The Sovereign Debt Crisis: Flights or Freezes?*

Per Östberg
University of Zurich
Swiss Finance Institute

Thomas Richter
University of Zurich
Swiss Finance Institute

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Abstract

Multiple asset pricing theories predict that large price changes should be associated with abnormal trading volume, inducing investor rebalancing and possibly leading to flights. In contrast, consistent with market microstructure theories, this paper documents freezes, a reduction in trading volume (approximately 30% relative to the previous trading week) during market stress episodes in the European sovereign bond market. We trace the market freezes to increasing transaction costs driven by reduced risk bearing capacity of market makers.

Keywords: Sovereign Debt Crisis, Trading volume, Liquidity, Flights, Rebalancing
JEL: G12, G14, G21, E44.

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Per Östberg (per.oestberg@bf.uzh.ch - corresponding author) and Thomas Richter (thomas.richter@bf.uzh.ch): Department of Banking and Finance, University of Zurich, Plattenstrasse 14, 8032 Zurich, Switzerland.

1 Introduction

Asset pricing models with heterogenous agents provide compelling arguments in favor of rebalancing / flights in response to price changes (e.g., Cochrane et al., 2008) while market microstructure researchers (e.g., Ho and Stoll, 1981) have emphasized that liquidity provision falls in times of high volatility. We evaluate the relative importance of these two perspectives and the net effect for trading volume during the European Sovereign Debt crisis. Additionally, we study when and why a market is characterized by flight activity and when it freezes.

During the European sovereign debt crisis bond markets experienced unprecedented yield changes.[1] Heterogenous agent asset pricing models with incomplete markets predict that wealth effects (yield changes) result in rebalancing (examples include Cochrane et al., 2008; Chabakauri; 2013 and Judd et al., 2003). Additionally, when agents have heterogeneous beliefs new information results in trade (Varian, 1985 and Harris and Raviv, 1993). Moreover, there are theories that predict flight-to-liquidity / safety and liquidity spirals in times of stress (e.g., Vayanos, 2004 and Brunnermeier and Pedersen, 2009). Thus, these strands of literature predict massive investor rebalancing during the sovereign debt crisis and hence abnormal trading volume.

Even though crises result in investor rebalancing needs, the same shock may affect liquidity provision (see Pelizzon et al., 2016 for evidence concerning the European

[1] The sovereign bond yields in the GIIPS (Greece, Italy, Ireland, Portugal and Spain) countries reached the highest levels since the introduction of the Euro. The 10-year yield for Spanish and Italian bonds peaked at 7.4% and 7.5%, respectively. The yields in Ireland, Portugal and Greece reached even higher levels of 12.0%, 18.1% and 49.3%, respectively.

sovereign debt crisis) implying that the costs of rebalancing might outweigh the benefits. Early work emphasized the link between credit risk / inventory risk (Stoll, 1978), risk bearing capacity of market makers (Ho and Stoll, 1981) and bid-ask spreads. Additionally, crises may coincide with increases asymmetric information and therefore also increased bid-ask spreads (see Glosten and Milgrom, 1985 for the link between asymmetric information and bid-ask spreads). The global financial crisis and the ensuing freeze in the issuance of asset backed securities and corporate lending (Bebchuk and Goldstein, 2011) prompted theoretical work to understand the mechanisms causing freezes. Bond and Leitner (2015) show that asymmetric information may interact with capital constraints to exacerbate adverse selection and result in a market freeze. Or if investors have incomplete preferences over portfolios (Easley and O'Hara, 2010) uncertainty increases may result in a freeze.[2]

We use high-frequency data from MTS, the largest interdealer platform in the European sovereign bond market, to evaluate the relative strength of the two perspectives.

Firstly, our empirical analysis zooms in on stress events defined in a similar way to Baele et al. (2013). The measure in Baele et al. (2013) is designed to study flights from equity to bond markets and we adapt it to capture flights within the European sovereign debt market from the periphery to the core (Germany). We examine volume around these stress events using event study methodology in the spirit of Kandel and Pearson (1995). We find that trading volume is approximately

[2] Acharya, Gale and Yorulmazer (2011) emphasize that rollover risk may result in market freezes. Additionally Diamond and Rajan (2011) show that freezes may be driven by expectations of a fire sale.

reduced by a remarkable 30% during the stress events.

Secondly, to evaluate the net effect on volume of shocks we estimate vector autoregressions (VARs) using sample-wide time-series aggregates of yield, trading volume, and bid-ask spreads. We consider two types of shocks: first shocks to liquidity provision (proxied for by bid-ask spreads) and secondly shocks to investors' demand for rebalancing (proxied for by changes in equity market volatility). We find that the response in volume to a shock in bid-ask spread is conditional of the state of the financial system. In crisis times trading freezes while in normal times volume is not significantly affected. We also find evidence of rebalancing / flights, a shock to the equity market (an increase in VSTOXX) results in increased volume during normal times, but not in crisis times.

Thirdly, we verify that drops in trading volume are driven by reductions in risk bearing capacity of market makers. To do this we use that: 1) market makers in this market have substantial holdings of the sovereign bonds (unlike in the U.S.) that are shocked, 2) the same bond may be traded on both a domestic and a pan-European platform and 3) market making on the domestic platform is primarily undertaken by local market makers that are particularly exposed to the shocked sovereign.[3,4] This implies that on the domestic platform spreads should increase more and volume should decrease more than on the pan-European platform in response to a shock. Difference-in-differences regressions that use within bond variation corroborate these

[3]European domestic banks hold on average 22.4% of the outstanding sovereign bonds (while the corresponding number for U.S. banks is only 2.8%. These numbers are sourced from the Bruegel database of sovereign bond holdings (the database covers Greece, Ireland, Italy, Spain, France, Germany, Netherlands, Portugal, UK and US) developed by Merler and Pisani-Ferry (2012).

[4]For example in Italy 24.1% of the market makers are Italian banks while on average in the other markets Italian banks constitute only 4.68% of the market makers.

predictions.

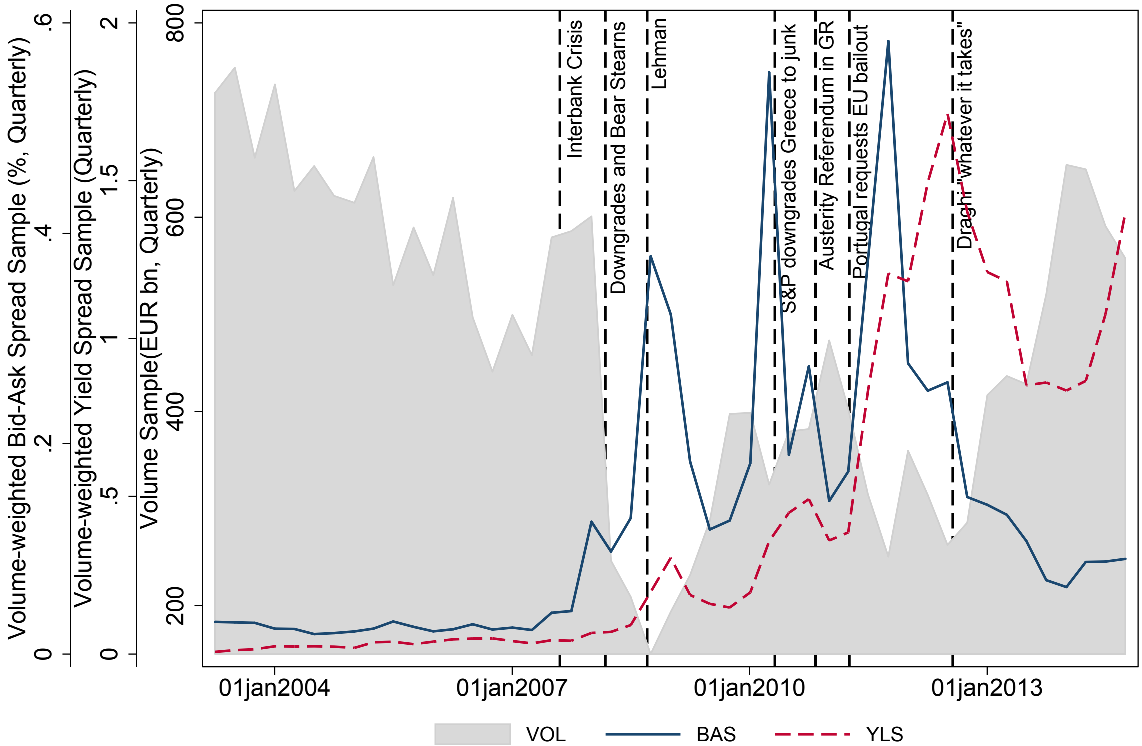

Figure 1: Volume, Bid-ask Spreads and Yield spreads

This Figure 1 displays average quarterly Euro volume, volume weighted bid-ask spread of our sample (all countries) and the mean (across countries) yield spread over 10 year Bunds. The dashed lines represent (1) August 2007 (start of interbank crisis), (2) March 2008 (MBS downgrades and Bear Stearns), (3) September 2008 (Lehman), (4) April 2010 (S&P downgrades Greece to junk), (5) November 2010 (Austerity referendum in Greece), (6) April 2011 (Portugal requests EU bailout), (8) July 2012 (Draghi "whatever it takes"). For a more detailed description of the variables see section 4 and Figure 3.

The contribution of this paper is twofold. First, this paper jointly focuses on flights and freezes and our empirical evidence suggests that the trading impact resulting from markets stress is contingent on the origin of the market stress. If risk-bearing capacity of market makers is impaired during the stress episode the freeze perspective dominates while if the shock does not adversely affect liquidity provision (e.g., it originates in the equity market) investors rebalance. The joint perspective helps to explain seemingly contradictory results in the previous literature concerning the effect of stress on trading volume. Bessembinder et al. (2018) finds that the financial crisis is associated with decreased capital commitment of market makers resulting in among other things lower trading volume while O'Hara and Zhou (2021) find that during the Covid-19 crisis trading volume and trading costs are positively related.

Second, we document the fragility of European sovereign bond trading when liquidity provision is impaired. Combined with our other evidence Figure 1 illustrates the degree of the freeze in this market. It graphs aggregate trading volume, volume-weighted bid-ask and yield spreads. The market stopped functioning. To our knowledge this is the first evidence presented of a large central secondary market freezing and it is striking how little trade we observe in this market during the crisis.

2 Related Literature

There is a large literature that studies the determinants of volume (Epps 1976; Hirshleifer et al., 1994; Chordia et al., 2001; Chordia et al., 2007). One of the most central findings is that there is a positive volatility-volume relation (i.e., investor rebalancing - see Karpoff, 1987, for findings and a review of the early literature). Among others, Foster and Viswanathan (1993) and Gallant, Rossi and Tauchen (1992) confirm the volatility-volume relation. This relation extends to bond markets (Huang, Cai and Wang, 2002). In contrast, we document that the European sovereign bond market primarily freezes in response to large price changes.[5]

[5]Engle, Fleming, Ghysels and Nguyen (2012) show increased trading activity during flight-to-safety episodes in the US Treasury markets. However, they study flights from the equity market to

There is overwhelming evidence that liquidity deteriorates in crisis times (e.g., Pelizzon et al., 2016), however the impact on trading activity is ambiguous (rebalancing versus freezes). We emphasize that trading volume is distinct from liquidity. For example, Fleming (2003, p.84) points out that "both high and low levels of trading activity are associated with periods of poor liquidity." Similarly, Mancini et al. (2013, p. 1180-1181) state "the relation between liquidity and trading activity is ambiguous."

There is a literature that studies yield premia and order-imbalances during flight-to-safety episodes (Beber et al., 2009; Longstaff, 2004 and Garcia and Gimeno, 2014). We contribute to this literature by focusing on trading volume and showing that changes in yields do not necessarily translate into investors actually rebalancing their portfolios. Additionally, to gauge the relative importance of rebalancing needs and transaction costs we need to study volume since order imbalances will mechanically be associated with selling pressure in falling markets that do not necessarily represent large-scale rebalancing

By the virtue of studying bond markets in times of stress this paper is related to research that investigates the liquidity of bonds in crisis times. Bao et al. (2011), Dick-Nielsen et al. (2012) and Friewald et al. (2012) document a relation between liquidity and corporate bond yield spreads. These papers document a liquidity-spread relation and find that the relation is stronger in crisis times. Liquidity has also been

the treasury market while we study flights within the European sovereign bond market. In their context transactions costs are less important since a flight episode is characterized by a drop in equity returns and an increase in bond prices. Put differently, we study the volume of the shocked market (where the price drop occurs) whereas they study volume of the safe market (which experiences a price increase).

used as the dependent variable. For example, Pelizzon et al. (2016) document that changes in credit risk (CDS spreads) have a large impact on the liquidity of the European sovereign debt market.

