity providers, enhance informed trading leading to price discovery improvements. Frijns et al. (2015) argue that the relation between price discovery and market quality is potentially endogenous. An enhancement in price discovery may attract investors to a market, whilst an increase in liquidity and trading activity may improve price discovery. Hendershott and Jones (2005) arrive at the same conclusion. When the Island ATS goes dark there is a large decline in market share, followed by a widening of spreads and a worsening of price discovery. Mizrach and Neely (2008) show that an increase in relative spreads in the spot U.S. Treasury market decreases its information share, showing that market quality and price discovery are linked to one another in a positive causal manner. One would expect this pattern to differ between the eurozone debt crisis and the pre-crisis period. Previous research has shown that the effect of the turbulence on the cost of trading was particularly pronounced. Upper and Werner (2007) find that bid-ask spreads of the bund future more than quadrupled a few days after the Russian default. Spreads temporarily declined to relatively normal levels but soared to almost six times the average during the first half of 1998.

Anand et al. (2009) show that when firms assign designated liquidity providers they experience an improvement in market quality and price discovery. Bellia et al. (2017) study whether the presence of low-latency traders in the pre-opening period contributes to market quality using a dataset from the Tokyo Stock Exchange and conclude that about one quarter of high-frequency traders contribute significantly to market quality in the pre-opening period. Buckle et al. (2018) study the effects the Markets in Financial Instruments Directive (MiFID) regulation has had on market quality and price discovery and note that fragmentation can lead to market quality improvements. Linton and Mahmoodzadeh (2018) find that high frequency trading can improve market quality and liquidity and enhance market efficiency. In a similar study Breckenfelder (2019) investigates how competition among high-frequency traders affects market quality and finds that when speculative trading increases as a result of increased competition among high-frequency traders, market quality deteriorates. Brolley and Cimon (2020) investigate informed trading in markets where latency delays are introduced and conclude that although delayed exchange liquidity improves, the overall impact is a worsening of aggregate investor welfare in fragmented markets. Yamada and Ito (2020) examine the forex market quality and its reaction to macro announcenents using a long dataset of EBS high-frequency data. The authors find that market quality in the forex market has not improved however, the speed of price discovery has been enhanced, although liquidity recovery has become slower.

This study also relates to the limited literature on price discovery during periods of stress. Due to the fact that new market specific information is reflected in asset prices via trading, one would expect the role and magnitude of price discovery to differ between calm and crisis periods. Price discovery is affected by trading volume, liquidity, and volatility, especially during turbulent periods where liquidity evaporates quickly, volatility intensifies, and trading volume tends to increase towards less risky assets. Price pressures during periods of stress have important implications for financial stability and can amplify the initial shocks to the financial system. News announcements of financial distress may affect trading through order flow and lead to permanent effects on equilibrium prices and liquidity (Glosten and Milgrom, 1985).

Upper and Werner (2007) find that the information share of the bond market declined to zero two weeks after the recapitalization of Long-Term Capital Management (LTCM) in September 1998. Furfine and Remolona (2005) analyse how price discovery in the inter-dealer market for U.S. Treasury securities differs between crisis and non-crisis periods and find that prices are affected more strongly by trading during crisis periods. Schulz and Stapf (2014) investigate whether the financial crisis changed the price discovery process between inflation-linked bonds and inflation swaps for breakeven inflation rate (BEIR). The authors find that price discovery ceased to take place in the swap market especially for short to medium maturities while the resulting widening of the bid-ask spreads during the autumn of 2008 hindered arbitrage between the bond and the swap market.

Finally, this study also relates to the literature on the microstructure of the European sovereign bond markets (Cheung et al., 2005; Beber et al., 2009; Favero et al., 2010; Pelizzon et al., 2016; Kinateder and Papavassiliou, 2019; O'Sullivan and Papavassiliou, 2020). Most previous studies focus on periods prior to the sovereign debt crisis and use lower frequency datasets that fail to fully capture extreme events in financial markets. In the analysis that follows we shed more light on this issue.

In brief, our findings are in line with those of Dufour and Nguyen (2013) in terms of the Italian 30-year benchmark's importance in the price discovery process. However, contrary to their work we show that the information shares of periphery countries at the popular 10-year maturity exceed by far the information shares of core countries during the crisis. Moreover, we find that the medium-term German benchmarks, although very liquid, fail to unambiguously lead price discovery in the crisis. We find statistically significant short-term increases in all spread measures in the crisis period for Italy and Spain, and to a lesser extent for the Dutch market, as a result of heightened risk aversion, confirming previous findings by Upper and Werner (2007).

3. Methodology and data

In Section 3.1. we present the methodological framework upon which this study is based. In Section 3.2. we describe the dataset and the data handling procedures.

3.1. Methodology

We employ the common factor model proposed by Hasbrouck (1995) to study the mechanics of price discovery which defines price discovery in terms of the variance of the innovations to the common factor. For two price series, $Y_t = (y_{1t}, y_{2t})'$ which are cointegrated $I(1)$, Hasbrouck's information shares (ISs) are derived from the following vector error correction model (VECM) specification:

$$\Delta Y_t = \Pi Y_{t-1} + \sum_{i=1}^{n} B_i \Delta Y_{t-i} + e_t \tag{1}$$

where Δ denotes the first difference operator and the matrix Π is decomposed as $\Pi = \alpha\beta$, with error correction vector α and cointegrating vector $\beta = (1, -1)^{'}$. The zero-mean vector $e_t = (e_{1t},\ e_{2t})^{'}$ contains innovations with covariance matrix Ω given by:

$$\Omega = \begin{pmatrix} \sigma_1^2 & \rho\sigma_1\sigma_2 \\ \rho\sigma_1\sigma_2 & \sigma_2^2 \end{pmatrix} \tag{2}$$

where ρ is the correlation between e_{1t} and e_{2t} and $diag\left\{\Omega\right\}$ contains the variances of e_{1t} and e_{2t}.

Hasbrouck decomposes the variance of the common factor innovations, that is, $var\left(\psi e_t\right) = \psi\Omega\psi'$, which shows that the IS of a particular market is simply the variance proportion in the common factor attributable to innovations in that market, where $\psi = (\psi_1, \psi_2)$ is the common row vector in a matrix polynomial of a vector moving average (VMA) transformation.

Hasbrouck's ISs of the two prices are given as:

$$S_1 = \frac{\left(\lambda_1 m_{11} + \lambda_2 m_{12}\right)^2}{\left(\lambda_1 m_{11} + \lambda_2 m_{12}\right)^2 + \left(\lambda_2 m_{22}\right)^2} \tag{3}$$

$$S_2 = \frac{\left(\lambda_2 m_{22}\right)^2}{\left(\lambda_1 m_{11} + \lambda_2 m_{12}\right)^2 + \left(\lambda_2 m_{22}\right)^2} \tag{4}$$

where λ_1, λ_2 are the parameters that are orthogonal to the error correction vector and $m_{11},\ m_{12},\ m_{22}$ are the elements of a lower triangular matrix M.

To remove contemporaneous correlation in the price innovations, Hasbrouck suggests using a Cholesky factorization of the covariance matrix, i.e. $\Omega = MM'$. We note that (a) when the first asset has its lower bound, the second asset has its upper bound, and (b) the ISs must add up to one ($S_1 + S_2 = 1$). Hasbrouck's ISs involves the estimation of upper and lower bounds so that the variable ordered first in the system experiences an increased IS. It follows that a re-ordering of the price series and then averaging the two results would yield the true IS for each market.

As a robustness test we use the Gonzalo and Granger (1995) permanent-transitory (PT) model. The PT model also uses the VECM as its basis, however, it is concerned with only the error correction process which involves only permanent, as opposed to transitory shocks that result in a disequilibrium (an excellent discussion is provided by Baillie et al., 2002). It measures a market's contribution to the common factor, where the contribution is a function of the market's error correction coefficients. The permanent-transitory contribution to the common factor for two markets is expressed as:

$$S_1 = \frac{\lambda_1}{\lambda_1 + \lambda_2} \tag{5}$$

$$S_2 = \frac{\lambda_2}{\lambda_1 + \lambda_2} \tag{6}$$

where λ_1, λ_2 are orthogonal to the error correction coefficients.

In a second step and in order to measure market quality across the yield curve in the European sovereign bond market we compare microstructure measures of market quality between the crisis and pre-crisis period using a t-test of equal means. Specifically, to measure the short- and long-term effects of the crisis on the market quality of core and periphery countries we consider the following two periods: (i) a period spanning the dates from July 2009 to

February 2010, which is comprised of a 4-month pre-crisis period (July 2009 – October 2009) and a 4-month crisis period (November 2009 – February 2010), and (ii) a second longer period which spans the dates from September 2008 to December 2010, and is comprised of a 14-month pre-crisis period (September 2008 – October 2009) and a 14-month crisis period (November 2009 – December 2010).

The longer 14-month event window includes a number of important macroeconomic events, such as credit rating downgrades by Fitch, Standard & Poors, and Moody's, Greece's and Ireland's bailout package, as well as the "Securities Markets Programme" (SMP) which was intended to inject liquidity in eurozone's debt securities markets and to restore the mechanisms through which monetary policy is implemented. Thus it is expected that the longer event window will provide a clearer picture of market quality and offer more robust evidence as to whether market quality improved or deteriorated in the crisis period.

Lastly, to determine whether the differences in spreads between the pre-crisis and crisis periods are due to changes in bond attributes over time, we calculate and collect four bond attributes (i.e. euro trading volume, average midquote price, realized volatility, and sovereign credit default swap (CDS) spreads) that are known to explain time-series variations in the spread. This approach is similar in spirit to that of Foerster and Karolyi (1998) and Zhao and Chung (2007). We define euro trading volume as the sum of the euro value of the bonds bid and offered at the best quotes. The quote midpoint is the average of the posted bid and ask quotes. Daily realized volatility is constructed by the summation of squared 5-minute intraday returns, following Andersen and Bollerslev (1998) and Andersen et al. (2001). We then regress the changes in each spread measure between the pre-crisis and crisis periods (crisis-pre-crisis) on the changes in the four bond attributes. We use a multiple regression model of the following form:

$$\Delta LIQ_t = \alpha + \beta_{1,t}\Delta VOL_t + \beta_{2,t}\Delta MP_t + \beta_{3,t}\Delta RV_t + \beta_{4,t}\Delta CDS_t + \varepsilon_t \quad (7)$$

where Δ denotes the first difference operator, LIQ_t denotes the spread liquidity measures at day t used as dependent variables, VOL_t is the euro trading volume at day t, MP_t is the daily average midquote price at day t, RV_t is the daily realized volatility at day t, CDS_t are the credit default swap (CDS) spreads at day t, and ε_t denotes the error term. We run the regression in Equation (7) for each liquidity measure separately, i.e. $L_t \in \{Quoted\ spread,\ Relative\ spread,\ Best\ bid - ask\ spread\}$.

3.2. Data

We employ a high-frequency dataset from MTS, Europe's largest electronic government bond market. MTS's daily volumes exceed €100 billion and apart from government bonds, other instruments such as quasi-government bonds, corporate bonds, covered bonds and repos are traded on the MTS platforms. Market makers provide liquidity on both interdealer and Dealer to Client (D2C) markets. A distinct feature of the MTS markets is that primary dealers are allowed to access either an order-driven market or a quote-driven market, taking advantage of the different characteristics of each market. Our dataset covers the period from January 2008 to December 2010. Similar to previous studies we consider November 2009 as the start of the European sovereign debt crisis period (O'Sullivan and Papavassiliou, 2020). We use Germany (DE) and the Netherlands (NL) as two representative markets from the core eurozone region, and Italy (IT) and Spain (ES) as the two most liquid markets in the periphery region. In agreement with Mizrach and Neely (2008), Dufour and Nguyen (2013), and O'Sullivan and Papavassiliou (2020) we work solely with benchmark fixed coupon-bearing bonds within four time-to-maturity groups: 2-, 5-, 10-, and 30-year. We account for time to maturity of the different European benchmarks in line with Brandt and

Kavajecz (2004) and Green (2004). The reason for conditioning on time to maturity is that price discovery may not occur uniformly across the maturity spectrum.

