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Liquidity in the euro-area sovereign bond market during the "dash for cash" driven by the COVID-19 crisis

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Abstract

We study the liquidity of the euro-area sovereign bond market during the March 2020 dash for cash. We provide evidence that liquidity was significantly impaired across the three core euro-area countries. We note that the liquidity deterioration was not as severe as that during the euro-area sovereign debt crisis. Spikes in illiquidity are reversed in the period immediately following the dash for cash episode. We also document strong commonalities in liquidity that are reduced after the dash for cash. This result indicates that variation in liquidity exhibits a strong common component highlighting the systemic risk that comes as a result.

Keywords: Liquidity, Sovereign bond markets, COVID-19 outbreak, Common factors
JEL Classification: C5; G01; G10; G15

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1. Introduction

The outbreak of the COVID-19 pandemic placed the global financial system under severe strain.[1] The financial market turmoil went through two phases. The first phase featured flight-to-safety episodes. In February 2020, safe haven assets such as U.S. Treasury bonds and German bunds experienced large price increases as investors' demand shifted towards less risky assets. Accordingly, liquidity conditions for riskier assets deteriorated substantially.

The second phase was characterised by a "dash for cash". In March 2020, investors became extremely risk-averse and the demand for cash and near-cash assets increased substantially. Bond and equity funds in both advanced and emerging economies experienced large cash outflows. Even the safest and most liquid assets such as sovereign bonds in the U.S. and Germany experienced massive sell-offs increasing risk aversion to extraordinary levels (Cantú, Cavallino, De Fiore, & Yetman, 2021). For example, on 17 March the 10-year U.S. Treasury yield jumped 36 basis points (the largest increase since 1995). The large sell-offs were accompanied by a collapse in liquidity in these markets. The turbulence in the government bond market spilled over to other markets and negatively affected funding conditions in both secured and unsecured money markets (Schrimpf, Shin, & Sushko, 2020). While the stress was largely due to overwhelming one-sided flows from investors, it also reflected the unwillingness and incapability of banks to intermediate.[2]

Policy responses around the globe were immediate and sizeable and succeeded in alleviating market stress in the financial system and restoring investor confidence. For example, the European Central Bank (ECB) announced the Pandemic Emergency Purchase Programme (PEPP), a €750

[1] A detailed discussion is provided in the Financial Stability Board (FSB) report, entitled: "Holistic review of the March market turmoil", November 2020 https://www.fsb.org/2020/11/holistic-review-of-the-march-market-turmoil/

[2] The Financial Stability Board (FSB) conducted a survey in order to assess the behaviour of market participants in government bond markets during the March 2020 turmoil: https://www.fsb.org/2022/10/liquidity-in-core-government-bond-markets/. Based on the responses, the major contributing factors to the unusual dealer behaviour were the high uncertainty level, large unidirectional flows, operational issues, and the dealers' internal risk management.

billion non-standard asset purchase programme that was subject to fewer constraints than previous similar programmes, that proved to be successful in slowing the widening of bond spreads in the euro-area. Moreover, the ECB expanded the assets it accepted as collateral for its liquidity operations and announced a comprehensive package of monetary policy measures, such as additional long-term refinancing operations at a reduced interest rate and a temporary capital relief to banks.

In this case study we examine liquidity conditions in the euro-area sovereign bond market during the dash for cash episode. Our analysis covers the three economic giants in the euro-area, Germany, France, and Italy whose GDPs make up more than half of the European Union's (EU) entire economic output.[3] We are motivated by the role liquidity plays during periods of market stress as its deterioration poses significant challenges to investors, policy-makers and regulators, given that it may lead to systematic breakdowns in liquidity (Chordia, Roll, & Subrahmanyam, 2000; Hasbrouck and Seppi, 2001) and a widening of liquidity premia along with flight-to-liquidity effects (Amihud and Mendelson, 1986; Vayanos, 2004).