Crises are often associated with freezes in security issuance. For example, during the global financial crisis issuance of mortgage-backed securities halted (see Benmelech and Bergman, 2018 for a description of issuance freezes). A number of papers study funding markets in crisis times. For example, Copeland, Martin and Walker (2014) and Krishnamurthy, Nagel and Orlov (2014) find that US repo volume decreases by over 30% from 2008 to 2010. In constrast, Mancini, Ranaldo and Wrampelmayer (2016) finds that CCP-based euro repo volume increased during the crisis, suggesting that market design is key to market resilience. Afonso, Kovner and Schoar (2011) find that the federal funds is stressed but not frozen and Pérignon, Thesmar and Vuillemey (2018) document dry-ups (individual bank "freezes" of certificate deposits), but find no evidence of aggregate market freezes. In sum, although there is evidence of issuance and repo freezes, we contribute by documenting extensive freezes in a central secondary market.

Our results have a parallel in the findings of Fleming and Remolona (1999), who study trading in the U.S. treasury market surrounding macro announcements. In the minute after the news release uncertainty is high and market makers protect themselves by increasing bid-ask spreads ultimately resulting in a decrease in trading volume. In the next minute and over the following one and half hours trading volume, price volatility, and bid-ask spreads are elevated. In contrast the decrease in trading activity in the European sovereign bond market lasts for at least a trading week, which allows us to investigate the reasons for the freezes.

3 Data

Our main data source is high frequency trade and quote data from the electronic interdealer platform MTS, covering the period from April 2003 to December 2014. Data from MTS provides a comprehensive picture of the European sovereign bond market since the majority of trading occurs on electronic trading platforms of which MTS has the largest market share.[6] MTS volume is representative of overall market volume since it is highly correlated with volumes figures reported by primary dealers (the reported data is at a more aggregate level and often at lower frequencies).[7]

The MTS dataset is organized into three types of files available on a monthly basis: the reference files which contain bond characteristics as well as the fills and best proposal files that contain all the trades and quote updates with millisecond timestamps. We use this data to calculate yields, volume and the cost of trading (bid-ask spreads).

[Insert Figure 2 here]

[6] According to industry research (Deutsche Bank, 2005) more than 95% of the bond trading takes place off-exchange. It finds that about 75% of orders and around 50% of volume is traded on electronic trading platforms in Europe. Dunne et al. (2010) estimate that MTS has a market share of 60.8% of the electronic trading. Own calculations using a report from primary dealers in Portugal (published by the Portuguese Treasury and Government Debt Agency) verify that MTS has indeed a high overall market share of volume (73.9% of the Portuguese electronic trading).

[7] Data from the French and Portuguese national treasury agencies as well as the Bank of Spain also include customer-dealer and non-MTS interdealer trading by primary dealers. The correlation between MTS volume and the total market volume (as reported by the Agence France Trésor) is 0.72 in France (based on monthly data), 0.90 in Portugal (based on monthly data) and 0.57 in Spain (based on daily data). Figure 2 shows the close co-movement between the transaction volume in the electronic, interdealer and the customer-dealer markets for the French sovereign bond market.

In screening the reference files, we only consider bonds that are issued by a central government. That is, we exclude ISINs where the issuer is classified as quasi-government, local government or corporate. Also, we exclude bonds for which we have no information on the issuer even though they are categorized as they were issued by a central government. We keep bonds issued by countries that have data coverage over the entire sample period (i.e., we exclude Denmark, Poland, Slovenia and the United Kingdom). This leaves us with the following 11 European countries: Austria (AT), Belgium (BE), Germany (DE), Spain (ES), Finland (FI), France (FR), Greece (GR), Ireland (IE), Italy (IT), the Netherlands (NL) and Portugal (PT). Additionally, we only keep fixed and zero-coupon bonds. That is, we exclude bonds with floating or indexed coupons and bonds with derivative features. To facilitate the yield curve estimations (see below) we exclude the 16 bonds that at any point in time during our sample have more than 40 years to maturity. All trades that are made by national treasury agencies are recorded under a separate ISIN code. Since these trades do not reflect investor rebalancing, we eliminate them from the sample.

When we merge the monthly reference files, we occasionally observe information that should be time-invariant (e.g., issuer category) changing. In such cases we look up the information in other data sources (DataStream, Bloomberg and Findex) for that particular ISIN.[8] If the information cannot be verified then the particular bond

[8]For the variable issuer country nine bonds were misclassified resulting in five changes and four drops. In case of the variable issuer type 34 bonds (33 dropped and one changed) were sorted into the wrong category. A total of 17 bonds were classified as coupon bonds even though they are index-linked bonds and were thus dropped. For the variable issue date 36 bonds had multiple entries (33 were changed and three deleted because verification was not possible). The variable coupon rate was sometimes missing and thus replaced by the coupon rate that was present in the reference files of the other months. In six cases we made changes to bonds with multiple coupon rates. Lastly, we changed 37 first coupon dates. Details are available upon request. We found that the reference

is dropped. Applying these screens implies that we have a total of 3,181 bonds.

Next, we merge the resulting reference file information with the best proposal files. In total we have 1.12 billion quote updates and 1.28 million bond-days at this point. We drop quotes were the mid price is missing, either the bid or ask price is 999 (error code) and quotes which imply negative bid-ask spreads (together these screens lead to a loss of 0.03% of the quotes). In April 2003 we occasionally observe inconsistencies in the order book (we observe three layers) in terms of sorting of the best bid and ask prices (e.g., the best bid price is smaller than the second-best bid price). In these instances, we drop these quotes (0.05% of the quotes). Additionally, we only consider quotes during regular trading hours (8:15 am to 5:30 pm which is referred to as the open market phase by MTS; this leads to a loss of 0.57% of the quotes).[9] We also drop quotes that imply a relative bid-ask spread in excess of 0.6 (this implies a loss of 414,531 quotes or 0.04% of the quotes).

We also exclude bond-days that occur during grey market trading (0.2% of the bond-days). Moreover we exclude bonds that have less than 30 days to maturity (2.4% of the bond-days). To remove quotes that are unlikely to reflect market wide liquidity changes we drop bond-days where the price changes (from close to close, in %) are five times larger than those of the entire country and the absolute price changes additionally exceed 4% on the day in question and reverses at least 4% the

file for May 2003 had a significant number of errors so we filled in data for May 2003 with data from June 2003 when it was identical to the record for April 2003. If this was not the case, we used external sources to try to reconcile the records.

[9]We ignore quotes from the pre market phase and the offer phase. For further information see London Stock Exchange Group: General MTS Domestic Market Rules, Effective as of 4th April 2016.

next day (a loss of 0.1% of bond-days).[10]

Moreover, we exclude dates that are in the dataset but are not regular trading days. These dates are 28^{th} of May 2007 (Whitsunday), the 24^{th} of December as well as the 31^{st} of December in the years 2003, 2004 and 2007 (on these days overall trading volume in the European sovereign bond market was roughly one hundredth of the normal level). Similarly, we drop two Saturdays that are present in the dataset (January 17, 2009 and November 22, 2008). After these screens we are left with a sample of 1.1 billion quote updates, 3.5 million trades, 1.2 million bond-days and 2,937 unique bonds.

This dataset is the basis from which we calculate our main variables: trading volume, bid-ask spreads and yields. All of these quantities are calculated per day and country.

[Insert Table 1 here]

Row (1) and (2) of Panel A, Table 1 provide descriptive statistics of the total number of trading days and bonds across our sample countries. We have a time-series of 2,957 trading days from April 2003 to December 2014 (covering both crisis and pre-crisis periods).[11] Larger countries with significant amount of debt outstanding such as France, Germany, Italy and Spain have more bonds in our sample (between 334 and 874) while smaller countries have fewer bonds (e.g., 33 in Austria, 27 in Finland, and 61 in Ireland).

[10]We remove these extreme idiosyncratic price movements that subsequently reverse since they are likely to adversely affect convergence in our yield curve estimations.

[11]The only exception is Greece where we have 2,602 days because a lack of valid bid-ask spreads during the height of the sovereign debt crisis.

Rows (3) to (7) of Panel A, Table 1 present the daily average number of bonds, trades and quotes as well as average trade size and Euro volume. On average we observe between 8.72 (IE) and 85.66 (FR) bonds per day. This cross-section of bonds allows to almost always estimate a daily country specific yield curve (see below). There is ample variation in the number of trades across our sample countries (from an average of 5.59 to 734.16 trades per day in Ireland and Italy, respectively). The daily cross-country average number of trades is 108.72 (the last column). Even though the absolute number of trades is small in some countries, given that the trade sizes in this market are substantial (mean cross-country trade size is EUR 7.77 million), the mean daily Euro trading volume is large (EUR 38.99 in Ireland to EUR 4,029.84 million in Italy). The large number of quote updates per day (between 7,390 in Ireland and 82,610 in Italy) provides us with ample number of observations to calculate daily average bid-ask spreads.

On the MTS platform designated market makers are obliged to continuously quote firm bid- and ask prices for at least five hours a day. From Panel B of Table 1 we see that for the average bond in our sample there are 12.85 market makers (the mean number of market makers ranges from 8.35 in Spain to 15.45 in Portugal). In addition to the market makers, there are on average between 33.29 and 78.09 market takers that can post market orders. Moreover, MTS defines a minimum quantity (cross-country average of EUR 7.45 million) that market makers have to quote to ensure depth. Pagano and von Thadden (2004) argue that the minimum quantity and the obligatory continuous quotes of bid-ask spreads result in the Euro MTS being the most important trading venue for European sovereign bonds.[12]

In Panel C of Table 1 we display the S&P ratings of our countries at the beginning and the end of the sample period. The sample is characterized by variation in credit quality across sovereigns and over time (many sovereigns experienced downgrades).

4 Variable Definition and Descriptive Statistics

4.1 Volume

For each trade on the MTS platform, we observe the price, the timestamp and the notional amount traded. We use this to calculate Euro volume per trade and sum up the volume over all trades within a country and day (similarly we calculate the number of bonds traded). To facilitate comparison of volume across countries (given the large heterogeneity) we scale volume with the average volume over the previous five days and can therefore interpret it as abnormal volume. Our relative volume measure ($RVOL$) is defined as:

$$RVOL_t = log(VOL_t) - \frac{1}{5}\sum_{l=1}^{5} log(VOL_{t-l}), \quad (1)$$

where VOL_t is either the euro volume of a particular country or the total volume of all countries excluding Germany (sample volume) during day t. Germany is excluded

[12] Additionally, it is the premier choice of academics: Bai, Juliard and Yuan (2012), Beber, Brandt and Kavajecz (2009); Caporale and Girardi (2013); Caporale, Girardi and Paesani (2012); Cheung, de Jong, and Rindi (2005); Darbha and Dufour (2013); Dufour and Nguyen (2008); Dufour and Skinner (2004); Dunne, Hau and Moore (2015); Dunne, Moore and Portes (2006); Favero, Pagano and von Thadden (2010); Garcia and Gimeno (2014); Gerlach, Schulz and Wolff (2010); Girardi (2008); Girardi and Impenna (2013); Pagano and von Thadden (2004); Paiardini (2010); Pelizzon, Subrahmanyan, Tomio and Uno (2016) and Schneider, Lillo, and Pelizzon (2016) all use the MTS data set for their empirical analysis.

because it is our reference country when classifying flights. In calculating the measure we use the log transformation of volume (as in Dong, 2012) since it implies a symmetric measure.[13]

[Insert Table 2 here]

[Insert Figure 3 here]

Table 2, Panel A contains the descriptive statistics of the time series of the volume ratio ($RVOL$). For the individual countries the means range from -0.0061 (GR) to -0.0006 (IE) and the sample average is -0.0009. In fact, all the means for all of our sample countries are very close to zero, but slightly negative. This reflects that volume is marginally decreasing over our sample period. Positive medians combined with the fact that negative extremes (minimum) are larger, in absolute terms, than positive extremes (maximum) suggest that our time series are characterized by large infrequent drops in volume. This pattern is also visible in Figure 3. Additionally, the extreme values show that there are days with very high or very low volume (compared to the previous five days) suggesting the potential existence of both extensive rebalancing activity and freezes.