Bond maturity is also an important factor to distinguish investor preference. Longer maturity bonds have wider spreads than shorter maturity bonds as shorter term benchmarks are more liquid (Pasquariello and Vega, 2009; O'Sullivan and Papavassiliou, 2020). O'Sullivan and Papavassiliou (2020) show that liquidity for the 30-year bond may improve during crisis periods whereas it deteriorates for bonds of shorter maturities showing that shorter maturity bonds are more vulnerable to liquidity squeezes due to lower selling pressure. It follows that the market quality index of shorter-term bonds is more likely to take on smaller values leading to a deterioration in market quality.

Following Bandi and Russell (2006) we employ midquote prices rather than transaction prices and artificially construct 5-minute quote midpoints applying linear interpolation methods around the endpoints of the sampling intervals. The selection of the 5-minute sampling frequency is the most popular choice as it balances both measurement errors and microstructure biases (Andersen et al., 2001). We have discarded quotations that are recorded outside standard trading hours such as those that are posted during pre-market trading and end-of-day trading. Moreover, we have removed all erroneous quotations that are usually found in unprocessed datasets.

Table 1 presents descriptive statistics of the midquote prices of benchmark bonds of all four countries. As we move from the short-term 2-year maturity bonds to the longer-term 30-year bonds the maximum price increases for both core and periphery countries which makes perfect sense as investors bear more risks by holding longer-term bonds. The same result is documented by O'Sullivan and Papavassiliou (2019). This result is evident in both the pre-crisis and the crisis periods. For instance, in the pre-crisis period prices of German bonds increase from 104.75 (2-year) to 126.20 (30-year). The range of prices for longer maturity bonds is higher than that of shorter maturity bonds due to their higher duration. It follows that longer term bonds will experience bigger price increases and decreases over time. We also note that as we move from short to long term bonds the standard deviation increases due to higher duration for long term bonds, which indicates heightened risk for long versus short term bonds. We note that 30-year bonds exhibit the highest skewness and kurtosis, especially pre-crisis, as a result of their higher convexity which results in the skewness being more positive (see Fabozzi and Mann, 2012 for a discussion). The kurtosis of 30-year German and Dutch bonds is slightly lower than the normal which makes sense as these bonds are considered relatively safer bonds. On the other hand, the kurtosis of Italian and Spanish 30-year bonds is higher than normal reflecting the fact that these bonds are riskier with more extreme outcomes.

In a second step, we construct a number of microstructure measures of market quality, averaged on a daily basis:

- **Best bid-ask spread:** defined as the difference between the best ask quote and the best bid quote
- **Quoted spread:** defined as the difference between the average of the three best ask prices and the average of the three best bid prices
- **Relative spread:** defined as the best bid-ask spread divided by the quote midpoint, where the quote midpoint is the average of the posted bid and ask quotes
- **Quoted depth:** defined as the depth at the best bid and ask prices which specifies the maximum quantities for which the respective prices apply
- **Market quality index:** defined as $\frac{Quoted\ depth/2}{Relative\ spread}$

The market quality index (MQI) has been proposed by Bollen and Whaley (1998) in order to measure the net effect on overall market liquidity. This measure aims at capturing the trade-off between spread-based and depth-based liquidity. An increase in the market quality index corresponds to an increase in market quality. It follows that the market quality index can increase: (a) when the numerator increases, (b) when the denominator declines, (c) when the numerator increases and the denominator declines simultaneously, (d) when the increase in the numerator outweighs the increase in the denominator, and (e) when the decrease in the denominator outweighs the decrease in the numerator. An improvement or deterioration of market quality can also be explained using the market microstructure literature. According to market microstructure theories, liquidity is mainly affected by inventory and adverse selection effects which are likely to vary during crisis periods (order processing costs on the other hand are usually kept constant in the long run and are not good candidates to explain variations in market liquidity). For instance, Glosten and Milgrom (1985) find that due to asymmetric information market makers would have to widen their bid-ask spreads and as a result liquidity traders will be driven away. Such microstructure models provide explanations about the reasons market liquidity may dry up leading to a worsening of market quality. Finally, we employ daily sovereign credit default swap (CDS) spreads for all countries and all four maturity segments obtained from Markit.

4. Empirical findings and discussion

We divide our empirical findings into two main sections. Section 4.1. discusses ISs between and within core and periphery eurozone countries and draws conclusions on the price discovery process during calm and turbulent periods. Section 4.2. discusses the results on market quality using both a short and a long event window surrounding the start of the crisis, i.e. November 2009.

4.1. Information shares

One of the basic requirements for cointegration is that the price series for each bond are $I(1)$. Along these lines, we apply ADF unit root tests to each price series in both levels and first differences and over pre-crisis and crisis periods (shown in Table 1). The number of lags in the models is being determined by the Schwarz information criterion (SIC). We find that all of the price series are $I(1)$ as the null cannot be rejected at any level of significance. Subsequently, we employ the Johansen method for cointegration, following Johansen (1988) and Johansen and Juselius (1990), and find that all series are cointegrated with a single cointegrated vector $(1, -1)$. In order to assess the magnitude of the contributions to price discovery we estimate VECM models as described in Equation (1) both within and between core and periphery markets and over tranquil and crisis periods.

Table 2 presents the IS estimates within core and periphery countries. The larger the IS of a market, the larger its contribution in discovering equilibrium prices. Panel A depicts the ISs between Italy and Spain. During the pre-crisis period Italy dominates the price discovery process, however, Spain's importance in price formation strengthens during the crisis period especially for the shorter-term 2-year benchmark bond. We find increases in ISs for the Spanish 2- and 10-year bond but decreases in ISs for the 5- and 30-year bond between pre-crisis and crisis periods. It seems that any price discovery enhancements during the crisis period are equally shared between the two distressed economies.

Panel B displays the corresponding ISs between Germany and the Netherlands. Germany has taken the lead in the price discovery process pre-crisis for the longer-term 10- and 30-year bonds, however, Netherland's contribution is enhanced during the crisis, with the exception of the 30-year benchmark which follows an autonomous path. ISs for Germany drop in the crisis with the exception of the 30-year bond indicating a deterioration in price discovery. Results for the Dutch market indicate a clear improvement in the price discovery process as ISs increase across the maturity spectrum with the exception of the longer-term 30-year bond. The deterioration in price discovery for the German market can be attributed to Germany's unique primary dealer system. Germany does not impose any obligations on primary dealers which affects their willingness to make markets in the secondary market (see O'Sullivan and Papavassiliou, 2020 for a discussion). Table 3 presents the Gonzalo-Granger permanent-transitory (PT) model estimates which are qualitatively similar to those of Hasbrouck's ISs.

Table 4 presents the ISs for pairs of countries between the core and periphery regions. In the pre-crisis period, the distressed economies of the South dominate price discovery across the short and the long end of the yield curve. However, the results are mixed across the medium-term benchmarks. In the crisis period, the 2-year bond in the periphery region is not very informative as the relevant ISs decline for Spain and Italy. Core eurozone countries have taken the lead in price discovery in the crisis at this maturity segment (ISs increase from 67 percent to 168 percent for NL2 and DE2, respectively). The strengthening of price revelation manifested in the 2-year bond could be attributed to the fact that flight-to-safety and flight-to-liquidity effects have taken place during the sovereign debt crisis in Europe as investors recalibrate their portfolios by including more liquid and safer assets. Although there is a huge increase in ISs for the IT5 benchmark in the crisis when compared to NL5, the Dutch dominance in price discovery is apparent in this maturity segment, with ISs close to 85 percent. The fact that Germany's contribution relative to Italy's is lowered, partly contradicts the finding of Dufour and Nguyen (2013). Although the medium-term German benchmarks are very liquid, driven by Eurex's German Bund futures market, they fail to overwhelmingly lead price discovery during the crisis.

The ISs of periphery countries at the 10-year maturity exceed by far those of the core countries in the crisis period. This finding contradicts that of Dufour and Nguyen (2013) who show that ISs are equally shared at the 10-year maturity due to stronger competition for price discovery at this maturity segment. ISs for ES30 decline by up to 45 percent but increase for IT30 confirming the findings of Dufour and Nguyen (2013) who show that the Italian 30-year benchmark is the most informative in the eurozone. In all, it is evident that periphery countries are the leading contributors to price discovery in the crisis and their dominance is mainly manifested in the 10- and 30-year benchmarks. Table 5 presents the Gonzalo-Granger permanent-transitory (PT) model estimates which are in line with those of Hasbrouck's ISs.

We conclude that price discovery can be enhanced in the crisis regardless of price and liquidity squezees that take place during periods of stress, however, there is no particular market that dominates across all maturity segments. It is recognized that country-specific liquidity varies substantially between calm and crisis periods. We shed light on liquidity's behavior amid crisis in the next section on market quality.

4.2. Market quality

In this section we study market quality in the eurozone sovereign bond market in periods of calmness and turbulence. The notion of market quality is important for policy and for designing reforms in trading systems with the aim to improve market liquidity. Table 6 depicts a t-test of equal means for a 4-month event window spanning the dates from July 2009 to October 2009 (pre-crisis) and from November 2009 to February 2010 (crisis). At a first glance, all spread measures widen for bonds of longer maturities both in the crisis and pre-crisis, confirming findings from earlier studies that shorter-term bonds are more liquid and are prefered over longer-term bonds (Pasquariello and Vega, 2009). We document statistically significant increases in all spread measures in the crisis period for Spain across the maturity spectrum and a statistically significant decline in quoted depth, with the exception of the 30-year benchmark. The increase in spreads suggests that liquidity provision was impaired during the crisis. The 2-year Spanish quoted spread increases remarkably by 120 percent in the crisis. The fact that quoted depth falls significantly whilst spreads widen indicates that investors were reluctant to take risks. The market quality index declines significantly between the pre-crisis and crisis period for all maturity segments indicating a deterioration of market quality due to wider spreads.

Results for Germany are mixed as spreads decline for the 5- and 30-year benchmarks whilst they exhibit mixed behavior for the shorter and medium maturity segments. The market quality index improves significantly for the 5-, 10-, and 30-year bonds whereas it drops for the shorter-term 2-year benchmark, though insignificantly. All Italian spreads, regardless of their measurement in absolute or relative terms, increase in the crisis as a result of risk aversion in the Italian market. Similar to the Spanish market, most of the adjustment is realized by the 2-year quoted and relative spread which rise to 135 percent and 200 percent respectively, in the crisis. Quoted depth declines with the exception of the 30-year benchmark which proves to be less vulnerable to massive sell-offs that took place at the time. This suggests that part of the rise in spreads for the 30-year bond can be attributed to the fact that spreads tend to widen as transaction size increases. Overall, market quality improves in the Italian market as the decrease in quoted depths dominates the increase in spreads in the crisis.

We note an increase in transaction costs for the Dutch market across the 2-, 5-, and 10-year maturity bucket, however, such increases are unambiguously statistically significant only for the 10-year benchmark. Quoted depth drops for the 2-year instrument whereas it increases for the rest of longer-term maturity bonds, showing an increased interest for bonds of higher credit ratings in the crisis. It seems that the market was able to handle a larger trading volume than during normal times. We report consistent increases in the market quality index for all maturities in the crisis, though not always statistically significant, which indicate that market quality is improved as quoted depth increases outweigh the corresponding spread increases. Figure 1 depicts the relative spread liquidity measure across the four time-to-maturity groups for all four countries during this period.