We make use of a wide array of liquidity measures that are able to capture different dimensions of liquidity and have been used in previous studies. Our contribution rests on the fact that we are the first to systematically analyse the dash for cash outbreak for euro-area sovereign bonds. We not only compare the bond liquidity of the three strongest euro-area economies during the dash for cash episode with their corresponding liquidity levels pre-COVID, but also with their liquidity levels during the peak of the euro-area sovereign debt crisis period. We consider the period from November 2011 to January 2012 as the sovereign debt crisis period during which the liquidity of all three countries' bond markets deteriorated the most, according to our dataset. Given the extent and magnitude of the euro-area sovereign debt crisis, it can be used as a solid benchmark to assess the severity of the dash for cash episode and to shed light on which stress episode was the worst in

[3]The output for Germany, France and Italy in 2020 reached $4 trillion, $2.7 trillion and $1.9 trillion respectively per data from the International Monetary Fund.

terms of liquidity deterioration. We use a rich high-frequency dataset from the MTS markets (Mercato dei Titoli di Stato), Europe's major interdealer fixed-income market for government bonds.

We also study for the first time commonality in liquidity in the euro-area sovereign bond market before, during, and after the dash for cash episode, using principal components analysis (PCA). The study of the common determinants of liquidity is of substantial importance given the practical implications for regulators, investors, and financial market stability. For example, the stock market crash of 1987 and the Russian financial crisis of 1998 (see Dungey, Goodhart, & Tambakis, 2008) are widely regarded as systematic breakdowns in liquidity that can be attributed to liquidity being driven by strong common factors. Such extreme liquidity conditions significantly affect financial asset prices (Amihud and Mendelson, 1986; Jacoby, Fowler, & Gottesman, 2000; Amihud, 2002; Pastor and Stambaugh, 2003; Acharya and Pedersen, 2005). Commonality in liquidity can be induced by variation in trading volume and volatility, as principal determinants of dealer inventory, and by asymmetric information in the dealership market (Chordia, Roll, & Subrahmanyam, 2000).

We find a clear deterioration in liquidity in March 2020 for all three countries, however, liquidity shortages were not as severe as those during the sovereign debt crisis. We document the presence of strong commonalities in spread-based and depth-based liquidity during the March outbreak, which are amplified compared to their pre-COVID levels, suggesting that liquidity contributes to systematic risk and its variation can cause market-wide effects.

Lastly, in an effort to identify whether the spikes in illiquidity during the dash for cash are eventually reversed in the subsequent period, we find a clear improvement in liquidity across all three countries and liquidity measures. Commonality in liquidity weakens in the period immediately following the dash for cash showing that the financial system's vulnerability to liquidity freezes is reduced. Although we don't investigate the effectiveness of the ECB interventions in alleviating liquidity distress rates, as it lies outside the aims and scope of this paper, we attribute the lessening of the extreme liquidity conditions to the immediate and effective policy responses by ECB.

The rest of the paper is organized as follows. Section 2 discusses the related literature. Section 3 describes the data and the liquidity measures used in the study. Section 4 presents and discusses the empirical findings. Finally, Section 5 concludes the paper.

2. Selective literature review

The majority of earlier studies on sovereign bond markets during the pandemic is focused on the U.S. Treasury market. Duffie (2020) reviews the functionality of the secondary market for U.S. Treasuries in March 2020, when the COVID-19 crisis triggered investor flows that overwhelmed intermediaries. The actions of the Fed were able to restore market liquidity through its unprecedented rate of Treasury purchases and through the relaxation of the Supplementary Leverage Ratio rule for reserves and Treasuries. Fleming (2020) studies the most liquid segment of the U.S. Treasury market – the electronic interdealer broker (IDB) market – for on-the-run notes and bonds to better understand how the Fed's actions evolved in relation to day-to-day market developments. Infante and Saravay (2020) using the collateral multiplier measure highlight that in March 2020 the low level of secured lending in the U.S. Treasury market was partly due to the dealers' inability and unwillingness to lend to speculative investors in sufficient quantities that contributed to the market disruption. Ermolov (2022) studies whether the Fed interventions were successful in supporting the government bond liquidity during the COVID-19 pandemic and argues that illiquidity was higher than the Great Recession Levels and that it took the Fed two weeks to normalise liquidity in the U.S. Treasury market.