4.2 Bid-Ask Spreads

In the MTS dataset we observe the first three layers of the order book. For each quote we calculate the relative bid-ask spread (BAS) as the difference between the best ask-

[13]Without the log transformation $RVOL$ would be restricted to the range of [-100%,+∞] implying a potential positive bias. Applying the log transformation leads to the symmetric range of [$-\infty$,+∞]. In the rare occasion that the daily total volume is zero we set the trading volume to be one since the log of zero is not defined.

price P^A and the best bid-price P^B divided by the mid price P^M. We aggregate this to a daily bid-ask spread for each bond by calculating the equally weighted average over all $K_{i,t}$ updates for bond i during day t as:

$$BAS_{i,t} = \frac{1}{K_{i,t}} \sum_{k=1}^{K_{i,t}} \left(\frac{P^A_{i,t,k} - P^B_{i,t,k}}{P^M_{i,t,k}} \right). \tag{2}$$

We aggregate the bond-level bid-ask spread to the country and sample level to get market-wide transaction cost estimates. In aggregating to the country or sample level we use volume weighting to reflect transaction costs of traded volume. The weight w of bond i is given by:

$$w_{i,t} = \frac{\sum_{m=6}^{25} VOL_{i,t-m}}{\sum_{i=1} \sum_{m=6}^{25} VOL_{i,t-m}}, \tag{3}$$

where the volume weighting of bond i depends on trading volume over days from $t = -25$ to $t = -6$. We calculate bid-ask spreads as the weighted sum of the individual bid-ask spreads for a country or our entire sample on a daily level.

Table 2 Panel B displays descriptive statistics for the volume weighted bid-ask spreads time series on country and sample level. The first three rows show the averages for the whole sample period as well as two sub periods which correspond to the crisis and non-crisis period (The crisis period starts, as in Nyborg and Östberg (2014), August 9, 2007 and lasts until the end of the sample period). The figures show that the European sovereign bond market is extremely liquid in the pre-crisis period. The average volume weighted bid-ask spread in the sample is 0.025%. In the pre-crisis period Italy is the most liquid country with an average bid-ask spread of 0.020%. This is consistent with the description of European sovereign bond markets as very liquid in the pre-crisis period (e.g., Cheung, De Jong and Rindi, 2005 and Pagano and von Thadden, 2004).

However during the crisis, the bid-ask spreads increase dramatically. The average volume weighted bid-ask spread in the crisis period is 7.7 times larger (increase from 0.025% to 0.194%) than in the pre-crisis period. Bid-ask spreads increase less in the CORE countries (E.g., in Germany the bid-ask spreads increase from 0.34% to 0.140%) than in the GIIPS countries (e.g. in Greece the bid-ask spreads increase 0.054% to 4.708%). Additionally, one should note that the average level in GIIPS countries also reaches very high values in absolute terms (the cross-country average bid-ask spread is 1.585%). The other figures in the Panel B show descriptive statistics for the whole sample period. The median values show the same patterns as described for the means. The standard deviations are high indicating a lot of time variation in bid-ask spreads. Maximum bid-ask spreads in Ireland, Greece and Portugal even cross the 10% level, reflecting the severity of the crisis. Overall, the statistics in Panel B indicate that trading costs increased significantly during the crisis.

4.3 Yields

The extant literature identifies flight episodes through yield spreads.[14] In particular we use a threshold model similar to Baele, Bekaert, Inghelbrecht and Wei (2013) to identify flights. Since the composition of our sample (in terms of maturity and

[14] Beber, Brandt and Kavajecz (2009) show that the yields spread between the sovereign par yield and the euro swap yield reflects flight-to-liquidity (using cross-country liquidity differences) and flight-to-quality (using cross-country differences in CDS premia). Similarly, Longstaff (2004) uses the yield spread between US Treasuries and Refcorp bonds to identify flights-to-liquidity. Garcia and Gimeno (2014) calculate a flight-to-safety and flight-to-liquidity factor based on agency spreads (e.g., the KfW-Bund spread).

duration) varies over time and countries we base our flight measure on the yield of a synthetic 10-year constant maturity bond. This yield is calculated from estimating a Nelson and Siegel (1987) model for each country and day. We selected this model since it represents a good trade-off between model complexity and tractability (Beber et al., 2009 use it for a MTS sample of sovereign bonds).

Our goal is to measure changes in relative safety of sovereigns. Both academics and the financial press view German bunds as a safe haven and as a result it is natural to consider the spread of a sovereign over the German yield (Geyer, Kossmeier, and Pichler (2004) and Favero, Pagano and von Thadden (2010) consider the spread over the German yields as well). For all of our countries (except Germany) the daily (t) yield spread YLS_t is calculated as:

$$YLS_t = \frac{Y_t - Y_t^{DE}}{Y_t^{DE}}, \tag{4}$$

where Y_t and Y_t^{DE} are the 10-year constant maturity yields of the sovereign and Germany (DE), respectively. In addition to the country-specific yield spreads a sample aggregate is required for our analysis. Thus we calculate volume weights on a country basis in a similar way as in Section 3.2 (effectively replacing the bond index in Eq. (3) with a country equivalent). We use these weights to calculate a daily sample yield spread. This yield spread can approximately be interpreted as the difference in sovereign risk (vis-a-vis Germany) of the average traded Euro.

Panel C of Table 2 contains descriptive statistics for the time series of these yield spreads (relative to the German yield). The statistics for median and average confirm that all the countries in the sample have to pay higher yields to borrow for 10 years than Germany. As expected, the yield spreads in the GIIPS countries are far above the German yield (they average between 63.87% (Spain) and 194.51% (Greece)). Also, in line with expectations the yields of highly rated CORE countries such as Finland (6.72%) or the Netherlands (6.88%) are only slightly above the German yield. This substantiates our choice of Germany as the benchmark country.[15]

From Figure 3 it is evident that yield spreads are highly time varying. The sample yield spread is very low (close to zero) in the beginning of the sample period. However, yields start to diverge when the financial crisis starts and then soar during the European sovereign debt crisis often connected to events such as bailouts and bank collapses. Yield spreads start to converge again for a short period after Mario Draghis "whatever it takes"- speech (See also Figure 1). The sovereign debt crisis is characterized by severe changes in yields spreads and thus relative safety of the individual countries.

5 Results

5.1 Flight events and volume

As outlined in the introduction the academic literature suggests that the flight-to-safety phenomenon leads to large-scale rebalancing in times of market stress. In order to investigate this claim we undertake an event study in the spirit of Kandel and Pearson (1995) to identify abnormal volume surrounding market stress events.

[15] In the beginning of the sample period the yields of all countries are very similar. In this period the German yield is occasionally above those of the other countries, which leads to the negative yield spreads displayed in the minimum statistics.

We identify market stress days using a threshold model in the spirit of Baele et al. (2013) that identifies days with an increase in the yield of one of our sample countries and a decrease in the German yield. The model is:

$$FTS_t = I\{\Delta Y_{j,t} > z_{j,t}\} \times I\{\Delta Y_t^{DE} < z_t^{DE}\}, \tag{5}$$

where I is an indicator function and $\Delta Y_{j,t}$ and ΔY_t^{DE} are the changes in the 10-year constant maturity yield of the country j and Germany, respectively. For each day t and country j (i.e., all except Germany) a day is classified as a flight event if the increase in the yield is greater than the threshold $z_{j,t}$ and the decrease in the German yield is lower than the threshold z_t^{DE}. The thresholds $z_{j,t}$ and z_t^{DE} are:

$$z_{j,t} = \kappa \times \sigma_{j,t} \quad and \quad z_t^{DE} = \kappa^{DE} \times \sigma_t^{DE}. \tag{6}$$

The $\sigma_{j,t}$ is the country-specific, time-varying volatility of the yield changes (calculated based on the previous 100 days) and κ is the threshold parameter. We apply three different values of κ which are 1.0, 1.5 and 2.0 while the κ^{DE} is fixed at -0.75.[16]

[Insert Table 3 here]

The number of events per country and event type are tabulated in Table 3, Panel A. 245 days were classified as event days using the threshold model with $\kappa = 1.0$. If κ is increased to 1.5 or 2.0 the number of observed events decreases to 138 and 84,

[16] We choose the values for κ in the risky countries in line with the previous literature. Baele et al. (2013) choose a κ of 1.5 and Engle et al. (2012), select κ's of 1.0, 1.5 and 2.0. Since these papers study flights from equity to bond markets and we study flights within the sovereign bond market we do not use a symmetric κ. There are several reasons for this: (1) An equal amount of rebalancing from the risky to the safe country is likely to have a larger impact on the yield of risky countries because on average these markets are considerably smaller (debt outstanding). (2) Yield changes in the risky country most likely reflect both rebalancing effects and information revelation whereas the yield changes in Germany are likely to include mostly rebalancing effects.

respectively. Not surprisingly most of the events occur in GIIPS countries since the yields of these countries and the German yield are more likely to diverge given the development of country-specific credit risks (See e.g. the evolution of the ratings in Table 1, Panel C).

We examine the volume ratio $RVOL$ as defined in Eq. (1) around these events. As discussed in section 3.1 this measure can be directly interpreted as abnormal volume since it compares the volume on the current day to the volume in the previous five days. We consider a window of 8 days around an event (in event time τ from $\tau = -2$ to $\tau = +5$). To ensure that we benchmark the volume at a particular day with volume that is not influenced by the event itself we compare the volume in this period with the volume in the five days from $\tau = -6$ to $\tau = -10$.[17]

We assess the significance of the volume ratio $RVOL$ at a particular day τ in the event-window using standard errors that are calculated using the ordinary cross-sectional method (See Boehmer et al., 1991).[18] It is defined as the standard deviation of the volume ratio of all events on event-day τ. Applying the described cross-sectional approach means that we use only observations from the event window and only one observation per event which results in standard errors that are not biased by auto-correlation (there is no time dimension) and event-induced variance (only data from

[17]If this period contains data that is associated with another event we consider the closest previous period that does not contain any other event.

[18]Formally, the standard error σ_τ^{cross} is defined for each event-day τ as:

$$\sigma_\tau^{cross} = \sqrt{\frac{1}{N(N-1)} \sum_{e=1}^{N} \left(RVOL_{n,\tau} - \sum_{n=1}^{N} \frac{RVOL_{n,\tau}}{N} \right)^2}, \tag{7}$$

where n is a single event, N is the number of all events and $RVOL_{n,\tau}$ is the volume ratio at event n at event-day τ.

events used).[19]

In Panel A of Table 4 we present the average values of the volume ratio $RVOL$ from day $\tau = -2$ to $\tau = 5$ (columns) and the different types of events (rows). The first row contains results using the threshold model with a κ of 2.0. From day $\tau = 1$ to $\tau = 5$ point estimates are negative and economically large. At $\tau = 1$ the volume ratio is -33.6 and statistically significant at the 5%-level. This implies that one day after the event volume is 33.6% lower than it was on average over days $\tau = -10$ to $\tau = -6$. As we progress in event time the volume ratio seems to stay negative. Prior to the event (event days $\tau = -1$ and $\tau = -2$) volume is not significantly different from zero suggesting our threshold measure identifies large shocks fairly well.

It is striking that when the shocks that we consider become smaller (i.e., the κ is reduced and we consider more events) the reduction in volume becomes less pronounced or even turns into an increase. When κ is reduced to 1.5 the freeze occurs later and is less severe. We only observe a significant drop in volume from day $\tau = 2$ on. For $\kappa = 1.0$ we even have a positive volume ratio of 4.3% at the event day ($\tau = 0$). However, after that volume turns negative again but the extent of the decrease is less pronounced. It is notable that the volume ratio is lower for high values of κ indicating that the freezes are more severe. The evidence in this panel shows that our events are associated with market freezes and more severe events are associated with significantly lower volume.

[19]We have also calculated standard errors with the traditional portfolio approach (based on the time series variation of our variables in an estimation window) which has resulted in slightly lower standard errors suggesting that we have event induced variance and / or autocorrelation. The advantage of the portfolio approach is that it deals with cross-event correlation, but there is little clustering of events in our sample.