Table 7 depicts a t-test of equal means for a 14-month event window spanning the dates from September 2008 to October 2009 (pre-crisis) and from November 2009 to December 2010 (crisis). There is a common pattern in Italy and Spain where spreads increase for the 2- and 5-year maturities and decrease for the longer-term 10- and 30-year bonds. Investors see the longer term bonds as relatively safer bets as compared to the shorter term 2- and 5-year bonds and, as a result, the liquidity of the longer term bonds improves when the crisis hits. Investors in the longer term bonds are more likely to be buy-and-hold investors with longer investment horizons. These investors may be hoping that the longer term bonds will recover by the time the crisis ends or may see the crisis as a buying opportunity. The Italian 2-year quoted and relative spreads widen by 71 percent and 86 percent respectively, on stressful days. We get mixed results for the market quality index which seems to improve significantly for the Spanish and Italian 30-year bonds but to decline for the 2-year instrument. This result shows that the 2-year benchmark is more vulnerable to liquidity drops (spread increases and depth declines) than the 30-year bond.

Results for Germany and the Netherlands are more clear cut. We document highly statistically significant decreases in spread measures in both countries across the maturity spectrum during the crisis along with quoted depth increases, which lead to a clear improvement in market quality as judged by the highly statistically significant increases in the market quality index. The increase in trading activity during the turbulence suggests that these markets' liquidity was not impaired. A visual illustration of relative spreads over this longer sample period is provided in Figure 2.

To determine whether the differences in spreads between the pre-crisis and crisis periods are due to changes in the bond attributes described in Section 3.1, we run regressions as per Equation (7). The relationship between liquidity and volatility is well documented. A market with higher liquidity tends to have lower price volatility (Black, 1971; Harris, 1994; Bessembinder and Kaufman, 1997; Li and Wu, 2006; Chordia et al., 2001,2002). The relationship between liquidity and trading volume is also well understood. Generally speaking, assets with high trading volumes will exhibit narrower spreads than those that are infrequently traded. When an asset has a low trading volume, it is considered illiquid as it is not easily converted to cash. In this case brokers will normally require more compensation resulting in larger spreads. Trading volume is regarded as one of the most influential determinants of an asset's bid-ask spread (Stoll, 2000).

Both the level of liquidity and liquidity risk are priced. Empirical studies show that the effects of liquidity on asset prices are statistically and economically significant, even after controlling for traditional risk measures and asset characteristics (Amihud et al., 2005; Kinateder and Wagner, 2017). The lower the price, the higher the bid-ask spread other things equal. The reason for this is illiquidity. The relationship between liquidity and sovereign credit risk is also well documented and it has been shown that liquidity influences sovereign risk and risk premia. A relevant discussion is provided by Augustin (2018).

Table 8 shows the regression results for the 4-month event window. We use HAC (Newey-West) standard errors for controlling the long-run covariance estimation. Differences in CDS spreads significantly impact on spread-based liquidity across all maturities in most cases, especially for Spain and Italy whose long term debt sustainability was challenged during the crisis, reflecting their increased sovereign credit risk. Realized volatility proves to be the second most contributing factor exhibiting a significant and positive relationship with spread changes in Spain and Italy, whilst its importance is lowered in the German and Dutch markets. This makes perfect sense as volatility in the bond markets of periphery countries increased during the crisis whereas it declined for those of core countries across the maturity spectrum (a discussion is provided by O'Sullivan and Papavassiliou, 2019;2020). Midquote price is the third most contributing factor in the liquidity of European bond markets and exhibits a significant and positive relationship in various instances (especially in Italy) in contrast to previous empirical evidence. Differences in trading volume impact spread differentials in a negative though insignificant manner in most cases, however, they exert significant influence on Dutch and Spanish spreads.

Table 9 shows the regression results for the 14-month event window. Realized volatility becomes the most contributing factor in both core and periphery countries. During this longer 14-month event window European bond markets became more volatile as a result of various important macroeconomic events, such as bailout packages and credit rating downgrades which led to higher selling pressure and portfolio rebalancing. Differences in CDS spreads continue to exert significant influence on the liquidity of periphery markets reflecting changes in their credit rating profile as we move from the tranquil to the more turbulent times. Midquote price appears with a reverse sign in almost all maturities showing that decreases in spreads are mainly attributed to decreases in price. Finally, trading volume gains importance in all countries and is clearly associated with an improvement in liquidity. This finding is in line with theoretical predictions of microstructure models such as that of Kyle's (1985), which suggest that volume is driven by uninformed trading which reduces adverse selection risk.

To sum up, the short-term impact of the sovereign debt crisis on the European bond market's liquidity was adverse. Spreads in all markets, regardless of their measurement in absolute or relative form, increased during the crisis as trading became more expensive due to heightened liquidity risk. However, there was a surge in trading activity due to massive liquidations of bonds of lower credit ratings as global investors were seeking for safer investment opportunities elsewhere, including in bonds of more creditworthy countries within the euro-area. This led to an enhanced market quality for Germany, Italy, and the Netherlands, as the increase in quoted depth liquidity overwhelmed the increase in spread-based liquidity.

The longer-term impact of the crisis on the bond market's liquidity was more clear cut for Germany and the Netherlands. It seems that the provision of financial help to the distressed economies of Greece and Ireland by the European Union and the IMF, along with the European Central Bank's implementation of the Securities Market Programme (SMP), significantly improved liquidity in eurozone's debt securities markets. German and Dutch spreads dropped significantly during the crisis whilst quoted depth increased due to investors' declined risk appetite and flights to safety toward benchmarks of higher credit ratings. These findings are in line with the theoretical predictions by Vayanos (2004). In Vayanos's model assets differ in their liquidity and liquidity premia are generated that are time-varying and increasing with volatility. It follows that times of high volatility are associated with flights to liquidity. The author shows that during crisis periods investors' effective risk aversion increases leading to flights to quality in the sense that the risk premium required by investors increases. It follows that illiquid assets become riskier and their market beta increases.

The longer-term impact on the liquidity of the periphery countries of Italy and Spain was less clear cut. Market quality improved for the 30-year buy-and-hold bonds but deteriorated for bonds of shorter maturities mainly due to wider spreads. This finding provides an indication of investor optimism about the long-term prosperity and economic stability in the euro-area, and in particular about the long-term prospects of distressed eurozone economies. However, at the same time it reveals a lack of eagerness to make major investments in the short term, not until fears about eurozone's fragility subside.

5. Conclusions

This study investigates whether price discovery is enhanced for euro-area sovereign benchmark bonds from core and periphery countries during the sovereign debt crisis period, compared to the calm period that preceded it. The recent availability of high-frequency data on secondary market trading in the European sovereign bond market allows the in-depth examination of the ways prices are formed in the marketplace. Our intention is to demonstrate how the bond markets in Europe are interlinked during periods of increased uncertainty. To the best of our knowledge this is the first study that has addressed this issue. We provide evidence that on average, the price discovery process improves in the crisis especially for the distressed periphery eurozone countries, showing that new market information is impounded into prices in a more robust manner. We note that no market, either from the core or the periphery region, dominates the price formation process across the maturity spectrum.

We also examine changes in market quality surrounding the eurozone sovereign debt crisis. Measures of liquidity tend to behave differently in periods of stress than they do under normal periods. Moreover, during periods of increased uncertainty, the informational role of individual factors that determine market liquidity changes may break down. We find market quality net improvements in most cases when quoted depths are considered, using both a short and a long event window surrounding the start of the crisis. This finding indicates that market quality can improve during crisis times and market liquidity can be enhanced, especially when appropriate measures are taken by regulators to resolve the crisis. We hope that these findings will provide avenues for future research in this area.

There are a number of takeaways for policy making from this analysis. It is a well-known fact that liquidity cannot be taken for granted and can dry-up during crisis periods leading to financial system failures. Financial market structures compete for liquidity in today's competitive financial landscape and thus the need to understand the mechanics of market liquidity has become a priority more than ever. A highly liquid market can enhance investors' confidence and can have a positive impact on its resiliency against financial market shocks, thus reducing systemic risk in the economy. Market liquidity is important for central banks as their main goal is the stability of the financial system. In markets where liquidity is abundant, price discovery becomes more efficient and thus asset prices are more informative for monetary policy. The liquidity of sovereign bond markets, in particular, is of paramount importance for central banks as it affects the effectiveness of their monetary policy. Central banks also have a genuine interest in the sovereign bond market and in the types and maturities of bonds issued as these characteristics affect liquidity in the secondary market and the liquidity premium offered to investors in the primary market[1] (more detailed information can be found in the report of the study group established by the central banks of the Group of Ten countries, which was published by the Bank of International Settlements on 3 May 1999).

The factors that determine liquidity during tranquil periods may differ substantially from those that prevail under periods of stress. Regulators should put in place adequate risk management systems in order to make sure that there is sufficient liquidity in the market and that market participants are not forced into distress selling that would magnify market tensions. Regulators and policymakers should also strive to strengthen market infrastructures so as to prevent market failures in crisis periods. The European sovereign debt crisis as a notable example induced various measures which aimed at improving trading mechanisms, settlement arrangements, and the mitigation of credit and counterparty risk. Regulators must be in a position to identify the market segments in the bond market that dominate the price discovery process during crisis periods. In doing so, they would be able to

[1]Liquidity and price discovery are two important functions for asset pricing in financial markets (O'Hara, 2003)

isolate the mechanics through which credit risk information is transmitted throughout the financial system that can lead to systemic breakdowns of liquidity. These actions will ultimately enhance both price discovery and market quality.

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Table 1: Descriptive statistics. Panel A shows the Mean, Maximum, Minimum, Standard Deviation, Skewness and Kurtosis values of the midquote prices of benchmark bonds of core (Germany (DE) and the Netherlands (NL)) and periphery (Spain (ES) and Italy (IT)) eurozone countries during the pre-crisis period (January 2008 - October 2009) and across the 2-, 5-, 10-, and 30- year maturity segments. Panel B shows the corresponding statistics for the crisis period (November 2009 - December 2010). Midquote prices at the 5-minute frequency are artificially constructed using linear interpolation techniques applied around the endpoints of the sampling intervals. The last two columns show the Augmented Dickey–Fuller unit root test (ADF) employing the Schwarz information criterion (SIC) at both levels and first differences. *** Denotes statistical significance at the 1 percent level.

Panel A: Pre-crisis								
Price	**Mean**	**Max.**	**Min.**	**S.D.**	**Skew.**	**Kurt.**	**ADF (SIC) Levels**	**ADF (SIC) 1st Differences**
DE2	101.67	104.75	97.16	1.78	0.03	2.07	-0.05	-224.43***
DE5	102.78	108.60	95.07	3.70	-0.17	1.57	-0.04	-223.55***
DE10	102.94	111.31	93.09	3.78	0.006	2.29	-0.06	-225.86***
DE30	101.70	126.20	85.96	8.61	0.29	2.32	-0.62	-219.89***
ES2	100.95	104.84	97.71	1.38	-0.30	2.50	-0.26	-227.85***
ES5	101.69	107.29	95.90	2.87	0.01	2.07	-0.11	-226.27***
ES10	100.75	107.44	91.53	3.40	-0.006	2.40	-0.14	-225.88***
ES30	103.29	123.62	86.38	5.34	0.47	4.07	-0.41	-220.88***
IT2	101.36	104.93	96.71	2.16	-0.31	1.88	-0.22	-226.46***
IT5	100.90	105.81	96.11	1.95	-0.16	2.61	-0.10	-227.07***
IT10	100.60	106.13	93.05	2.35	-0.21	3.08	-0.21	-226.43***
IT30	99.63	115.25	80.04	7.17	-0.38	3.34	-1.02	-220.82***
NL2	101.17	104.51	97.92	1.38	-0.13	2.97	-0.09	-224.56***
NL5	99.80	101.79	97.28	1.33	-0.04	1.70	-0.62	-164.16***
NL10	102.29	108.82	91.03	3.15	-0.58	3.43	-0.24	-225.12***
NL30	98.66	119.02	84.99	9.46	0.63	2.14	-0.99	-219.64***
Panel B: Crisis								
Price	**Mean**	**Max.**	**Min.**	**S.D.**	**Skew.**	**Kurt.**	**ADF (SIC) Levels**	**ADF (SIC) 1st Differences**
DE2	100.68	101.55	99.26	0.43	-0.86	4.05	-0.20	-178.20***
DE5	106.27	110.76	98.46	2.97	-0.41	2.20	-0.22	-178.70***
DE10	106.47	117.45	94.27	5.15	-0.23	2.36	-0.55	-179.37***
DE30	118.93	143.84	97.69	9.24	0.53	2.70	-0.52	-177.50***
ES2	100.43	104.08	94.93	2.10	-0.62	2.31	-0.79	-131.93***
ES5	101.04	107.21	92.47	3.09	-0.30	3.07	-0.40	-179.91***
ES10	101.67	107.50	91.96	3.34	-0.63	2.90	-0.45	-179.78***
ES30	98.24	118.05	74.50	8.56	0.18	3.02	-1.04	-175.70***
IT2	101.94	104.55	96.38	1.86	-0.47	2.16	-0.35	-180.02***
IT5	102.30	106.51	96.33	1.74	-0.77	3.76	-0.36	-179.66***
IT10	102.80	108.51	91.54	2.84	-1.04	5.46	-0.45	-179.82***
IT30	102.81	115.60	85.11	5.96	-0.33	3.82	-0.75	-175.53***
NL2	102.28	103.49	101.11	0.55	0.08	2.26	-0.21	-180.45***
NL5	103.36	106.20	99.80	1.72	-0.32	1.75	-0.94	-187.94***
NL10	106.89	114.47	99.46	2.71	0.26	2.71	-0.14	-179.04***
NL30	111.85	139.83	95.79	11.34	0.39	2.13	-0.70	-177.73***

Table 2: Panel A shows Hasbrouck's Information Shares (ISs) within periphery (Spain (ES) and Italy (IT)) eurozone sovereign bond markets. Panel B shows the corresponding results for core (Germany (DE) and the Netherlands (NL)) eurozone sovereign bond markets. The pre-crisis refers to the period from January 2008 to October 2009 whilst the crisis refers to the period from November 2009 to December 2010. The dataset includes benchmark fixed coupon-bearing bonds within four time-to-maturity groups: 2-, 5-, 10-, and 30-year. Price measures are artificially constructed from linearly interpolated 5-minute quote midpoints. ΔIS denotes the percentage changes in Information Shares between the pre-crisis and crisis periods.

Panel A - within periphery						
	Pre-crisis		Crisis			
Benchmarks	IS				ΔIS	ΔIS
	ES	**IT**	**ES**	**IT**	**ES**	**IT**
ES2-IT2	0.468	0.532	0.969	0.031	107.05	-94.17
ES5-IT5	0.369	0.631	0.243	0.757	-34.15	19.97
ES10-IT10	0.313	0.687	0.505	0.495	61.34	-27.95
ES30-IT30	0.719	0.281	0.368	0.632	-48.82	124.91
Panel B - within core						
	Pre-crisis		Crisis			
Benchmarks	IS				ΔIS	ΔIS
	DE	**NL**	**DE**	**NL**	**DE**	**NL**
DE2-NL2	0.347	0.653	0.053	0.947	-84.73	45.02
DE5-NL5	0.005	0.995	0.038	0.962	660.00	-3.32
DE10-NL10	0.699	0.301	0.251	0.749	-64.09	148.84
DE30-NL30	0.691	0.309	0.715	0.285	3.47	-7.77

Table 3: Panel A shows Gonzalo and Granger permanent-transitory (PT) model within periphery (Spain (ES) and Italy (IT)) eurozone sovereign bond markets. Panel B shows the corresponding results for core (Germany (DE) and the Netherlands (NL)) eurozone sovereign bond markets. The pre-crisis refers to the period from January 2008 to October 2009 whilst the crisis refers to the period from November 2009 to December 2010. The dataset includes benchmark fixed coupon-bearing bonds within four time-to-maturity groups: 2-, 5-, 10-, and 30-year. Price measures are artificially constructed from linearly interpolated 5-minute quote midpoints. ΔPT denotes the percentage changes in each market's contribution to the common factor between the pre-crisis and crisis periods.

Panel A - within periphery						
	Pre-crisis		Crisis			
Benchmarks	PT				ΔPT	ΔPT
	ES	**IT**	**ES**	**IT**	**ES**	**IT**
ES2-IT2	0.321	0.679	0.993	0.007	209.35	-98.97
ES5-IT5	0.487	0.513	0.361	0.639	-25.87	24.56
ES10-IT10	0.500	0.500	0.643	0.357	28.60	28.60
ES30-IT30	0.944	0.056	0.470	0.530	-50.21	846.43
Panel B - within core						
	Pre-crisis		Crisis			
Benchmarks	PT				ΔPT	ΔPT
	DE	**NL**	**DE**	**NL**	**DE**	**NL**
DE2-NL2	0.393	0.607	0.002	0.998	-99.49	64.42
DE5-NL5	0.001	0.999	0.011	0.989	1,000.00	-1.00
DE10-NL10	0.852	0.148	0.295	0.705	-65.38	376.35
DE30-NL30	0.768	0.232	0.718	0.282	-6.51	21.55

Table 4: Hasbrouck's Information Shares (ISs) between periphery (Spain (ES) and Italy (IT)) and core (Germany (DE) and the Netherlands (NL)) eurozone sovereign bond markets. The pre-crisis refers to the period from January 2008 to October 2009 whilst the crisis refers to the period from November 2009 to December 2010. The dataset includes benchmark fixed coupon-bearing bonds within four time-to-maturity groups: 2-, 5-, 10-, and 30-year. Price measures are artificially constructed from linearly interpolated 5-minute quote midpoints. ΔIS denotes the percentage changes in Information Shares between the pre-crisis and crisis periods.

	Pre-crisis		Crisis			
Benchmarks	IS				ΔIS	ΔIS
	ES	**DE**	**ES**	**DE**	**ES**	**DE**
ES2-DE2	0.669	0.331	0.422	0.578	-36.92	74.62
ES5-DE5	0.564	0.436	0.484	0.516	-14.18	18.35
ES10-DE10	0.314	0.686	0.841	0.159	167.83	-76.82
ES30-DE30	0.641	0.359	0.350	0.650	-45.40	81.06
	Pre-crisis		Crisis			
Benchmarks	IS				ΔIS	ΔIS
	ES	**NL**	**ES**	**NL**	**ES**	**NL**
ES2-NL2	0.637	0.363	0.393	0.607	-38.40	67.22
ES5-NL5	0.032	0.968	0.108	0.892	237.50	-7.85
ES10-NL10	0.555	0.445	0.628	0.372	13.15	-16.40
ES30-NL30	0.789	0.211	0.598	0.402	-24.21	90.52
	Pre-crisis		Crisis			
Benchmarks	IS				ΔIS	ΔIS
	IT	**DE**	**IT**	**DE**	**IT**	**DE**
IT2-DE2	0.665	0.335	0.102	0.898	-84.66	168.06
IT5-DE5	0.759	0.241	0.829	0.171	9.22	-29.05
IT10-DE10	0.479	0.521	0.781	0.219	63.05	-57.97
IT30-DE30	0.455	0.545	0.468	0.532	2.86	-2.39
	Pre-crisis		Crisis			
Benchmarks	IS				ΔIS	ΔIS
	IT	**NL**	**IT**	**NL**	**IT**	**NL**
IT2-NL2	0.455	0.545	0.003	0.997	-99.34	82.94
IT5-NL5	0.003	0.997	0.152	0.848	4966.67	-14.94
IT10-NL10	0.642	0.358	0.541	0.459	-15.73	28.21
IT30-NL30	0.540	0.460	0.688	0.312	27.41	-32.17

Table 5: Gonzalo and Granger permanent-transitory (PT) model between periphery (Spain (ES) and Italy (IT)) and core (Germany (DE) and the Netherlands (NL)) eurozone sovereign bond markets. The pre-crisis refers to the period from January 2008 to October 2009 whilst the crisis refers to the period from November 2009 to December 2010. The dataset includes benchmark fixed coupon-bearing bonds within four time-to-maturity groups: 2-, 5-, 10-, and 30-year. Price measures are artificially constructed from linearly interpolated 5-minute quote midpoints. ΔPT denotes the percentage changes in each market's contribution to the common factor between the pre-crisis and crisis periods.

	Pre-crisis		Crisis			
Benchmarks	PT				ΔPT	ΔPT
	ES	**DE**	**ES**	**DE**	**ES**	**DE**
ES2-DE2	0.719	0.281	0.401	0.599	-44.23	113.17
ES5-DE5	0.545	0.455	0.346	0.654	-36.51	43.74
ES10-DE10	0.093	0.907	0.908	0.092	876.34	-89.86
ES30-DE30	0.455	0.545	0.168	0.832	-63.08	52.66
	Pre-crisis		Crisis			
Benchmarks	PT				ΔPT	ΔPT
	ES	**NL**	**ES**	**NL**	**ES**	**NL**
ES2-NL2	0.636	0.364	0.342	0.658	-46.23	80.77
ES5-NL5	0.021	0.979	0.011	0.989	-47.62	1.02
ES10-NL10	0.630	0.370	0.981	0.019	55.71	-94.86
ES30-NL30	0.679	0.321	0.314	0.686	-53.76	113.71
	Pre-crisis		Crisis			
Benchmarks	PT				ΔPT	ΔPT
	IT	**DE**	**IT**	**DE**	**IT**	**DE**
IT2-DE2	0.745	0.255	0.249	0.751	-66.58	194.51
IT5-DE5	0.638	0.362	0.863	0.137	35.27	-62.15
IT10-DE10	0.234	0.766	0.712	0.288	204.27	-62.40
IT30-DE30	0.070	0.930	0.037	0.963	-47.14	3.55
	Pre-crisis		Crisis			
Benchmarks	PT				ΔPT	ΔPT
	IT	**NL**	**IT**	**NL**	**IT**	**NL**
IT2-NL2	0.433	0.567	0.009	0.991	-97.92	74.78
IT5-NL5	0.015	0.985	0.013	0.987	-13.33	0.20
IT10-NL10	0.577	0.423	0.525	0.475	-9.01	12.29
IT30-NL30	0.555	0.445	0.601	0.399	8.29	-10.34

Table 6: Short-term effects on market quality for Spain (ES), Germany (DE), Italy (IT), and the Netherlands (NL). The table depicts a t-test of equal means over a 4-month event window spanning the dates from July 2009 to October 2009 (pre-crisis) and from November 2009 to February 2010 (crisis). The dataset includes benchmark fixed coupon-bearing bonds within four time-to-maturity groups: 2-, 5-, 10-, and 30-year. Quoted spread is defined as the difference between the simple average of the three best ask prices and bid prices. Relative spread is defined as the best bid-ask spread divided by the midpoint of the bid and ask quotes. Best bid-ask spread is defined as the difference between the best ask quote and the best bid quote. Euro depth is the sum of the euro value of the bonds bid and offered at the best quotes. Quoted depth is defined as the quantity of securities bid or offered for sale at the posted bid and offer prices. Market quality index is defined as half quoted depth divided by the relative spread. P denotes the pre-crisis period and C denotes the crisis period. *, **, and *** denote statistical significance at the 10, 5, and 1 percent level, respectively.