To evaluate whether the volume response to the shock is conditional on transaction costs we classify all of our events (within a country) into two groups depending on whether they are associated with above or below median bid-ask spreads. In order to have a significant number of events we use the events classified with a κ of 1.0.

[Insert Table 4 here]

The high bid-ask spread events are associated with significant market freezes. At the event day the volume ratio is -14.7% and insignificant. Given that the shock to yield spreads can occur at any point during the day it is quite likely that the volume reaction will only be fully incorporated a day later. Consistent with this we find that on day $\tau = 1$ the volume ratio is -42.2% with an associated t-statistic of -3.54. The volume ratio is statistically significant below zero in the following days ($\tau = 1$ to $\tau = 5$). The magnitude of the freeze is remarkable since the decrease in volume is between -37.4% and -55.3%.

For low bid-ask spread events we observe the opposite, volume increases suggesting that investors rebalance. At the event day ($\tau = 0$) the volume ratio is 22.9% and statistically significant at the 1% level. This suggests that in the absence of large increases in transaction costs investors choose to rebalance. This is consistent with evidence of flights in sovereign bond markets during the pre-crisis period (Beber, Brandt and Kavajecz, 2009) and in equity markets (Ben-Raphael, 2014). Following the event day, we observe neither the market freezing nor rebalancing. This suggests that rebalancing occurs fairly immediately and is not persistent (unlike the freezes).

The third row of Panel B shows the differences in volume ratios between the two groups of events and the associated t-statistics (based on a two-sample t-test). In the six days from the event date $\tau = 0$ to $\tau = 5$ the differences are negative as well as economically and statistically significant. They range between 26.8% and 59.3%. The differences are not as large before the event day. This suggests that the differences are not only driven by the differences in the two groups but also by a differential impact of the event itself across groups.

Now we examine whether the decrease in the volume ratio is driven by (abnormal) increases of the bid-ask spreads. Abnormal values of the bid-ask spread are calculated as the bid-ask spread on a particular day in the event window less the average bid-ask spread from $\tau = -10$ to $\tau = -6$. The bid-ask spreads increase substantially around our events, both when the bid-ask spreads are at a high level and when they are at a low level. For both high and low bid-ask spreads the increase in bid-ask spreads precedes the decrease in volume. The absolute increases in bid-ask spreads are greater for the high bid-ask spread group suggesting that the larger decrease in volume is due to the more pronounced responses in the bid-ask spreads.[20]

[Insert Figure 4 here]

In Figure 4, we present the evolution (over our event window) of our main quantities of interest: relative volume, bid-ask spreads and yield spreads. Essentially the figure graphically presents the results of Table 4 while providing a benchmark based

[20] In order to ensure that our results are not driven by Greece (for which we have occasionally sparse data) we estimated Table 4 without Greece. Additionally, to make sure that our results are not driven by trends in volume we use alternative benchmark models. Instead of using $RVOL$ we calculate the abnormal volume as the difference between $RVOL$ at a particular day in the event window minus the average RVOL from $\tau = -10$ to $\tau = -6$ (from $\tau = -205$ to $\tau = -6$) to control for short term (long term) trends. None of these deviations changes our qualitative results (available upon request).

on placebo events. The red line represents the point estimates, and the grey shaded area is the 95% confidence interval around them. In the leftmost graphs we plot relative volume. In the overall sample, displayed in the top panel there is an insignificant increase in volume on the event day. The middle and bottom panels display the results for high and low bid-ask spread events separately. From this it is evident that the insignificant increase in the top graph is due to low bid-ask spread events which experience an immediate increase in volume. Examining the bottom volume ratio graph (low bid-ask spreads) it is apparent that rebalancing only occurs on the event day and after this day volume is not higher than it was during our benchmark period. In contrast for high bid-ask spread events volume falls on the event day and remains low throughout our event period (i.e., the freeze is persistent).

The middle graphs display the changes in bid-ask spreads during our events. In the top graph we examine bid-ask spreads around the pooled sample of events. The bid-ask spreads are elevated throughout the event period. The elevated levels prior to the event day are suggestive of bid-ask spreads eliciting the observed volume responses. Bid-ask spreads seem to exhibit a sharp increase from day $\tau = -1$ to $\tau = 1$ followed by an incomplete reversal that leaves bid-ask spreads at a persistent higher level than during our benchmark period. The difference in bid-ask spreads between the middle (high spread events) and bottom (low spread events) graphs are striking. On the event day, the mean abnormal bid-ask spread is 1% for the high bid-ask spread events whereas the corresponding number for low bid-ask spread events is 0.1%. This large difference explains the asymmetric volume response across groups.

In order to exclude that our results are generated by an incomplete benchmark model or mechanical relations in the data we perform a placebo test. We draw 15 random events per country and resample them 200 times. We calculate the mean abnormal values of our quantities of interest in the same way as our actual abnormal quantities. In each graph the blue lines represent the mean of the placebo quantities, and it is reassuring that they are always very close to zero.

[Insert Table 5 here]

In Table 5 the events are split according to whether they occur in a CORE or in a GIIPS country. The table shows that the GIIPS countries are more likely to experience decreases in volume (statistically and economically significant for days $\tau = 1$ to $\tau = 5$) while for CORE countries the effect of stress seems to lead to rebalancing. At the event day we observe a positive volume ratio of more than 27.7%. The difference in the volume ratios between the CORE and the GIIPS countries is always negative confirming that volume decreases are more severe and common in the GIIPS countries. The evidence in Table 5 corroborates our previous finding that increasing transactions costs lead to market freezes. First, the bid-ask spreads increase significantly more for GIIPS which are the countries that also experience a market freeze. Second, increases in the bid-ask spread occur prior to decreases in volume.

5.2 Transaction costs versus rebalancing

In our event study analysis, we have shown that flight episodes are associated with both freezes and rebalancing. In contrast, the existing literature presents only limited evidence in favor of freezes, in particular freezes of such long duration and magnitude (roughly a decline in volume of 30%). In the European sovereign bond market, liquidity provision is undertaken by large banks that have significant exposure to the broader financial system. Hence, we posit that in this market liquidity provision will halt whenever the financial system is stressed (crisis times).

In this section, we use daily aggregate time-series information to explore the drivers of volume in crisis and non-crisis times while acknowledging that volume, bid-ask spreads and yield spreads are all jointly determined. In order to examine whether the relations among our variables differ during crisis and normal times, we divide our time-series into a crisis period and a normal period (defining crisis periods as in Nyborg and Östberg, 2014) and estimate separate vector auto-regressions (VAR) for the two periods.

In our VARs we include bond market variables such as volume, yield and bid-ask spreads as well as variables external to the bond market that might precipitate investor rebalancing, such as equity market volatility and the dollar euro exchange rate. Table 6 presents descriptive statistics of our aggregate time-series. It is notable that during crisis times the volatility of bid-ask spreads is roughly 4 times larger than in normal times, illustrating that the price of liquidity is highly volatile in this market during crisis times.[21]

Lag selection is based on the Bayesian Information Criterion and selects one lag for the pre-crisis period and two lags for the crisis period. In the interest of brevity we only report results for the case when volume is the dependent variable (the volume

[21]We consider all of our time-series variables in first-differences and reject stationarity using the Augmented Dickey-Fuller test.

equation). Column (2) of Table 7 presents our pre-crisis VAR while column (1) presents our crisis results.

[Insert Table 6 here]

[Insert Table 7 here]

Consistent with previous results in the literature we document a positve volatility-volume relation (rebalancing). This effect is present in both normal and crisis times, increased equity volatility (VSTOXX) is associated with increased trading volume. Also, interbank market stress as captured by the LOIS is associated with rebalancing in the crisis period (which is consistent with liquidity pull-back).

We also find evidence of a liquidity-volume relation, but the relation is only statistically significant during the crisis period. In the normal period a one standard deviation larger change in the bid-ask spread is associated with a volume decrease of euro 4.5 million while a one standard deviation change in the crisis period (only considering the first lag of the bid-ask-spread) is associated with a decrease in volume of euro 86.5 million. Overall, this corroborates that liquidity provision is highly volatile during crisis periods and the findings of the event-study analysis when using time-series aggregates while excluding contemporaneous variation.

Granger causality tests among our variables are presented in Table 8. For the volume equation, the Granger causality mirrors the description given concerning the VAR coefficients. In addition, we present results concerning the bid-ask spread equation. Interestingly, in the pre-crisis period none of our variables granger cause bid-ask spreads. However, in the crisis period trading volume granger causes bid-ask spreads in the crisis period (bi-directional causality in a low volume state is consistent with fixed costs of market making as e.g., in Anshuman und Kalay, 1998).

[Insert Table 8 here]

In order to evaluate the *net* effect of shocks on volume we calculate cumulative ordered impulse response functions (cOIRFs).[22] We consider the following ordering: VOL, BAS, $LOIS$, $VSTOXX$, $FXUSD$, $EQRET$, $EQRET^2$, and $FXUSD^2$. The economic motivation for this ordering is that view the trading volume as the most endogenous and quantities such as the dollar-EUR exchange and equity returns as more peripheral (they are quantities from other markets).

Figure 5 presents cOIRFs. Panel (a) of Figure 5 presents the impact of a standardized shock in VSTOXX on bond trading volume in the pre-crisis period. Consistent with the rebalancing motive, the shock results in significant trading volume. In contrast during the crisis period (in Panel (b)) a standardized shock does not result in elevated volume. Panels (c) and (d) consider shocks in the bid-ask spread during the normal and crisis period, respectively. Comparing the two panels indicates that the response is highly conditional on whether the financial system is stressed. In the crisis period volume is significantly reduced by a standardized shock while in the pre-crisis period volume remains unaffected. As robustness, we have considered alternative orderings, in particular we have placed the bid-ask spread as the most exogenous variable and we find that the volume response is qualitatively unchanged.

[Insert Figure 5 here]

[22]We consider cumulative IRFs to be able to project the results into levels, but we have verified that all shocks die out when we do not consider cumulative IRFs.

One possible criticism of our VAR analysis is that the crisis and normal periods derived from the the existing literature. To endogenize the state of the market we estimate a threshold vector auto-regression (TVAR). The TVAR nests the crisis and non-crisis states in one VAR and accommodates different coefficients in the two states (in the spirit of Pelizzon et al. 2016). Intuitively, the TVAR jointly estimates which state each period is according to the yield spread, and the VAR co-efficients associated with each of the two states using maximum likelihood. Our results are presented in Table 9 . Consistent with previous results, in the high yield spread state (column, 1), the bid-ask spread is negatively related to volume while insignificant in the non-crisis period. Additionally, the highly significant coefficient on VSTOXX provides further evidence in favor of rebalancing.

[Insert Table 9 here]

Overall, the results of this section highlight that the *net* effect on volume is highly conditional on the underlying state of the financial system. In normal times shocks to investor's portfolios result in rebalancing while in crisis times a shock to liquidity provision results in the market freezing.

5.3 Stress and market making on two platforms

The liquidity providers in this market are heavily exposed to domestic sovereign debt.[23] Additionally, MTS has two platforms, one domestic (with predominantly

[23]Merler and Pisani-Ferry (2012) document that European domestic banks hold on average 22.4% of the outstanding sovereign debt. Potential reasons for these large exposures of banks to domestic sovereign bonds could be home bias (French and Poterba, 1991) and moral suasion (Ongena et al., 2016).

local market makers) and one international (European Bond Market) where large international financial institutions act as market makers.[24] This implies that a shock to the domestic sovereign should disproportionately impact the risk bearing capacity of market makers on the domestic platform. Thus, volume should be particularly depressed and bid-ask spreads should widen disproprotionately on the domestic platform.

[Insert Table 10 here]

In this section we consider volume and bid-ask spreads on the bond level. Apart from providing more power this has two additional advantages. First, since we compare volume and bid-ask spreads for a particular bond across platforms we can exclude that bond characteristics are driving our results. Second, it is quite likely that the bonds that are traded on the two platforms differ (selection), by considering the same bond across the domestic and international platform we can alleviate selection concerns.