Panel A: Spain						
Variable	P	C	C-P	C-P (%)	t-test	p-value
ES2						
Quoted spread (€)	0.0868	0.1917	0.1049	120.85	-6.35***	0.000
Relative spread (%)	0.0007	0.0015	0.0008	114.29	-7.34***	0.000
Best bid-ask spread (€)	0.0727	0.1548	0.0821	112.93	-7.38***	0.000
Euro depth (billion €)	3.70	3.06	-0.64	-17.30	5.17***	0.000
Quoted depth (million €)	36.20	29.80	-6.40	-17.68	5.20***	0.000
MQI (billion €)	26.50	16.80	-9.70	-36.60	6.64***	0.000
ES5						
Quoted spread (€)	0.1259	0.2250	0.0991	78.71	-6.58***	0.000
Relative spread (%)	0.0010	0.0019	0.0009	90.00	-6.68***	0.000
Best bid-ask spread (€)	0.1092	0.1925	0.0833	76.28	-6.61***	0.000
Euro depth (billion €)	3.08	2.82	-0.26	-8.44	3.02***	0.003

Quoted depth (million €)	29.68	27.32	-2.36	-7.95	2.79***	0.006
MQI (billion €)	15.52	11.92	-3.60	-23.20	3.42***	0.001
ES10						
Quoted spread (€)	0.1638	0.2492	0.0854	52.14	-5.73***	0.000
Relative spread (%)	0.0014	0.0021	0.0007	50.00	-5.31***	0.000
Best bid-ask spread (€)	0.1452	0.2183	0.0731	50.34	-5.40***	0.000
Euro depth (billion €)	3.00	2.59	-0.41	-13.67	6.23***	0.000
Quoted depth (million €)	28.95	24.89	-4.06	-14.02	6.45***	0.000
MQI (billion €)	11.52	9.16	-2.36	-20.49	3.24***	0.000
ES30						
Quoted spread (€)	0.4309	0.5236	0.0927	21.51	-4.76***	0.000
Relative spread (%)	0.0036	0.0046	0.0010	27.78	-5.43***	0.000
Best bid-ask spread (€)	0.3796	0.4640	0.0844	22.23	-4.79	0.000
Euro depth (billion €)	1.31	1.34	0.03	2.29	-0.86	0.390
Quoted depth (million €)	12.42	13.19	0.77	6.20	-2.18**	0.031
MQI (billion €)	1.81	1.66	-0.15	-8.29	2.07**	0.040
Panel B: Germany						
Variable	P	C	C-P	C-P (%)	*t*-test	*p*-value
DE2						
Quoted spread (€)	0.2178	0.0714	-0.1464	-67.22	2.03**	0.044
Relative spread (%)	0.0005	0.0005	0.0000	0.00	-0.30	0.767
Best bid-ask spread (€)	0.0541	0.0545	0.0004	0.74	-0.19	0.848

Euro depth (billion €)	2.65	2.54	-0.11	-4.15	0.81	0.417
Quoted depth (million €)	26.04	25.17	-0.87	-3.34	0.62	0.535
MQI (billion €)	35.59	32.94	-2.65	-7.45	1.03	0.303
DE5						
Quoted spread (€)	0.1062	0.1061	-0.0001	-0.09	-0.03	0.977
Relative spread (%)	0.0007	0.0006	-0.0001	-14.29	3.26***	0.001
Best bid-ask spread (€)	0.0795	0.0690	-0.0105	-13.21	3.43***	0.001
Euro depth (billion €)	2.24	2.56	0.32	14.29	-3.02***	0.003
Quoted depth (million €)	21.14	24.41	3.27	15.47	-3.22***	0.001
MQI (billion €)	14.97	20.69	5.72	38.21	-6.00***	0.000
DE10						
Quoted spread (€)	0.1133	0.1116	-0.0017	-1.50	0.29	0.773
Relative spread (%)	0.0008	0.0008	0.0000	0.00	-0.19	0.851
Best bid-ask spread (€)	0.0810	0.0819	0.0009	1.11	-0.28	0.780
Euro depth (billion €)	2.00	2.41	0.41	20.50	-5.17***	0.000
Quoted depth (million €)	19.06	22.89	3.83	20.09	-5.20***	0.000
MQI (billion €)	13.47	16.40	2.93	21.75	-4.05***	0.000
DE30						
Quoted spread (€)	0.5154	0.4643	-0.0511	-9.91	3.64***	0.000
Relative spread (%)	0.0038	0.0034	-0.0004	-10.53	3.92***	0.000
Best bid-ask spread (€)	0.4059	0.3773	-0.0286	-7.05	2.38**	0.018

Euro depth (million €)	930.44	920.08	-10.36	-1.11	0.41	0.681
Quoted depth (million €)	8.75	8.28	-0.47	-5.37	2.19**	0.030
MQI (billion €)	1.26	1.36	0.10	7.94	-1.67*	0.096
Panel C: Italy						
Variable	P	C	C-P	C-P (%)	*t*-test	*p*-value
IT2						
Quoted spread (€)	0.0317	0.0745	0.0428	135.02	-5.19***	0.000
Relative spread (%)	0.0002	0.0006	0.0004	200.00	-4.52***	0.000
Best bid-ask spread (€)	0.0252	0.0580	0.0328	130.16	-4.49***	0.000
Euro depth (billion €)	2.51	2.22	-0.29	-11.55	2.93***	0.004
Quoted depth (million €)	24.27	21.57	-2.70	-11.12	2.82***	0.005
MQI (billion €)	80.57	62.87	-17.70	-21.97	2.29**	0.023
IT5						
Quoted spread (€)	0.0806	0.1240	0.0434	53.85	-2.81***	0.006
Relative spread (%)	0.0006	0.0010	0.0004	66.67	-2.80***	0.006
Best bid-ask spread (€)	0.0641	0.1027	0.0386	60.22	-2.83***	0.005
Euro depth (billion €)	2.43	2.36	-0.07	-2.88	0.88	0.378
Quoted depth (million €)	23.55	22.84	-0.71	-3.01	0.90	0.371
MQI (billion €)	43.25	56.17	12.92	29.87	-1.66*	0.100
IT10						
Quoted spread (€)	0.1880	0.2026	0.0146	7.77	-1.24	0.217
Relative spread (%)	0.0014	0.0015	0.0001	7.14	-0.82	0.415

Best bid-ask spread (€)	0.1430	0.1512	0.0082	5.73	-0.89	0.372
Euro depth (billion €)	2.36	2.10	-0.26	-11.02	3.53***	0.001
Quoted depth (million €)	23.11	20.45	-2.66	-11.51	3.67***	0.000
MQI (billion €)	14.16	14.56	0.40	2.82	-0.09	0.924
IT30						
Quoted spread (€)	0.4391	0.5093	0.0702	15.99	-3.32***	0.001
Relative spread (%)	0.0036	0.0038	0.0002	5.56	-1.98**	0.049
Best bid-ask spread (€)	0.3580	0.4056	0.0476	13.30	-3.55***	0.001
Euro depth (million €)	932.20	1,159.43	227.23	24.38	-5.92***	0.000
Quoted depth (million €)	9.27	10.89	1.62	17.48	-4.76***	0.000
MQI (billion €)	1.46	1.66	0.20	13.70	-2.75***	0.007
Panel D: Netherlands						
Variable	P	C	C-P	C-P (%)	*t*-test	*p*-value
NL2						
Quoted spread (€)	0.0591	0.0804	0.0213	36.04	-1.81*	0.072
Relative spread (%)	0.0004	0.0004	0.0000	0.00	-0.39	0.698
Best bid-ask spread (€)	0.0445	0.0454	0.0009	2.02	-0.40	0.686
Euro depth (billion €)	3.60	3.31	-0.29	-8.06	2.96***	0.003
Quoted depth (million €)	35.20	32.34	-2.86	-8.13	2.99***	0.003
MQI (billion €)	47.84	48.86	1.02	2.13	-0.13	0.895
NL5						
Quoted spread (€)	0.1254	0.1403	0.0149	11.88	-1.99**	0.047

Relative spread (%)	0.0010	0.0010	0.0000	0.00	-0.59	0.555
Best bid-ask spread (€)	0.1002	0.1048	0.0046	4.59	-0.86	0.392
Euro depth (billion €)	3.17	3.38	0.21	6.62	-2.03**	0.044
Quoted depth (million €)	31.76	33.49	1.73	5.45	-1.61	0.109
MQI (billion €)	17.06	19.91	2.85	16.71	-2.65***	0.009
NL10						
Quoted spread (€)	0.1550	0.1801	0.0251	16.19	-2.61***	0.010
Relative spread (%)	0.0012	0.0013	0.0001	8.33	-1.79*	0.074
Best bid-ask spread (€)	0.1265	0.1389	0.0124	9.80	-1.97**	0.051
Euro depth (billion €)	3.14	3.27	0.13	4.14	-1.33	0.186
Quoted depth (million €)	30.14	31.20	1.06	3.52	-1.10	0.271
MQI (billion €)	13.62	14.55	0.93	6.83	-0.87	0.384
NL30						
Quoted spread (€)	0.5024	0.3967	-0.1057	-21.04	7.00***	0.000
Relative spread (%)	0.0042	0.0034	-0.0008	-19.05	6.47***	0.000
Best bid-ask spread (€)	0.4377	0.3477	-0.0900	-20.56	6.85***	0.000
Euro depth (billion €)	1.22	1.27	0.05	4.10	-2.00**	0.047
Quoted depth (million €)	11.79	12.58	0.79	6.70	-4.27***	0.000
MQI (billion €)	1.46	1.99	0.53	36.30	-9.64***	0.000

Table 7: Long-term effects on market quality for Spain (ES), Germany (DE), Italy (IT), and the Netherlands (NL). The table depicts a t-test of equal means over a 14-month event window spanning the dates from September 2008 to October 2009 (pre-crisis) and from November 2009 to December 2010 (crisis). The dataset includes benchmark fixed coupon-bearing bonds within four time-to-maturity groups: 2-, 5-, 10-, and 30-year. Quoted spread is defined as the difference between the simple average of the three best ask prices and bid prices. Relative spread is defined as the best bid-ask spread divided by the midpoint of the bid and ask quotes. Best bid-ask spread is defined as the difference between the best ask quote and the best bid quote. Euro depth is the sum of the euro value of the bonds bid and offered at the best quotes. Quoted depth is defined as the quantity of securities bid or offered for sale at the posted bid and offer prices. Market quality index is defined as half quoted depth divided by the relative spread. P denotes the pre-crisis period and C denotes the crisis period. *, **, and *** denote statistical significance at the 10, 5, and 1 percent level, respectively

Panel A: Spain						
Variable	P	C	C-P	C-P (%)	t-test	p-value
ES2						
Quoted spread (€)	0.2378	0.3539	0.1161	48.82	-5.29***	0.000
Relative spread (%)	0.0019	0.0029	0.0010	52.63	-6.30***	0.000
Best bid-ask spread (€)	0.1961	0.2870	0.0909	46.35	-6.10***	0.000
Euro depth (billion €)	2.78	2.61	-0.17	-6.12	2.89***	0.004
Quoted depth (million €)	27.37	25.92	-1.45	-5.30	2.55**	0.011
MQI (billion €)	12.81	9.96	-2.85	-22.25	3.52***	0.001
ES5						
Quoted spread (€)	0.3534	0.4009	0.0475	13.44	-2.08**	0.037
Relative spread (%)	0.0029	0.0034	0.0005	17.24	-3.02***	0.003
Best bid-ask spread (€)	0.2949	0.3442	0.0493	16.72	-2.65***	0.008
Euro depth (billion €)	2.57	2.46	-0.11	-4.28	2.53**	0.012

Quoted depth (million €)	24.84	24.28	-0.56	-2.25	2.53**	0.012
MQI (billion €)	7.86	7.16	-0.70	-8.91	1.37	0.170
ES10						
Quoted spread (€)	0.5244	0.4677	-0.0567	-10.81	1.87*	0.062
Relative spread (%)	0.0045	0.0040	-0.0005	-11.11	1.74*	0.083
Best bid-ask spread (€)	0.4462	0.4057	-0.0405	-9.08	1.70*	0.090
Euro depth (billion €)	2.46	2.47	0.01	0.41	-0.05	0.962
Quoted depth (million €)	24.36	24.20	-0.16	-0.66	0.47	0.637
MQI (billion €)	5.39	5.58	0.19	3.53	-0.36	0.719
ES30						
Quoted spread (€)	0.9592	0.7634	-0.1958	-20.41	6.82***	0.000
Relative spread (%)	0.0083	0.0070	-0.0013	-15.66	3.55***	0.000
Best bid-ask spread (€)	0.8654	0.6784	-0.1870	-21.61	5.47***	0.000
Euro depth (billion €)	1.13	1.21	0.08	7.08	-3.93***	0.000
Quoted depth (million €)	10.78	12.33	1.55	14.38	-7.90***	0.000
MQI (million €)	969.02	1,240.18	271.16	27.98	-4.80***	0.000
Panel B: Germany						
Variable	P	C	C-P	C-P (%)	*t*-test	*p*-value
DE2						
Quoted spread (€)	0.2112	0.0804	-0.1308	-61.93	5.22***	0.000
Relative spread (%)	0.0009	0.0005	-0.0004	-44.44	10.25***	0.000
Best bid-ask spread (€)	0.0915	0.0510	-0.0405	-44.26	10.59***	0.000

Euro depth (billion €)	2.26	2.34	0.08	3.54	-1.63	0.103
Quoted depth (million €)	22.03	23.21	1.18	5.36	-2.31**	0.212
MQI (billion €)	20.67	29.10	8.43	40.78	-6.68***	0.000
DE5						
Quoted spread (€)	0.1549	0.1912	0.0363	23.43	-0.48	0.629
Relative spread (%)	0.0011	0.0008	-0.0003	-27.27	7.21***	0.000
Best bid-ask spread (€)	0.1147	0.0821	-0.0326	-28.42	7.14***	0.000
Euro depth (billion €)	2.27	2.63	0.36	15.86	-6.51***	0.000
Quoted depth (million €)	21.65	24.74	3.09	14.27	-5.88***	0.000
MQI (billion €)	12.94	20.45	7.51	58.04	-10.70***	0.000
DE10						
Quoted spread (€)	0.2076	0.1952	-0.0124	-5.97	0.23	0.814
Relative spread (%)	0.0014	0.0009	-0.0005	-35.71	6.43***	0.000
Best bid-ask spread (€)	0.1524	0.0916	-0.0608	-39.90	6.27***	0.000
Euro depth (billion €)	1.98	2.29	0.31	15.66	-6.02***	0.000
Quoted depth (million €)	18.89	21.40	2.51	13.29	-5.32***	0.000
MQI (billion €)	10.77	14.18	3.41	31.66	-6.24***	0.000
DE30						
Quoted spread (€)	0.8087	0.5211	-0.2876	-35.56	9.20***	0.000
Relative spread (%)	0.0057	0.0034	-0.0023	-40.35	17.75***	0.000
Best bid-ask spread (€)	0.6112	0.4101	-0.2011	-32.90	13.60***	0.000

Euro depth (million €)	925.04	996.59	71.55	7.73	-5.56***	0.000
Quoted depth (million €)	8.77	8.42	-0.35	-3.99	2.88***	0.004
MQI (million €)	942.43	1,435.66	493.23	52.34	-12.35***	0.000
Panel C: Italy						
Variable	P	C	C-P	C-P (%)	*t*-test	*p*-value
IT2						
Quoted spread (€)	0.1240	0.2117	0.0877	70.73	-4.58***	0.000
Relative spread (%)	0.0007	0.0013	0.0006	85.71	-6.56***	0.000
Best bid-ask spread (€)	0.0774	0.1378	0.0604	78.04	-6.52***	0.000
Euro depth (billion €)	2.19	2.04	-0.15	-6.85	3.27***	0.001
Quoted depth (million €)	21.29	19.95	-1.34	-6.29	2.99***	0.003
MQI (billion €)	36.84	28.01	-8.83	-23.97	2.77***	0.006
IT5						
Quoted spread (€)	0.2216	0.2837	0.0621	28.02	-2.77***	0.006
Relative spread (%)	0.0015	0.0019	0.0004	26.67	-3.28***	0.001
Best bid-ask spread (€)	0.1563	0.1994	0.0431	27.58	-3.33***	0.001
Euro depth (billion €)	2.04	2.11	0.07	3.43	-1.77*	0.077
Quoted depth (million €)	19.95	20.62	0.67	3.36	-1.58	0.114
MQI (billion €)	19.62	22.52	2.90	14.78	-1.02	0.309
IT10						
Quoted spread (€)	0.3579	0.3559	-0.0020	-0.56	0.11	0.909
Relative spread (%)	0.0027	0.0025	-0.0002	-7.41	1.34	0.181

Best bid-ask spread (€)	0.2728	0.2592	-0.0136	-4.99	1.02	0.306
Euro depth (billion €)	2.04	1.89	-0.15	-7.35	3.42***	0.001
Quoted depth (million €)	20.17	18.33	-1.84	-9.12	4.25***	0.000
MQI (billion €)	7.79	7.71	-0.08	-1.03	0.04	0.970
IT30						
Quoted spread (€)	0.7740	0.5958	-0.1782	-23.02	6.87***	0.000
Relative spread (%)	0.0061	0.0047	-0.0014	-22.95	7.10***	0.000
Best bid-ask spread (€)	0.6063	0.4848	-0.1215	-20.04	6.12***	0.000
Euro depth (million €)	797.25	976.71	179.46	22.51	-9.05***	0.000
Quoted depth (million €)	8.04	9.45	1.41	17.54	-7.95***	0.000
MQI (million €)	906.72	1,339.07	432.35	47.68	-9.41***	0.000
Panel D: Netherlands						
Variable	P	C	C-P	C-P (%)	*t*-test	*p*-value
NL2						
Quoted spread (€)	0.1132	0.0691	-0.0441	-38.96	6.60***	0.000
Relative spread (%)	0.0009	0.0004	-0.0005	-55.56	13.39***	0.000
Best bid-ask spread (€)	0.0877	0.0432	-0.0445	-50.74	13.30***	0.000
Euro depth (billion €)	2.90	3.23	0.33	11.38	-6.05***	0.000
Quoted depth (million €)	28.50	31.60	3.10	10.88	-5.80***	0.000
MQI (billion €)	26.39	49.78	23.39	88.63	-12.72***	0.000
NL5						
Quoted spread (€)	0.1725	0.1399	-0.0326	-18.90	3.40***	0.001

Relative spread (%)	0.0013	0.0010	-0.0003	-23.08	4.83***	0.000
Best bid-ask spread (€)	0.1308	0.1010	-0.0298	-22.78	4.40***	0.000
Euro depth (billion €)	2.75	3.59	0.84	30.55	-14.20***	0.000
Quoted depth (million €)	27.40	34.71	7.31	26.68	-12.55***	0.000
MQI (billion €)	16.61	22.19	5.58	33.59	-6.90***	0.000
NL10						
Quoted spread (€)	0.2612	0.1850	-0.0762	-29.17	7.77***	0.000
Relative spread (%)	0.0021	0.0013	-0.0008	-38.10	11.77***	0.000
Best bid-ask spread (€)	0.2219	0.1373	-0.0846	-38.13	11.12***	0.000
Euro depth (billion €)	2.97	3.21	0.24	8.08	-5.32***	0.000
Quoted depth (million €)	28.82	29.99	1.17	4.06	-2.75***	0.006
MQI (billion €)	10.20	14.58	4.38	42.94	-7.04***	0.000
NL30						
Quoted spread (€)	0.7626	0.4089	-0.3537	-46.38	20.43***	0.000
Relative spread (%)	0.0067	0.0032	-0.0035	-52.24	23.64***	0.000
Best bid-ask spread (€)	0.6737	0.3556	-0.3181	-47.22	21.24***	0.000
Euro depth (billion €)	1.20	1.36	0.16	13.33	-10.95***	0.000
Quoted depth (million €)	11.79	12.21	0.42	3.56	-3.91***	0.000
MQI (billion €)	1.04	2.25	1.21	116.35	-23.62***	0.000

Table 8: Regression results for a 4-month event window using HAC (Newey-West) standard errors. Countries are: Spain (ES), Germany (DE), Italy (IT), and the Netherlands (NL). The 4-month event window spans the dates from July 2009 to October 2009 (pre-crisis) and from November 2009 to February 2010 (crisis). The dataset includes benchmark fixed coupon-bearing bonds within four time-to-maturity groups: 2-, 5-, 10-, and 30-year. We run regression models as per Equation (7). Changes in each spread measure between the pre-crisis and crisis periods (crisis-pre-crisis) are regressed on the changes in the four bond attributes. $\beta_{1,t}$, $\beta_{2,t}$, $\beta_{3,t}$, $\beta_{4,t}$ denote the regression coefficients of euro trading volume, midquote price, realized volatility, and CDS spreads, respectively. Euro trading volume is the sum of the euro value of the bonds bid and offered at the best quotes. Midquote price is defined as half the summation of the posted best ask and bid price for each benchmark security. Daily realized volatility is constructed by the summation of squared 5-minute intraday returns. Quoted spread (QS) is defined as the difference between the simple average of the three best ask prices and bid prices. Relative spread (RS) is defined as the best bid-ask spread divided by the midpoint of the bid and ask quotes. Best bid-ask spread (BS) is defined as the difference between the best ask quote and the best bid quote. *, **, and *** denote statistical significance at the 10, 5, and 1 percent level, respectively.