We use a difference-in-difference regression framework to quantify the different response of volume and bid-ask spreads to stress on the two platforms. We compare the domestic and the EBM market before and after our stress events and predict that the domestic market experiences larger increases in bid-ask spreads and larger decreases in trading activity. We consider 21 days around our events (from τ = -10 to +10), where the sample events (denoted by e) are defined by our threshold model

[24] The share of domestic market makers in the domestic market is high e.g. in the Italian market 24.1% of the market makers are Italian banks while in the other markets under study only 4.7% of the market makers are Italian (see Table 10). Unfortunately, MTS does not provide a participant list for the EBM. However anecdotal evidence suggests that market making is facilitated by a more international group of market makers on the EBM.

with varying κ's.[25] We estimate the following regressions:

$$VOL_{b,p,\tau,e} = \alpha_{b,e} + \alpha_\tau + \beta\ DOM_p + \gamma DOM_p \times post_\tau + \sum_{k=1}^{K} \delta_k Control_{b,p,\tau,e} + u_{b,p,\tau,e}, \quad (8)$$

$$BAS_{b,p,\tau,e} = \alpha_{b,e} + \alpha_\tau + \beta\ DOM_p + \gamma DOM_p \times post_\tau + \sum_{k=1}^{K} \delta_k Control_{b,p,\tau,e} + u_{b,p,\tau,e}, \quad (9)$$

where $VOL_{b,p,\tau,e}$ is the sum of the Euro trading volume for bond b on platform p on event day τ during event e. $BAS_{b,p,\tau,e}$ is the average daily relative bid-ask spread aggregated across all quotes for a bond respectively.

DOM_p is a dummy variable that takes the value of 1 for volume (bid-ask spreads) traded (quoted) on the domestic platform and 0 otherwise. The dummy variable $post_\tau$ takes the value of 0 before the event and 1 on the event day and afterwards. A statistically significant γ on the interaction term $DOM_p \times post_\tau$ indicates that our events have an asymmetric impact across platforms. We expect γ to be negative when we consider volume, indicating that volume falls more in the domestic market than in the international market and vice versa for bid-ask-spreads.

The intercept $\alpha_{b,e}$ is a bond×event fixed effect. This implies that we are effectively using within-bond-event variation. This ensures that our results cannot be driven by bond characteristics that are invariant within the event (e.g., 21 days). Also, this excludes our results being driven by market conditions which are constant throughout the event. Additionally, we introduce 21 event-day dummies α_τ (one for each event-day τ from -10 to 10) to ensure that our results are not driven by mechanical trading patterns around events.

[25] We only consider events for which we observe quotes on both the international and the domestic MTS platform (we lose some events due to this restriction). The number of events drops from 245 ($\kappa = 1.0$), 138 ($\kappa = 1.5$), 84 ($\kappa = 2.0$) to 240, 135 and 83, respectively. Additionally, we require active trading for at least three dates per platform to include the platform volume for a particular event.

[Insert Table 11 here]

The results with volume as the dependent variable is presented in Panel A of Table 11. The coefficient γ of the interaction term $DOM \times post$ is always negative and statistically significant at the 1% level. This shows that trading volume decreases disproportionately in the domestic market. This is consistent with a larger decrease of risk bearing capacity of domestic market makers. Based on specification (6) this corresponds to an additional decrease of Euro 4.39 million (or 20.2% relative to the unconditional mean) on the domestic platform. The coefficient on *post* is negative and statistically significant at the 1% level. This is consistent with volume falling on both platforms in response to stress. The coefficient on DOM is always positive and statistically significant showing that the trading volume is on average higher in the domestic market.

The results for the bid-ask spread are in Panel B of Table 11. Here the coefficient γ of the interaction term $DOM \times post$ is always positive and statistically significant at the 1% or 5% level. This shows that spreads increase more on the domestic platform than on the EBM. Based on specification (5) this corresponds to an additional increase in bid-ask spreads of 0.0008 (or 6.2% relative to the unconditional mean) on the domestic platform. Even though the economic magnitudes are small in absolute terms, given that this is a competitive market it is significant that the change in average spread of the same bond differs across platforms. The coefficient on the variable post indicates that bid-ask spreads rise significantly in response to stress events and that the increase is monotonically increasing with the degree of market stress (increasing κ).[26]

This section has shown that the reduction in trading volume primarily occurs in the domestic market and that domestic spreads increase disproportionately. For domestic market makers our events represent a larger decrease in their risk bearing capacity due to the overweighting of domestic sovereign bonds in their balance sheet. Thus, this section is consistent the existence of a link between market maker wealth and liquidity provision (Ho and Stoll, 1981). Essentially, this section documents that when the exposure to the shock is large and market makers are homogenous the freeze is more palpable.

6 Conclusion

The European sovereign bond market is central to the operation of the European financial system. Not only is the functioning of this secondary market essential for countries that need to borrow, but also affects monetary transmission in the Euro area since sovereign debt is often used as collateral in refinancing operations with the European Central Bank. Given that liquidity providers (large banks) have significant exposure to stress events the recent European sovereign debt crisis provides an ideal setting to study the impact of reductions in risk bearing capacity and the follow-on effects on liquidity (bid-ask spreads) and ultimately trading. We choose to study trading volume since changes in yields and liquidity levels do not reflect actual investor

[26] Similar to Figure 4 in section 5.1 we have generated placebo events and verify that these events are not associated with abnormal volume and a divergence between volume in the domestic and EBM market.

rebalancing activity (flights).

In this paper we use trade-by-trade data from the MTS platform from April 2003 to December 2014. In particular, we find that in times of stress, trading is occasionally almost halted. The response of the market to stress is conditional on the willingness / capacity of market makers to provide liquidity. Additionally, we show that more exposed market makers quote higher spreads which depresses trading activity.

Given the central nature of this market, freezes may contribute to system wide instability. Our research suggests that the functioning of the European sovereign bond markets depends on a small number of dealer banks whose balance sheets are not able to facilitate intermediation in times of stress. In other markets alternative market makers such as high frequency traders step in (Carrion, 2013, notes that high-frequency traders provide liquidity in the equity market when other providers are unable). Potentially, regulators should thus aim at making this market more resilient by facilitating more market makers and disentangling the market maker balance sheets from sovereign risk. Extrapolating, the reduction in liquidity provision is potentially a negative side effect of moral suasion (Ongena et al., 2016). Overall, this paper challenges the view that the recent sovereign debt crisis was associated with large scale rebalancing.

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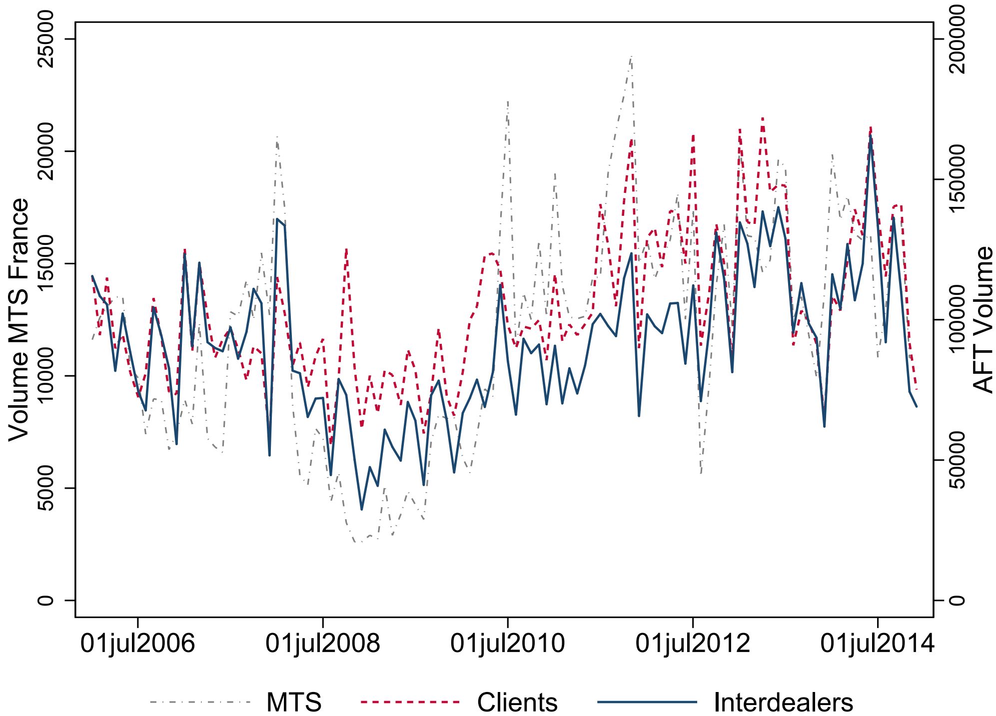

Figure 2: Volume by Market Segments in the French Market

This figure displays time series of monthly trading volume in the French sovereign bond market. The blue solid line labeled Interdealer is the total trading volume (in EUR) when both parties of a trade are dealers. The red dashed line labeled Clients is the total trading volume (denominated in EUR) when one party is a client and the other is a dealer. The Interdealer and the Clients data is supplied by the French treasury agency (Agence France Trésor). The grey dotted-dashed line labeled MTS is the overall volume traded in the French segment of the MTS platform.

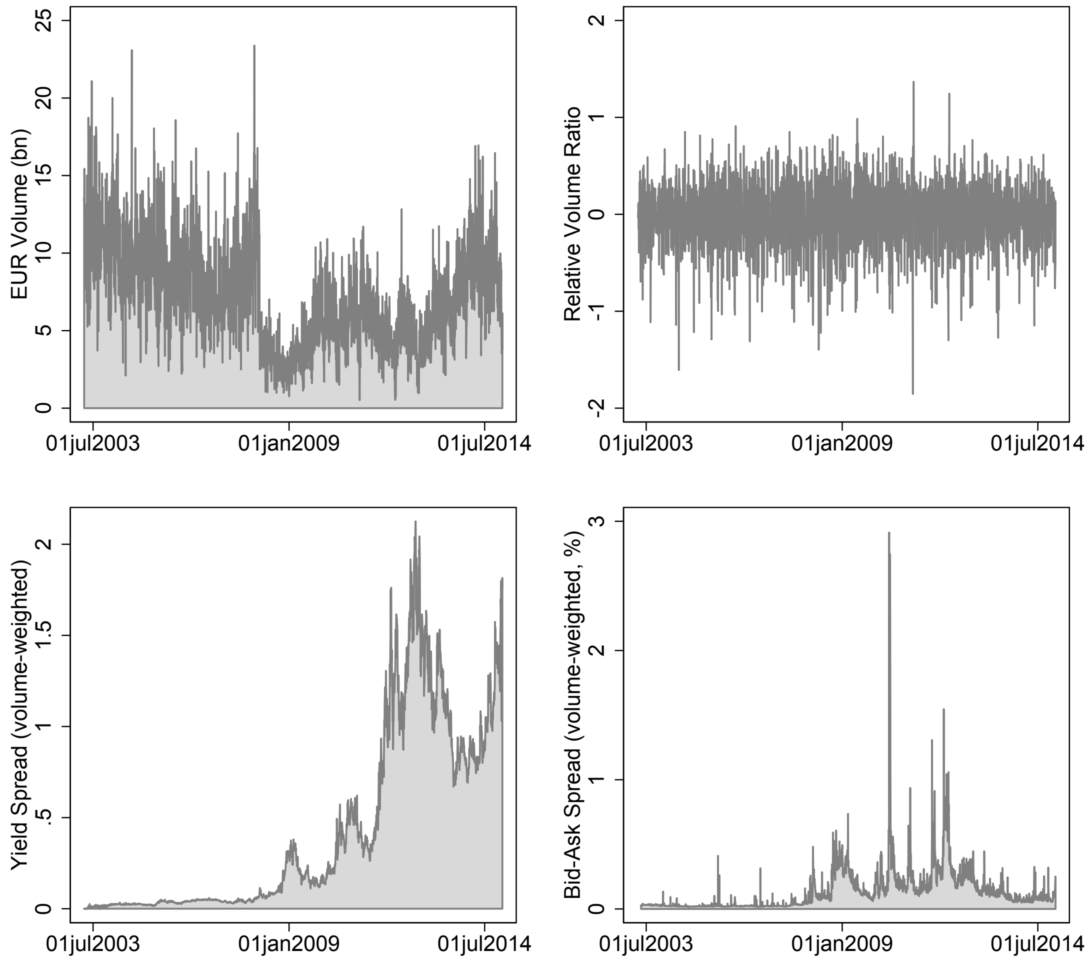

Figure 3: Time series of daily volume, relative volume, bid-ask spreads and yield spreads

The top left panel displays the total euro volume of our sample (excluding Germany). The top right graph shows the average of the relative volume ratio (RVOL) of our sample countries (see Eq. 1). The bottom left graph shows yield spreads. The yield spread is calculated as the difference between 10-year constant maturity yields of Germany and the respective country divided by the German yield and then aggregated to the sample level using volume weighting (based on the last 20 trading days). The bottom right graph shows relative bid-ask spreads calculated as volume weighted average (based on the last 20 trading days) across all bonds in the sample. All quantities are calculated from April 2003 to December 2014.