Dependent variable	α	$\beta_{1,t}$	$\beta_{2,t}$	$\beta_{3,t}$	$\beta_{4,t}$
Panel A: Spain					
ES2					
ΔQS (€)	0.0283 (1.64)	-0.0752 (-0.91)	-0.0376* (-1.76)	107.5197*** (5.31)	14.1810*** (3.64)
ΔRS (%)	0.0002 (1.12)	-0.0007 (-0.99)	-0.0004*** (-2.68)	0.3634*** (4.48)	0.1378*** (4.11)
ΔBS (€)	0.0183 (1.10)	-0.0745 (-0.99)	-0.0425** (-2.61)	36.7146*** (4.44)	14.0945*** (4.13)
ES5					
ΔQS (€)	-0.0619*** (-2.78)	-0.1983** (-2.13)	0.0047 (1.04)	34.6030** (1.99)	37.9488*** (7.23)
ΔRS (%)	-0.0006*** (-2.92)	-0.0015* (-1.95)	0.00004 (1.12)	0.2282 (1.51)	0.3272*** (7.58)
ΔBS (€)	-0.0574*** (-2.93)	-0.1586** (-2.03)	0.0059 (1.57)	24.0729 (1.54)	33.6593*** (7.65)
ES10					
ΔQS (€)	-0.1405*** (-6.89)	-0.3102*** (-3.02)	0.0008 (0.23)	50.7561*** (5.13)	46.3995*** (8.45)
ΔRS (%)	-0.0013*** (-7.19)	-0.0026*** (-2.79)	0.00004 (0.12)	0.4462*** (5.02)	0.4237*** (8.59)

ΔBS (€)	-0.1378*** (-7.22)	-0.2783*** (-2.87)	0.0020 (0.57)	45.4327*** (4.96)	43.5543*** (8.57)
ES30					
ΔQS (€)	-0.0687* (-1.85)	-0.2959* (-1.68)	0.0046** (2.51)	34.7653*** (2.77)	41.1313*** (4.65)
ΔRS (%)	-0.0008*** (-2.65)	-0.0016 (-1.02)	-0.000006 (-0.04)	0.3132*** (3.04)	0.4079*** (5.17)
ΔBS (€)	-0.0845** (-2.57)	-0.1778 (-1.09)	0.0042** (2.54)	32.6885*** (3.02)	42.2496*** (5.25)
Panel B: Germany					
DE2					
ΔQS (€)	-0.0083 (-0.26)	0.0155 (0.43)	0.0148 (1.14)	38.7387*** (7.61)	9.8050 (1.24)
ΔRS (%)	0.0001* (1.85)	-0.0001 (-0.62)	0.0002*** (4.01)	0.3674*** (7.83)	0.0679** (2.05)
ΔBS (€)	0.0143* (1.86)	-0.0114 (-0.62)	0.0173*** (4.14)	37.2724*** (7.83)	6.9558** (2.06)
DE5					
ΔQS (€)	-0.0179** (-2.14)	0.0526 (1.28)	-0.0056 (-1.29)	12.3843 (0.62)	18.7857*** (3.45)
ΔRS (%)	-0.0001** (-2.48)	-0.0001 (-0.78)	-0.00002 (-0.94)	0.0340 (0.46)	0.0439** (2.17)
ΔBS (€)	-0.0134** (-2.51)	-0.0122 (-0.76)	-0.0007 (-0.49)	3.5811 (0.47)	4.6948** (2.21)
DE10					
ΔQS (€)	-0.0109 (-0.99)	-0.0176 (-0.37)	0.0023** (2.21)	-1.2599 (-0.18)	11.6519*** (2.79)
ΔRS (%)	-0.00003 (-0.42)	-0.0002 (-0.49)	0.00005 (0.69)	0.0177 (0.37)	0.0742** (2.62)
ΔBS (€)	-0.0033 (-0.38)	-0.0175 (-0.49)	0.0013* (1.71)	1.7456 (0.34)	7.6688** (2.58)
D30					
ΔQS (€)	-0.0718*** (-3.15)	-0.4081** (-2.19)	-0.00002 (-0.01)	-2.5583 (-0.27)	19.5008* (1.79)
ΔRS (%)	-0.0005*** (-2.78)	-0.0023* (-1.67)	-0.00003 (-1.45)	-0.0459 (-0.65)	0.2012** (2.47)

ΔBS (€)	-0.0567*** (-2.84)	-0.2752* (-1.78)	0.0010 (0.55)	-5.4661 (-0.70)	21.1577** (2.32)
Panel C: Italy					
IT2					
ΔQS (€)	0.0094 (1.06)	-0.0363 (-1.42)	0.0146** (2.35)	96.5389*** (9.10)	7.6797*** (3.49)
ΔRS (%)	0.00004 (0.49)	-0.0001 (-0.56)	0.0001*** (2.64)	0.7979*** (7.55)	0.0748*** (4.03)
ΔBS (€)	0.0039 (0.51)	-0.0140 (-0.60)	0.0158*** (2.77)	81.5259*** (7.41)	7.7645*** (4.04)
IT5					
ΔQS (€)	0.0278 (1.42)	-0.0660 (-1.15)	0.0188** (2.31)	96.3525*** (11.81)	4.8550 (1.06)
ΔRS (%)	0.0003 (1.37)	-0.0004 (-0.88)	0.0002** (2.02)	0.8174*** (10.87)	0.0369 (0.88)
ΔBS (€)	0.0264 (1.38)	-0.0463 (-0.89)	0.0178** (2.15)	84.6218*** (10.79)	3.7398 (0.86)
IT10					
ΔQS (€)	-0.0807*** (-3.99)	0.0706 (0.90)	0.0099 (1.45)	43.1549*** (3.84)	30.1980*** (4.95)
ΔRS (%)	-0.0008*** (-4.56)	0.0009 (1.31)	0.0010 (1.48)	0.3579*** (4.15)	0.2631*** (4.97)
ΔBS (€)	-0.0766*** (-4.51)	0.0918 (1.29)	0.0118*** (1.69)	37.4350*** (4.10)	26.9905*** (4.93)
IT30					
ΔQS (€)	0.0270 (0.47)	-0.2217 (-1.58)	0.0033 (1.19)	11.7729 (0.62)	17.0752 (1.23)
ΔRS (%)	-0.0007** (-2.28)	0.0003 (0.28)	0.00009 (0.57)	0.0749 (0.94)	0.2885*** (4.13)
ΔBS (€)	-0.0728** (-2.28)	0.0164 (0.16)	0.0048*** (3.14)	8.1701 (0.98)	29.6692*** (4.21)
Panel D: Netherlands					
NL2					
ΔQS (€)	0.0162 (1.63)	-0.1892 (-1.64)	-0.0019 (-0.13)	14.5471 (0.59)	-2.4432 (-0.23)

ΔRS (%)	0.000008 (0.03)	-0.0010** (-1.80)	0.00007 (0.17)	0.0757 (0.73)	0.0526 (1.24)
ΔBS (€)	0.00008 (0.03)	-0.1027** (-1.80)	0.0011 (0.27)	7.6158 (0.72)	5.3471 (1.23)
NL5					
ΔQS (€)	0.0602* (1.78)	-0.1666** (-2.34)	-0.0335 (-1.48)	9.2526 (1.32)	22.8445** (2.25)
ΔRS (%)	0.0003 (1.43)	-0.0012** (-2.27)	-0.0002 (-1.41)	0.0819* (1.93)	0.1696*** (2.69)
ΔBS (€)	0.0307 (1.42)	-0.1212** (-2.28)	-0.0188 (-1.33)	8.1961* (1.92)	16.7953** (2.62)
NL10					
ΔQS (€)	0.0239 (1.58)	-0.4856*** (-3.06)	0.0052 (1.05)	14.6680* (1.76)	19.7812 (1.39)
ΔRS (%)	0.00006 (0.65)	-0.0029*** (-3.62)	0.000008 (0.003)	0.0908** (2.02)	0.2387** (2.61)
ΔBS (€)	0.0064 (0.72)	-0.3043*** (-3.60)	0.0013 (0.50)	9.5527** (2.02)	24.5419** (2.55)
NL30					
ΔQS (€)	-0.1039*** (-3.28)	0.6456** (2.60)	0.0018 (0.87)	10.5425 (0.88)	7.2234 (0.23)
ΔRS (%)	-0.0007*** (-2.92)	0.0059*** (2.85)	-0.00002 (-1.01)	0.1030 (1.17)	-0.0719 (-0.27)
ΔBS (€)	-0.0806*** (-3.01)	0.6117*** (2.78)	0.0022 (1.37)	11.7327 (1.30)	-2.1236 (-0.08)

Table 9: Regression results for a 14-month event window using HAC (Newey-West) standard errors. Countries are: Spain (ES), Germany (DE), Italy (IT), and the Netherlands (NL). The 14-month event window spans the dates from September 2008 to October 2009 (pre-crisis) and from November 2009 to December 2010 (crisis). The dataset includes benchmark fixed coupon-bearing bonds within four time-to-maturity groups: 2-, 5-, 10-, and 30-year. We run regression models as per Equation (7). Changes in each spread measure between the pre-crisis and crisis periods (crisis-pre-crisis) are regressed on the changes in the four bond attributes. $\beta_{1,t}$, $\beta_{2,t}$, $\beta_{3,t}$, $\beta_{4,t}$ denote the regression coefficients of euro trading volume, midquote price, realized volatility, and CDS spreads, respectively. Euro trading volume is the sum of the euro value of the bonds bid and offered at the best quotes. Midquote price is defined as half the summation of the posted best ask and bid price for each benchmark security. Daily realized volatility is constructed by the summation of squared 5-minute intraday returns. Quoted spread (QS) is defined as the difference between the simple average of the three best ask prices and bid prices. Relative spread (RS) is defined as the best bid-ask spread divided by the midpoint of the bid and ask quotes. Best bid-ask spread (BS) is defined as the difference between the best ask quote and the best bid quote. *, **, and *** denote statistical significance at the 10, 5, and 1 percent level, respectively.

Dependent variable	α	$\beta_{1,t}$	$\beta_{2,t}$	$\beta_{3,t}$	$\beta_{4,t}$
Panel A: Spain					
ES2					
ΔQS (€)	-0.0908** (-2.41)	-0.00001 (-1.04)	0.0355** (2.58)	118.8828*** (5.51)	20.0248*** (5.29)
ΔRS (%)	-0.0010*** (-3.49)	-0.000004 (-0.38)	0.00009 (1.07)	0.6437*** (6.47)	0.1835*** (6.56)
ΔBS (€)	-0.0994*** (-3.48)	-0.000005 (-0.57)	0.0119 (1.43)	64.7544*** (6.38)	18.3899*** (6.53)
ES5					
ΔQS (€)	-0.2097*** (-3.61)	-0.00008*** (-3.05)	0.0056 (1.08)	77.9337*** (3.76)	29.2864*** (5.20)
ΔRS (%)	-0.0018*** (-3.75)	-0.000007*** (-3.07)	0.00006 (1.31)	0.5970*** (3.88)	0.2702*** (5.73)
ΔBS (€)	-0.1803*** (-3.80)	-0.00007*** (-3.18)	0.0087** (2.00)	59.3083*** (3.92)	27.3828*** (5.83)
ES10					
ΔQS (€)	-0.4394*** (-5.24)	-0.0001** (-2.51)	0.0136** (2.27)	70.7742*** (3.63)	47.3414*** (5.78)