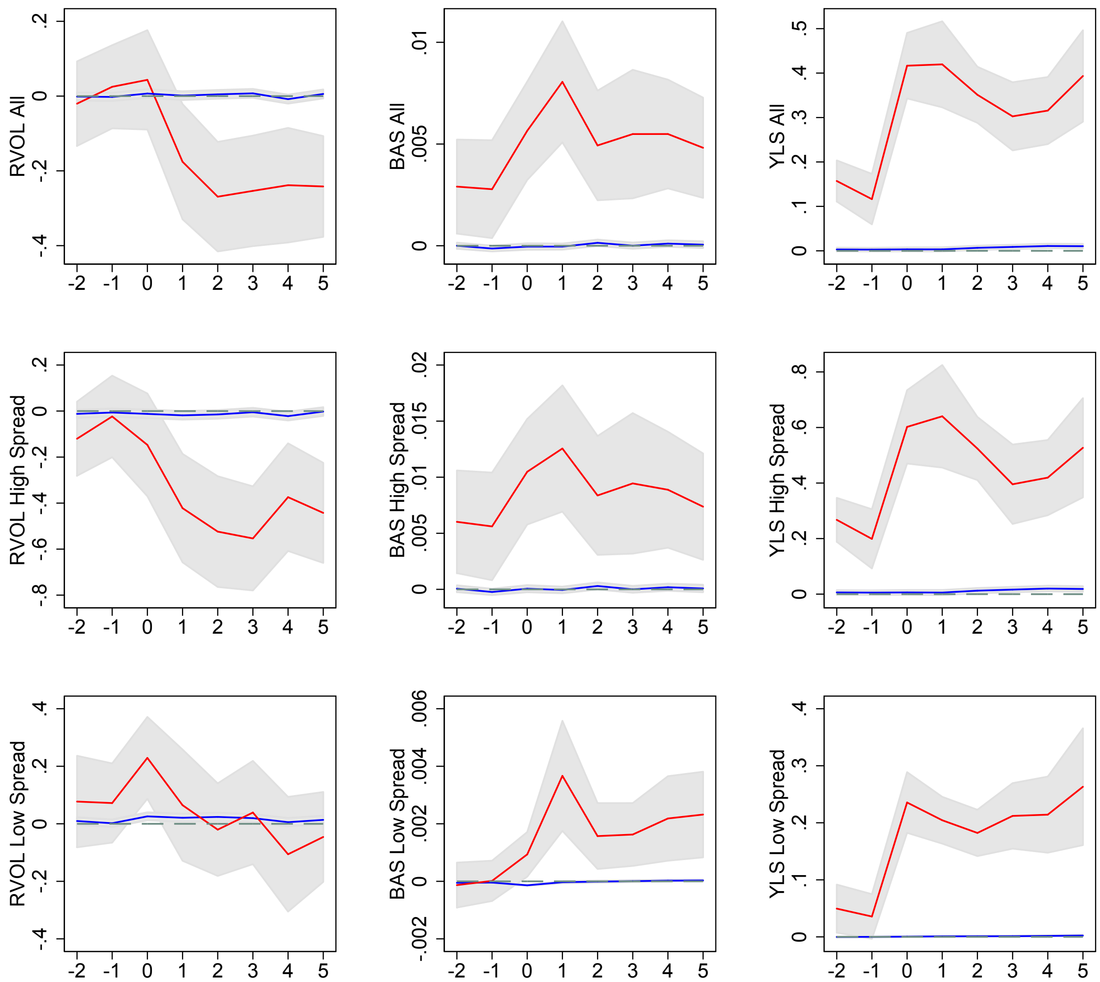

Figure 4: Relative volume, bid-ask spread and yield spread in event time

This figure shows the evolution of the average relative volume ratio, the abnormal bid-ask spread and the abnormal yield spread (calculated as the difference between the value of the variable at a particular day in the event window and the five day average from $\tau = -10$ to $\tau = 6$) for events as defined by the threshold model with $\kappa = 1.0$ and $\kappa^{DE} = -0.75$ over the event window from $\tau = -2$ to $\tau = 5$. The relative volume ratio, yield spreads and bid-ask spreads are calculated as described in Figure 3 (Note here the aggregation takes place on the country level). The red solid line represents the mean of the variable of interest calculated from the actual events and the blue line represents the means calculated from 15 random (placebo) events (resampled 200 times). The grey shaded areas are 95% confidence intervals (calculated using standard errors obtained with the cross-sectional approach). From left to right the figure shows the graphs for different variables: volume ratio $RVOL$ (left), bid-ask spread BAS (middle) and yield spread YLS (right). From top to the bottom we plot different sets of events. The graphs at the top show the average for all events. In the middle and at the bottom we show graphs for high and low bid-ask spread events. We split events according to the bid-ask spread at the event day. If the bid-ask spread is below (above) the median bid-ask-spread across all events in a country it is classified as low (high) bid-ask spread event.

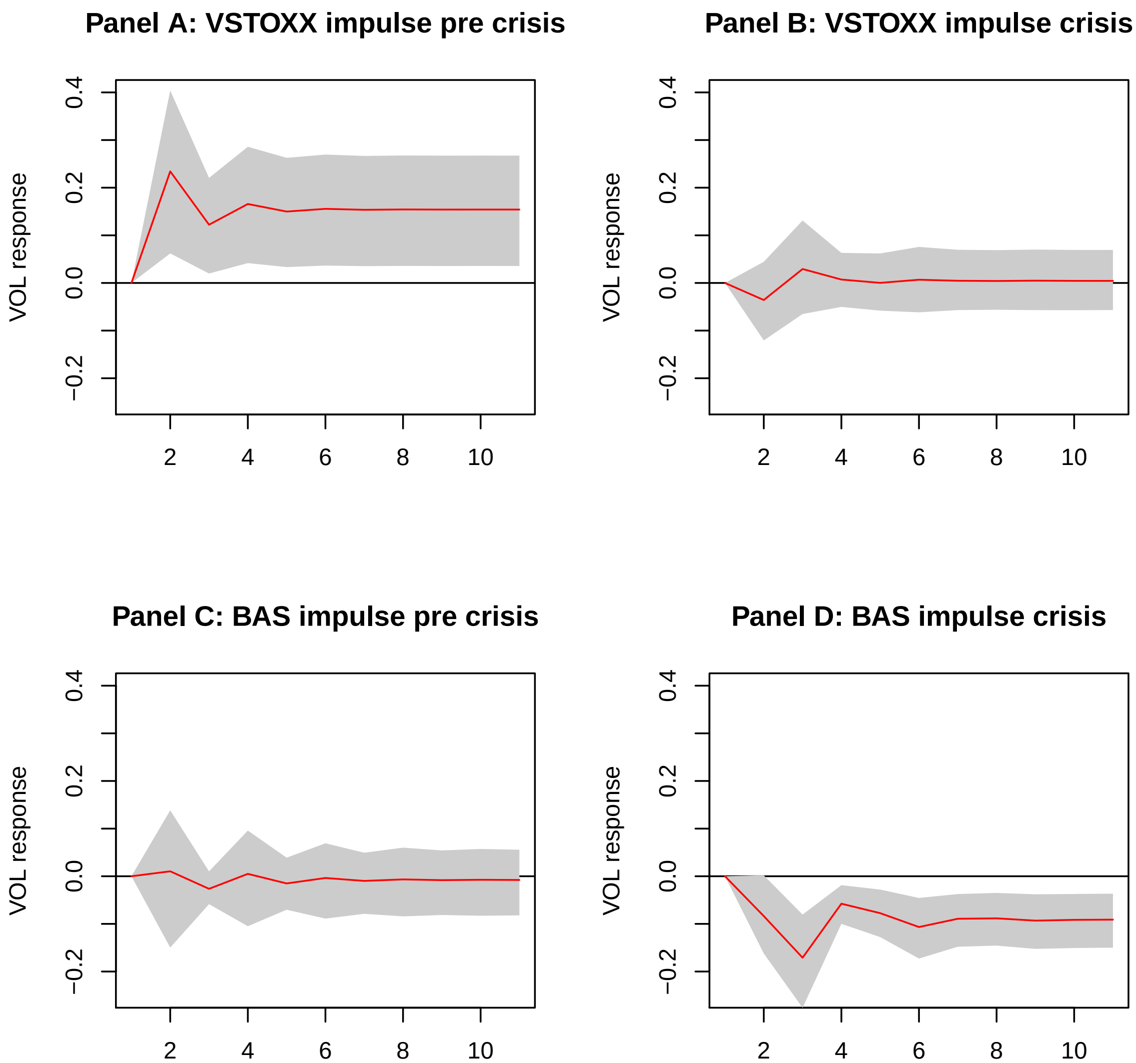

Figure 5: Cumulative Ordered Impulse Response Functions

This figure shows the cumulative ordered impulse response function. These impulse response function are based on the vector auto-regression results described in table 7. The graphs on top show the volume response to a shock in the VSTOXX in the pre-crisis (Panel A) and the post-crisis period (Panel B). The graphs on the bottom show the volume response to a shock in the BAS in the pre-crisis (Panel C) and the post-crisis period (Panel D). The red line is the estimated impulse response. The gray-shaded area around the estimate is a 95% confidence interval. We consider the following ordering: VOL, BAS, $LOIS$, $VSTOXX$, $FXUSD$, $EQRET$, $EQRET^2$, and $FXUSD^2$.

Table 1: Descriptive statistics - Sample size, trading environment and ratings

This table contains descriptive statistics of the sample size (Panel A), the trading environment (Panel B) and credit ratings (Panel C) at country and sample level. Panel A shows the *Number of trading days* (number of days where we can calculate the full set of variables), the *Number of bonds* (overall number of bonds in the dataset), the number of bonds, trades and quotes observed in the cross-section on the average day (*Bonds/trading day, Trades/trading day* and *Quotes/trading day*), the average *Trade size* (ratio of EUR volume in millions and number of trades) and the average daily *EUR volume* in millions (first summed over all bonds every day and then averaged across days). Panel B shows averages (across both time and the cross-section of bonds) for the *Minimum quantity* which is the minimum EUR amount in millions that has to be quoted on the MTS platform (varies across securities), the *Number of participants* (number of banks that trade on the MTS platform), the *Number of market makers* which shows the number of participants that have quoting obligations and the *Compliance time* which is the minimum time in hours that market makers have to quote prices. Panel C shows the Standard & Poors (S&P) credit ratings for the issuer in 2003 (beginning of the sample) and 2014 (end of the sample).

	AT	**BE**	**DE**	**ES**	**FI**	**FR**	**GR**	**IE**	**IT**	**NL**	**PT**	**Sample**
	Panel A: Sample Size Statistics											
Number of trading days	2957	2957	2957	2957	2957	2957	2602	2957	2957	2957	2957	2928.29
Number of bonds	33	258	383	334	27	874	103	61	565	216	116	271.84
Bonds/trading day	15.65	43.84	62.21	58.55	9.56	85.66	19.75	8.72	71.01	26.69	19.31	38.47
Trades/trading day	12.54	86.97	56.83	64.59	18.33	74.51	38.53	5.59	734.16	52.15	43.09	108.7
Quotes/trading day (k)	19.43	33.49	53.7	43.24	12.68	55.3	18.33	7.39	82.61	24.54	16.43	33.54
Trade size (mn)	7.85	9.21	7.08	8.03	9.15	8.32	5.86	6.74	5.49	9.6	7.59	7.77
EUR volume (mn)	103.46	812.92	405.64	496.32	174.17	623.95	284.25	38.99	4029.84	492.74	361.12	715.93
	Panel B: Trading Environment (averages)											
Minimum quantity (mn)	7.57	8.59	7.30	9.20	9.75	7.03	8.60	7.21	4.08	9.23	8.17	7.45
Number of participants	50.85	33.29	56.05	45.44	43.29	33.51	40.88	34.38	78.09	43.00	41.56	48.84
Number of market makers	13.10	13.65	12.62	8.35	15.81	14.42	12.39	12.88	12.70	14.76	15.45	12.85
Compliance time	5.22	5.14	5.28	6.90	5.26	5.22	5.00	5.22	5.31	5.23	5.24	5.48
	Panel C: Overview Rating											
S&P Rating in 2014	AA+	AA	AAA	BBB-	AA+	AA	CCC-	BBB+	BBB-	AA+	BB	-
S&P Rating in 2003	AAA	AA	AAA	AAA	AAA	AAA	A	AA+	AA-	AAA	AA	-

Table 2: Descriptive statistics main variables

This table shows mean, standard deviation (sd), median as well as the minimum (min) and the maximum (max) for the main variables in our analysis. The last column shows the statistics for the whole sample (excluding Germany) while the other columns show the corresponding statistics for the single countries. The statistics on this table are calculated for the entire sample period from April 2003 to December 2014. In panel A this table shows descriptive statistics of the relative volume ratio ($RVOL$) which is calculated as follows:

$$RVOL_t = log(VOL_t) - \frac{1}{5}\sum_{l=1}^{5} log(VOL_{t-l}),$$

where VOL is the euro volume of the country/sample (EUR value of the traded quantity at a particular day over all bonds in a country/the sample excluding Germany). Panel B shows statistics for the relative bid-ask spreads. For each quote (we observe each quote update of best bid- and ask prices) the bid-ask spread is calculated as the difference between the best ask price and the best bid price divided by the mid price (average of bid and ask price). The daily bid-ask spread is calculated as an equally weighted average across all the quotes (for a particular bond). Next the daily country/sample bid-ask spread is calculated as volume weighted average (based on the last 20 trading days) across all bonds. Lastly, Panel C shows statistics for the yield spread. The yield spread for each country is the difference between 10-year constant maturity yields of Germany and the other sample countries divided by the German yield and then aggregated to the sample level using volume weighting (based on the last 20 trading days). The 10-year constant maturity yields are estimated from the cross-section of bonds in each country using the Nelson and Siegel (1987) method.

	AT	**BE**	**DE**	**ES**	**FI**	**FR**	**GR**	**IE**	**IT**	**NL**	**PT**	**Sample**
Panel A: Descriptive Statistics Volume Ratio												
mean	-0.004	-0.001	-0.002	-0.001	-0.003	-0.001	-0.006	-0.001	-0.001	-0.003	-0.002	-0.001
median	0.094	0.028	0.035	0.047	0.102	0.027	0.039	0.060	0.011	0.036	0.065	0.019
sd	1.271	0.657	0.621	0.729	1.304	0.565	0.743	1.478	0.372	0.669	1.073	0.309
min	-5.207	-6.838	-4.653	-5.406	-6.229	-4.669	-5.118	-4.750	-1.736	-5.338	-5.719	-1.853
max	4.008	2.613	2.730	3.277	4.236	2.158	2.756	4.505	1.303	2.384	4.342	1.367
count	2957	2957	2957	2957	2957	2957	2602	2957	2957	2957	2957	2957

(This table continous on the next page)

Continuation of Table 2

Panel B: Descriptive Statistics Relative Bid-Ask Spreads (%)												
mean (all)	0.300	0.091	0.101	0.249	0.143	0.099	2.777	0.967	0.123	0.062	0.749	0.132
mean (pre crisis)	0.038	0.027	0.034	0.031	0.025	0.032	0.054	0.040	0.020	0.024	0.033	0.025
mean (crisis)	0.451	0.127	0.140	0.375	0.211	0.137	4.708	1.501	0.182	0.085	1.160	0.194
median	0.165	0.042	0.068	0.112	0.086	0.067	0.216	0.265	0.064	0.042	0.197	0.081
sd	0.396	0.127	0.097	0.351	0.173	0.105	6.075	1.690	0.178	0.070	1.296	0.169
min	0.023	0.014	0.020	0.022	0.016	0.016	0.023	0.024	0.012	0.013	0.017	0.016
max	5.026	1.418	1.394	4.253	1.482	1.247	56.245	23.429	2.666	1.330	11.773	2.914
count	2957	2957	2957	2957	2957	2957	2602	2957	2957	2957	2957	2957
Panel C: Descriptive Statistics Yield Spreads												
mean	0.124	0.226	-	0.142	0.639	0.067	1.945	0.779	0.644	0.069	1.210	0.434
median	0.082	0.086	-	0.042	0.119	0.044	0.117	0.366	0.186	0.039	0.132	0.155
sd	0.162	0.297	-	0.200	0.897	0.085	3.480	0.984	0.824	0.078	1.760	0.515
min	-0.072	-0.011	-	-0.016	-0.017	-0.049	-0.506	-0.075	0.007	-0.070	-0.003	-0.001
max	1.032	1.565	-	1.034	4.592	0.418	23.193	4.546	3.879	0.408	11.322	2.126
count	2957	2957	-	2957	2957	2957	2602	2957	2957	2957	2957	2957

Table 3: Flight events

Panel A shows the frequency of events for the different countries. We define events by using a threshold model which defines events as days where both the decrease in the German yield is below a certain threshold and the increase in the yield of the corresponding country is above a certain threshold (at the same time). The thresholds are calculated as the product of past volatility of yield changes and the parameter κ (i.e., $z_{m,t} = \kappa \times \sigma_t$). For Germany we use a fixed κ^{DE} of -0.75, while for the other countries we use different values (κ is either 1.0, 1.5 or 2.0).

	$\kappa = 2.0$	$\kappa = 1.5$	$\kappa = 1.0$
Austria	1	3	6
Beligium	4	11	20
Spain	15	27	51
Finland	2	2	3
France	0	1	5
Greece	21	27	38
Ireland	11	21	38
Italy	17	24	50
Netherlands	2	2	2
Portugal	11	20	32
Total	84	138	245

Table 4: Market Stress, Trading Volume and Liquidity

Panel A contains the event study results for different degrees of stress (κ). The event window is from $\tau = -2$ to $\tau = 5$. Events are defined as in Table 3. Our outcome variable is the relative volume ratio $RVOL$ as defined in Table 2. In Panel B we split events into two groups according to whether they are associated with above or below median (within the country) bid-ask spreads at the event day. The top of Panel B contains the results when $RVOL$ is the outcome variable. The first (second) row contains the result for the high (low) bid-ask spread group. The third row shows the difference between $RVOL$ in the two groups. The bottom of Panel B considers abnormal bid-ask spreads BAS as the outcome variable for the groups and the difference between the two groups. The abnormal bid-ask spread is calculated as the difference between the bid-ask spread in a given day in the event window and the average bid-ask spread in the [-10,-6] period. This analysis is based on the threshold model with a $\kappa = 1$. The t-statistics (in parantheses) are based on standard errors from the cross-sectional approach. ***,**,* denote statistical significance at the 1%, 5% and 10% level.

	-2	**-1**	**0**	**1**	**2**	**3**	**4**	**5**
Panel A: RVOL for different flight measures								
$\kappa = 2.0$	-0.080	-0.057	-0.180	-0.336**	-0.381***	-0.335***	-0.404***	-0.369***
	(-0.75)	(-0.52)	(-1.32)	(-2.45)	(-2.75)	(-2.83)	(-3.08)	(-2.83)
$\kappa = 1.5$	-0.067	0.038	-0.052	-0.167	-0.253**	-0.298***	-0.379***	-0.326***
	(-0.77)	(0.49)	(-0.55)	(-1.55)	(-2.52)	(-2.97)	(-3.52)	(-3.41)
$\kappa = 1.0$	-0.020	0.025	0.043	-0.176**	-0.269***	-0.253***	-0.238***	-0.242***
	(-0.35)	(0.44)	(0.64)	(-2.24)	(-3.62)	(-3.38)	(-3.06)	(-3.53)
Panel B: RVOL and abnormal BAS for high and low bid-ask spread Events ($\kappa = 1.0$)								
HS $RVOL$	-0.120	-0.024	-0.147	-0.422***	-0.524***	-0.553***	-0.374***	-0.443***
	(-1.48)	(-0.26)	(-1.30)	(-3.54)	(-4.31)	(-4.84)	(-3.17)	(-4.03)
LS $RVOL$	0.077	0.072	0.229***	0.065	-0.020	0.039	-0.106	-0.046
	(0.96)	(1.04)	(3.19)	(0.66)	(-0.25)	(0.43)	(-1.05)	(-0.58)
Difference	-0.197*	-0.096	-0.376***	-0.487***	-0.504***	-0.593***	-0.268*	-0.397***
	(-1.73)	(-0.85)	(-2.83)	(-3.17)	(-3.46)	(-4.07)	(-1.73)	(-2.95)
HS BAS	0.006**	0.006**	0.010***	0.013***	0.008***	0.009***	0.009***	0.007***
	(2.60)	(2.32)	(4.41)	(4.42)	(3.13)	(2.99)	(3.40)	(3.08)
LS BAS	-0.000	0.000	0.001**	0.004***	0.002***	0.002***	0.002***	0.002***
	(-0.33)	(0.04)	(2.39)	(3.79)	(2.72)	(2.95)	(2.94)	(3.09)
Difference	0.006***	0.006**	0.010***	0.009***	0.007**	0.008**	0.007**	0.005**
	(2.65)	(2.31)	(4.01)	(2.99)	(2.51)	(2.46)	(2.49)	(2.03)

Table 5: Market Stress, Trading Volume and Liquidity - CORE and GIIPS results

This table presents separate event study results (executed as described in Table 4) for CORE (Austria, Belgium, Finland, France and the Netherlands) and GIIPS (Greece, Italy, Ireland, Portugal or Spain). The top of the table contains the results for abnormal volume (based on the relative volume ratio $RVOL$ as defined in Table 2) for the two groups. The bottom of the table contains the results for abnormal bid-ask spreads (calculated as described in Table 4 from bid-ask spreads calculated as described in Table 2) for the two groups. The t-statistics (in parantheses) are based on standard errors from the cross-sectional approach. ***,**,* denote statistical significance at the 1%, 5% and 10% level.

	-2	**-1**	**0**	**1**	**2**	**3**	**4**	**5**
GIIPS RVOL	-0.051	0.016	0.003	-0.199**	-0.305***	-0.269***	-0.246***	-0.274***
	(-0.82)	(0.28)	(0.04)	(-2.43)	(-3.85)	(-3.36)	(-2.95)	(-3.76)
CORE RVOL	0.157	0.079	0.277	-0.040	-0.059	-0.165	-0.194	-0.054
	(1.05)	(0.40)	(1.40)	(-0.17)	(-0.28)	(-0.76)	(-0.89)	(-0.28)
GIIPS BAS	0.003**	0.003**	0.006***	0.009***	0.005***	0.006***	0.006***	0.005***
	(2.46)	(2.21)	(4.42)	(5.19)	(3.44)	(3.27)	(3.81)	(3.67)
CORE BAS	0.000	0.001	0.002***	0.002***	0.002**	0.002***	0.002***	0.002**
	(0.66)	(1.35)	(2.88)	(3.24)	(2.56)	(2.90)	(3.21)	(2.37)

Table 6: Descriptive statistics time series regressions

This table contains descriptive statistics for the time series of first differences for the aggregate volume (sample) expressed in EUR bn, the bid ask spread in %, the VSTOXX, the Libor-OIS expressed in %, the Euro-to-US Dollar exchange rate and the returns of the EuroStoxx50 (expressed in %) between April 2003 and December 2014. The euro volume is the volume of all trades at a particular day summed across all bonds in the sample. The bid-ask spread is calculated as a volume-weighted sample average. The Libor-OIS spread is the difference between the EUR 3-Month London Interbank Offering Rate and the middle rate of the EUR 3-Month Overnight Index Swap (EONIA Swap). The VSTOXX is the implied volatility of EuroStoxx50 index options. EuroStoxx50 returns are calculated from index close prices. The Euro-to-US Dollar exchange rate is the Reuters closing spot middle rate. THe volume and the bid-ask spread are calculated from MTS data. All other data is retrieved from DataStream.