ΔRS (%)	-0.0036*** (-6.81)	-0.000010*** (-2.68)	0.00004 (0.90)	0.5228*** (6.80)	0.4061*** (7.32)
ΔBS (€)	-0.3673*** (-6.79)	-0.00010*** (-2.74)	0.0081* (1.87)	51.8479*** (6.68)	40.7927*** (7.34)
ES30					
ΔQS (€)	-0.7284*** (-8.27)	-0.0004*** (-3.64)	0.0124*** (4.92)	25.0092*** (3.36)	79.9738*** (10.74)
ΔRS (%)	-0.0059*** (-7.78)	-0.00003*** (-3.41)	0.00002 (0.46)	0.1444** (2.28)	0.6953*** (10.26)
ΔBS (€)	-0.6207*** (-7.58)	-0.0003*** (-3.34)	0.0096*** (4.06)	14.7910** (2.31)	71.7869*** (9.98)
Panel B: Germany					
DE2					
ΔQS (€)	-0.3118** (-2.33)	-0.0002** (-2.08)	-0.1001** (-2.02)	17.4857 (0.47)	-10.2278 (-0.85)
ΔRS (%)	-0.0003*** (-3.45)	-0.000009*** (-3.16)	-0.00004 (-1.27)	0.3289*** (6.05)	0.0691*** (3.25)
ΔBS (€)	-0.0280*** (-3.45)	-0.000009*** (-3.15)	-0.0029 (-1.01)	33.4565*** (6.01)	7.1035*** (3.29)
DE5					
ΔQS (€)	-0.0101 (-0.28)	0.00003 (0.76)	-0.0146 (-1.01)	-21.6029 (-0.42)	-153.8027 (-1.21)
ΔRS (%)	-0.0001* (-1.74)	-0.000006 (-1.34)	0.00001 (0.11)	0.2106*** (3.01)	0.0134 (0.32)
ΔBS (€)	-0.0153** (-1.85)	-0.000006 (-1.33)	0.0009 (0.76)	21.5254*** (2.99)	1.7418 (0.40)
DE10					
ΔQS (€)	0.0800 (0.81)	-0.00005 (-1.24)	0.0091** (1.97)	71.9127** (2.52)	-122.2273 (-1.25)
ΔRS (%)	-0.0004*** (-2.93)	-0.000002 (-0.83)	0.00004** (2.03)	0.3008*** (3.02)	0.0944* (1.93)
ΔBS (€)	-0.0395*** (-2.95)	-0.00002 (-0.84)	0.0051** (2.51)	31.4009*** (2.99)	10.3165** (2.00)
D30					
ΔQS (€)	-0.3269** (-2.55)	-0.0002** (-2.10)	0.0086 (1.51)	33.4035*** (3.90)	82.4443*** (3.63)

ΔRS (%)	-0.0017*** (-5.26)	-0.000001** (-2.22)	-0.000008 (-0.07)	0.2609*** (6.92)	0.5654*** (4.99)
ΔBS (€)	-0.1988*** (-5.23)	-0.0001** (-2.03)	0.0043*** (2.86)	27.4976*** (6.65)	63.6012*** (5.04)
Panel C: Italy					
IT2					
ΔQS (€)	0.0322 (1.20)	-0.00004 (-1.57)	-0.0105* (-1.88)	92.2037*** (6.43)	0.1368 (0.02)
ΔRS (%)	0.0002* (1.67)	-0.000001 (-1.40)	-0.00005 (-1.31)	0.6511*** (9.59)	0.0163 (0.72)
ΔBS (€)	0.0203* (1.66)	-0.00002 (-1.45)	-0.0037 (-1.06)	65.5677*** (9.62)	1.6007 (0.69)
IT5					
ΔQS (€)	0.0661 (1.45)	-0.00008** (-2.09)	0.0119 (1.58)	105.8437*** (6.82)	-2.9378 (-0.35)
ΔRS (%)	0.0003 (1.22)	-0.000003** (-2.08)	0.0001** (2.36)	0.7966*** (10.59)	0.0221 (0.60)
ΔBS (€)	0.0280 (1.21)	-0.00003** (-2.06)	0.0124*** (2.75)	81.1505*** (10.54)	2.2669 (0.60)
IT10					
ΔQS (€)	-0.0347 (-1.04)	0.00004* (1.67)	0.0016 (0.25)	78.7469*** (6.20)	19.1998*** (4.05)
ΔRS (%)	-0.0005** (-2.29)	0.000003 (1.62)	0.00001 (0.28)	0.5814*** (8.57)	0.1799*** (5.41)
ΔBS (€)	-0.0544** (-2.30)	0.00003 (1.60)	0.0043 (1.00)	59.1280*** (8.56)	18.1044*** (5.35)
IT30					
ΔQS (€)	-0.1139** (-2.33)	-0.0002*** (-3.27)	0.0078*** (3.04)	56.9405*** (7.57)	25.6782*** (3.95)
ΔRS (%)	-0.0011*** (-3.08)	-0.000008* (-1.91)	0.00003 (1.36)	0.3946*** (6.77)	0.2339*** (4.57)
ΔBS (€)	-0.1052*** (-2.95)	-0.0001** (-2.15)	0.0084*** (3.88)	40.6781*** (6.81)	22.9953*** (4.34)
Panel D: Netherlands					
NL2					

ΔQS (€)	-0.0140** (-2.17)	-0.00003*** (-3.03)	0.0116 (1.33)	48.8422*** (3.40)	-2.7555 (-0.52)
ΔRS (%)	-0.0002*** (-2.95)	-0.000002*** (-4.04)	0.00004 (0.99)	0.3583*** (5.23)	0.0089 (0.36)
ΔBS (€)	-0.0155*** (-2.94)	-0.00002*** (-4.06)	0.0052 (1.20)	36.6995*** (5.24)	0.9667 (0.39)
NL5					
ΔQS (€)	-0.1376*** (-4.15)	–0.00002* (-1.92)	0.0281*** (3.74)	54.6369*** (4.30)	-7.6317 (-1.32)
ΔRS (%)	-0.0011*** (-4.82)	-0.000001 (-1.60)	0.0002*** (4.03)	0.4413*** (5.71)	-0.0099 (-0.27)
ΔBS (€)	-0.1112*** (-4.82)	-0.00001 (-1.61)	0.0223*** (4.19)	44.8975*** (5.73)	-0.9370 (-0.26)
NL10					
ΔQS (€)	-0.0643*** (-3.74)	-0.00004*** (-3.16)	0.0071*** (2.69)	41.3376*** (4.60)	8.4482* (1.70)
ΔRS (%)	-0.0006*** (-4.84)	-0.000003*** (-2.81)	0.00002 (1.64)	0.3372*** (5.59)	0.1304*** (3.89)
ΔBS (€)	-0.0603*** (-4.92)	-0.00003*** (-2.87)	0.0040*** (2.65)	34.7188*** (5.66)	13.5503*** (3.93)
NL30					
ΔQS (€)	-0.3404*** (-11.10)	-0.0002* (-1.86)	0.0095*** (4.39)	31.1010*** (4.83)	13.7485 (1.62)
ΔRS (%)	-0.0028*** (-10.83)	-0.000008 (-0.99)	0.00003* (1.90)	0.2582*** (4.39)	0.1862*** (2.95)
ΔBS (€)	-0.2987*** (-11.19)	-0.00001 (-1.33)	0.0073*** (4.29)	24.3336*** (4.62)	17.7598*** (2.62)

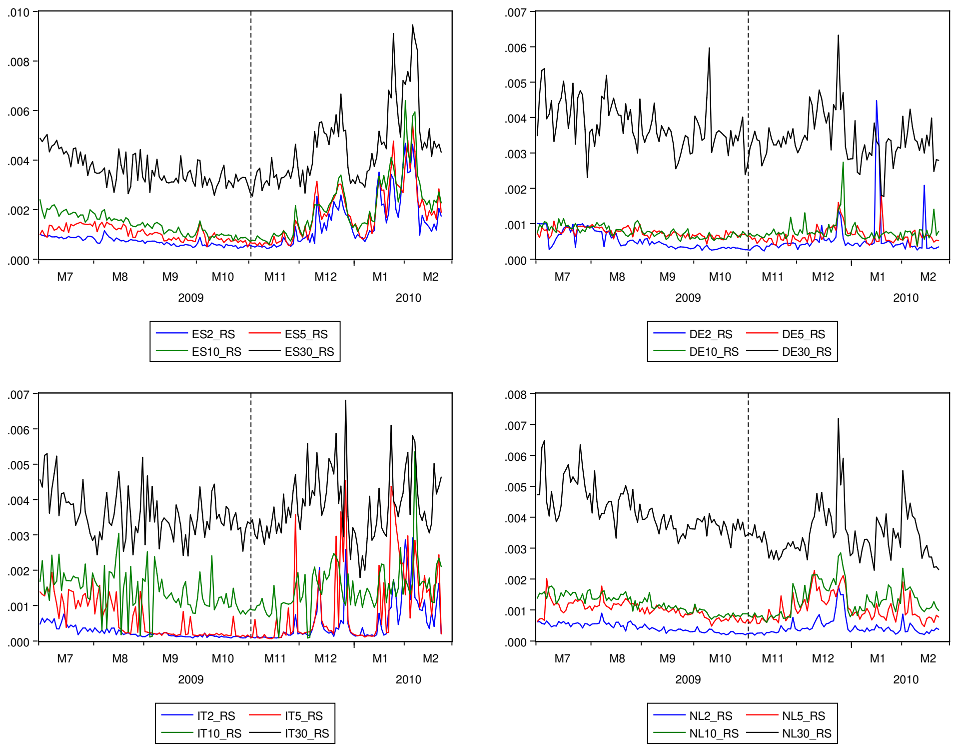

Figure 1: Plotted are relative spreads for the period spanning the dates from July 2009 to February 2010 across four time-to-maturity groups: 2-, 5-, 10-, and 30-year. Countries are: Spain (ES), Germany (DE), Italy (IT), and the Netherlands (NL). Vertical dashed lines correspond to the start of the crisis period, i.e. November 2009.

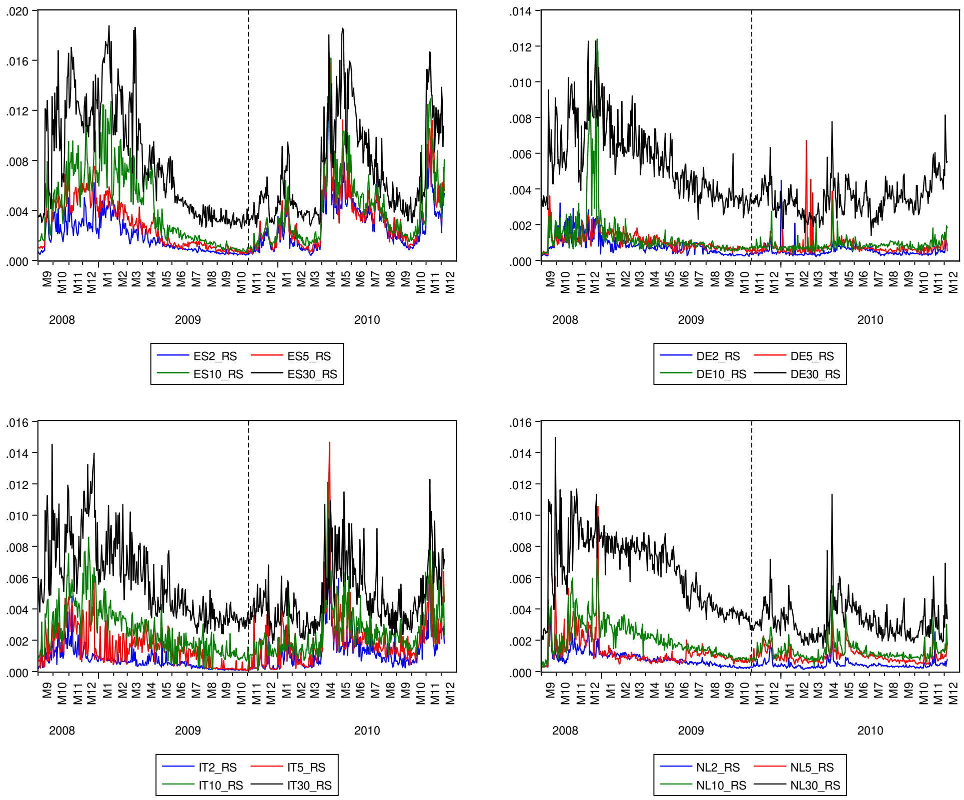

Figure 2: Plotted are relative spreads for the period spanning the dates from September 2008 to December 2010 across four time-to-maturity groups: 2-, 5-, 10-, and 30-year. Countries are: Spain (ES), Germany (DE), Italy (IT), and the Netherlands (NL). Vertical dashed lines correspond to the start of the crisis period, i.e. November 2009.