	Mean	**Median**	**SD**	**Min**	**Max**	**N**
Panel A: Entire sample Period						
VOL	-0.00271	-0.05843	2.42611	-14.51555	12.91831	2956
BAS	0.00005	-0.00017	0.08214	-1.79349	1.94550	2956
VSTOXX	-0.00002	-0.00095	0.01769	-0.13980	0.22640	2956
EQRET	0.00936	0.05141	1.20679	-9.00086	10.21875	2956
FXUSD	-0.00002	-0.00006	0.00473	-0.03442	0.02707	2956
Panel A: Pre crisis Period						
VOL	-0.00409	-0.06142	2.96632	-14.51555	12.91831	1050
BAS	0.00000	-0.00002	0.02650	-0.38709	0.36864	1050
VSTOXX	-0.00015	-0.00070	0.01005	-0.03880	0.06140	1050
EQRET	0.05246	0.07564	0.79842	-3.49569	2.58072	1050
FXUSD	-0.00012	-0.00012	0.00448	-0.01552	0.01418	1050
Panel B: Crisis Period						
VOL	-0.00195	-0.05537	2.07003	-10.63002	10.33398	1906
BAS	0.00008	-0.00113	0.10039	-1.79349	1.94550	1906
VSTOXX	0.00005	-0.00120	0.02073	-0.13980	0.22640	1906
EQRET	-0.01439	0.02192	1.38073	-9.00086	10.21875	1906
FXUSD	0.00004	0.00000	0.00486	-0.03442	0.02707	1906

Table 7: VAR Volume Equation

This table contains point estimates and t-statistics (in parentheses) of the volume equation from estimating a vector auto-regression with the first differences of volume, bid-ask-spread, the LIBOR-OIS spread, the VSTOXX, the EUR-USD exchange rate and equity returns (including squared terms of the latter):

$$\Delta y_t = \sum_{j=1}^{p} \Gamma_j \Delta X_{t-j} + \epsilon_t.$$

The vector-auto-regression is estimated for the crisis and the pre-crisis period and $X_t = (1, y_{t-1}, ..., y_{t-p})'$. The variables are defined in Table 6. Lags are selected based on the BIC. ***,**,* denote statistical significance at the 1%, 5% and 10% level, respectively.

	Crisis Period	Pre-Crisis Period
ΔVOL_{t-1}	-0.428^{***}	-0.385^{***}
	(-19.202)	(-13.391)
ΔVOL_{t-2}	-0.264^{***}	
	(-11.859)	
ΔBAS_{t-1}	-0.861^{*}	-0.168
	(-1.883)	(-0.053)
ΔBAS_{t-2}	-1.630^{***}	
	(-3.569)	
$\Delta LOIS_{t-1}$	4.347^{**}	-4.972
	(2.270)	(-0.685)
$\Delta LOIS_{t-2}$	-2.425	
	(-1.269)	
$\Delta VSTOXX_{t-1}$	9.017^{**}	51.666^{***}
	(2.535)	(4.051)
$\Delta VSTOXX_{t-2}$	2.624	
	(0.743)	
$\Delta FXUSD_{t-1}$	-8.358	-18.888
	(-0.883)	(-0.965)
$\Delta FXUSD_{t-2}$	-1.003	
	(-0.107)	
$EQRET_{t-1}$	0.187^{***}	0.429^{***}
	(3.639)	(2.659)
$EQRET_{t-2}$	-0.002	
	(-0.033)	
$EQRET^2_{t-1}$	-0.017^{**}	-0.179^{**}
	(-2.154)	(-2.301)
$EQRET^2_{t-2}$	0.010	
	(1.301)	
$\Delta FXUSD^2_{t-1}(\div 100)$	-0.286	-2.695
	(-0.036)	(-0.103)
$\Delta FXUSD^2_{t-2}(\div 100)$	2.428	
	(0.303)	
Observations	1,904	1,049
Adjusted R^2	0.183	0.160

Table 8: Granger Causality Tests

This table contains the F statistics and p-values from Granger causality tests performed on the equation system described in table 7. The table contains results for the bid-ask spread equation as well as the volume equation for both the crisis and pre-crisis period. The F-statistics are calculated from a comparison of a restricted model without the excluded variable and an unrestricted. ***,**,* denote statistical significance at the 1%, 5% and 10% level, respectively.

		Crisis		**Pre Crisis**	
Equation	**Excluded**	*F statistic*	*p value*	*F statistic*	*p value*
ΔBAS	ΔVOL	10.51	0.00***	0.81	0.37
ΔBAS	ΔLOIS	1.19	0.30	0.51	0.48
ΔBAS	ΔVSTOXX	0.61	0.54	0.36	0.55
ΔBAS	Δ FXUSD	1.10	0.33	0.18	0.67
ΔBAS	EQRET	2.17	0.11	0.97	0.33
ΔBAS	$EQRET^2$	3.73	0.02**	2.57	0.11
ΔBAS	Δ $FXUSD^2$	0.56	0.57	0.02	0.90
ΔVOL	ΔBAS	6.95	0.00***	0.00	0.96
ΔVOL	ΔLOIS	3.31	0.04**	0.47	0.49
ΔVOL	ΔVSTOXX	3.44	0.03**	16.41	0.00***
ΔVOL	ΔFXUSD	0.40	0.67	0.93	0.33
ΔVOL	EQRET	6.63	0.00***	7.07	0.01**
ΔVOL	$EQRET^2$	2.58	0.08*	5.29	0.02**
ΔVOL	Δ $FXUSD^2$	0.05	0.95	0.01	0.92

Table 9: Threshold VAR Volume Equation

This table contains point estimates and t-statistics (in parentheses) of the volume equation from estimating a threshold vector auto-regression with the first differences of volume, bid-ask-spread, the LIBOR-OIS spread, the VSTOXX, the EUR-USD exchange rate and equity returns (including squared terms of the latter):

$$\Delta y_t = \Gamma_1 \Delta X_{t-1} + \Gamma_2 \Delta X_{t-1} I[z_{t-1} > z^*] + \epsilon_t.$$

Γ are the state contingent vectors of coefficients and $X_t = (1, y_{t-1})'$. The state is determined based on the sample yield spread using an endogenously determined threshold z^*. The variables are defined in Table 6. ***,**,* denote statistical significance at the 1%, 5% and 10% level, respectively.

	(1)	**(2)**
Intercept	0.0307	0.0226
	(0.4895)	(0.3118)
ΔVOL_{t-1}	-0.354***	-0.369***
	(-12.13)	(-17.19)
ΔBAS_{t-1}	-0.908*	-1.278
	(-1.668)	(-0.638)
$\Delta LOIS_{t-1}$	4.7672*	0.2494
	(1.7245)	(0.0737)
$\Delta VSTOXX_{t-1}$	12.874***	17.324***
	(2.5961)	(2.7470)
$\Delta FXUSD_{t-1}$	-10.35	-20.68
	(-0.842)	(-1.450)
$EQRET_{t-1}$	0.2304***	0.2025**
	(3.2359)	(2.2606)
$EQRET^2_{t-1}$	-0.012	-0.021*
	(-1.040)	(-1.722)
$\Delta FXUSD^2_{t-1}$	-176.8	-632.3
	(-0.175)	(-0.321)
Threshold Variable	YLS	
% Regime	46.50%	53.50%

Table 10: Share of Domestic Market Makers

The table shows the share of market makers by their nationality for each of the 10 domestic MTS markets. The calculations are based on the participant lists published on the MTS website on November 21, 2016. The rows of the table contain the market while the columns contain the market maker nationality. For example column one shows the number of Austrian market makers in the MTS domestic market indicated in each row. The first row splits market makers in Austria by their nationality. The mean is calculated across all rows. The difference is calculated as the difference between the share of domestic market makers and the mean. The t-value assesses the statistical significance. The standard deviation is calculated column-wise.

	AT	**BE**	**ES**	**FI**	**FR**	**GR**	**IE**	**IT**	**NL**	**PT**
AT	**8.33%**	0.00%	8.33%	0.00%	16.7%	0.00%	0.00%	4.17%	4.17%	0.00%
BE	0.00%	**4.55%**	4.55%	0.00%	18.2%	0.00%	0.00%	0.00%	13.6%	0.00%
ES	0.00%	0.00%	**29.2%**	0.00%	20.8%	0.00%	0.00%	0.00%	0.00%	0.00%
FI	0.00%	0.00%	0.00%	**10.00%**	15.0%	0.00%	0.00%	5.00%	5.0%	0.00%
FR	0.00%	0.00%	8.70%	0.00%	**17.4%**	0.00%	0.00%	8.70%	4.35%	0.00%
GR	0.00%	0.00%	0.00%	0.00%	14.3%	**14.3%**	0.00%	4.76%	4.76%	0.00%
IE	0.00%	0.00%	0.00%	0.00%	15.0%	0.00%	**5.00%**	0.00%	5.00%	0.00%
IT	0.00%	0.00%	6.90%	0.00%	13.79%	0.00%	0.00%	**24.1%**	3.45%	0.00%
NL	0.00%	0.00%	9.09%	4.55%	18.2%	0.00%	0.00%	0.00%	**13.6%**	0.00%
PT	0.00%	0.00%	8.00%	0.00%	16.0%	0.00%	0.00%	0.00%	4.00%	**20.0%**
mean	0.83%	0.45%	7.47%	1.45%	16.53%	1.43%	0.50%	4.68%	5.80%	2.00%
Diff	7.50%	4.09%	21.69%	8.55%	0.86%	12.9%	4.50%	19.5%	7.84%	18.0%
t-value	3.00	3.00	2.69	2.71	0.42	3.00	3.00	2.74	1.89	3.00

Table 11: Difference-in-Difference - Bond Level

This table contains point estimates and t-statistics (in parentheses) from estimating the following regression,

$$Y_{b,p,\tau,e} = \alpha_{b,e} + \alpha_\tau + \beta\ DOM_p + \gamma DOM_p \times post_\tau + \sum_{k=1}^{K} \delta_k Control_{b,p,\tau,e} + u_{b,p,\tau,e}.$$

We consider 21 days around our events (from τ = -10 to +10), where the sample events (denoted by e) are defined by our threshold model with varying κ's. We only consider events for which we observe quotes on both the international and the domestic MTS platform. Additionally we require active trading for at least three dates per platform to include the platform volume for a particular event. The dependent variable is the euro volume ($VOL_{b,p,\tau,e}$) or the bid-ask spread ($BAS_{b,p,\tau,e}$) of bond b, on platform p at event day τ for event e. The volume is expressed in millions EUR divided by 10 and bid-ask spreads are expressed in % times 10. The variable post is an indicator variable that takes the value of 1 after the event and 0 before the event. The variable treatment takes the value of 1 for the domestic market and 0 for the EBM market. The control variables include dummies for the country, the weekday and the month as well as indicator variables for EU wide macroeconomic announcements (CPI, Employment GDP) and for ECB monetary policy decisions (change of main refinancing rate) and the minimum price tick. The specification also contains Bond×Event fixed effects and event time fixed effects. Standard errors are clustered around events. ***,**,* denote statistical significance at the 1%, 5% and 10% level, respectively.

	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
	$\kappa = 1.0$	$\kappa = 1.5$	$\kappa = 2.0$	$\kappa = 1.0$	$\kappa = 1.5$	$\kappa = 2.0$
Panel A: Results for EUR Volume						
Post	-0.032**	-0.085***	-0.081***			
	(-2.49)	(-3.18)	(-2.89)			
DOM	1.862***	1.788***	2.018***	3.408***	3.491***	3.820***
	(13.94)	(9.42)	(7.38)	(17.76)	(10.92)	(8.89)
DOM × Post	-0.254***	-0.441***	-0.429***	-0.249***	-0.453***	-0.439***
	(-3.71)	(-4.85)	(-3.77)	(-3.33)	(-4.27)	(-3.29)
N	163,149	81,900	53,739	163,149	81,900	53,739
R^2	0.042	0.034	0.039	0.314	0.310	0.334
Panel B: Results for Bid-Ask Spreads						
Post	2.616***	4.002***	4.640***			
	(7.48)	(6.46)	(5.00)			
DOM	3.823***	5.028***	5.467***	-0.458***	-0.534***	-0.677***
	(8.54)	(6.12)	(5.33)	(-4.56)	(-2.95)	(-3.06)
DOM × Post	0.832***	0.770**	0.882*	0.716***	0.808**	1.128***
	(4.24)	(2.19)	(1.87)	(3.71)	(2.34)	(2.68)
N	163,149	81,900	53,739	163,149	81,900	53,739
R^2	0.019	0.021	0.023	0.615	0.592	0.588
Controls	NO	NO	NO	YES	YES	YES
Bond×Event FE	NO	NO	NO	YES	YES	YES
Event Time FE	NO	NO	NO	YES	YES	YES