Studies on the liquidity of sovereign bond markets during the pandemic outside the U.S. are limited. Gubareva (2021) analyses the liquidity of emerging market bonds during the COVID-19 crisis and provides evidence of a decoupling in the liquidity dynamics and credit risk metrics, due to tighter credit spreads resulting from the repricing of default risk. Poli and Taboga (2021) propose a new composite indicator of market liquidity for euro-area sovereign bonds and find that ECB's interventions have had a significant pos-

itive impact on sovereign bond liquidity during the COVID-19 crisis. Zaghini (2023) argues that the euro-area bond market was not significantly affected by the COVID-19 news until the last week of February 2020 when the first lockdown was enforced in Europe. Our study is the most comprehensive of all previous studies on the liquidity of the euro-area sovereign bond market during the dash for cash episode.

Our study also relates to the literature on commonality in liquidity. The seminal papers on commonality in liquidity are those of Chordia, Roll, & Subrahmanyam (2000), Hasbrouck and Seppi (2001), and Huberman and Halka (2001) which document the existence of common factors in liquidity for U.S. listed stocks. Kamara, Lou, & Sadka (2008) find that the divergence of systematic liquidity can be attributed to an increase in institutional investing and the introduction of index-based financial products, whilst Hameed, Kang, & Viswanathan (2010) show that commonality in liquidity increases during periods of market declines.

Evidence of liquidity commonality in bond markets is scarce. Fleming (2003) finds considerable commonality in liquidity in the U.S. Treasury market whilst Chordia, Sarkar, & Subrahmanyam (2005) analyse liquidity comovements across stocks and bonds and highlight the systemic nature of liquidity shocks in both markets. Schneider, Lillo, & Pelizzon (2016) study commonality in liquidity in the Italian sovereign bond market during the period 2011-2015 and find that liquidity is correlated across bonds and that correlation strengthens as the difference in maturity between bonds becomes smaller. O'Sullivan and Papavassiliou (2020) find that the magnitude of liquidity commonality is higher in the GIIPS region of the euro-area sovereign bond market where market-wide liquidity risk is higher. Richter (2022) finds that local market-level liquidity changes exert a substantial influence on the liquidity of individual bonds in the euro-area sovereign bond market. Our study is the first to examine commonality in sovereign bond liquidity during the pandemic.

Finally, our study is also related to the literature on the microstructure of European sovereign bond markets with most studies focusing on non-crisis periods (Cheung, Rindi, & De Jong, 2005; Dunne, Moore, & Portes,

2007; Beber, Brandt, & Kavajecz, 2009; Favero, Pagano, & Von Thadden, 2010; Caporale and Girardi, 2013; Paiardini, 2014; Pelizzon, Subrahmanyam, Tomio, & Uno, 2016; Kinateder and Papavassiliou, 2019; O'Sullivan and Papavassiliou, 2019,2021). We are the first to systematically analyse the dash for cash outbreak for euro-area sovereign bonds and compare the liquidity deterioration in March 2020 with that of the peak of the euro-area sovereign debt crisis and with a period that immediately follows the dash for cash. We hope that our findings will shed light on this liquidity episode and motivate new research in this area.

3. Liquidity measures and data description

Liquidity has several dimensions (Borio, 2000; Lybec and Sarr, 2002). The two most well studied are tightness and depth. Tightness, measures transaction costs, i.e. the difference between buy and sell prices while depth relates to the quantity of transactions in financial markets. In this section, we present the liquidity measures that correspond to the different facets of liquidity for the German, French, and Italian sovereign bond markets. We focus on the 10-year on-the-run benchmark fixed coupon-bearing government bonds from the domestic German, French, and Italian MTS markets and consider quotes recorded during regular trading hours, i.e. from 8:15 am to 5:30 pm Central European Time (CET). Benchmark bonds have an outstanding value of at least €5 billion and trade on both the domestic MTS platforms and the EuroMTS platform. We construct the following liquidity measures following O'Sullivan and Papavassiliou (2020) and Hasbrouck and Seppi (2001):

- **Best 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 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 best bid size plus best ask size, where size denotes the bid or offered quantities of securities for sale
- **Quote slope**, defined as best spread divided by the logarithm of quoted depth
- **Market quality index (MQI)**, defined as half of quoted depth divided by the relative spread [4].

The higher the value of the spread-based (depth-based) liquidity proxies the lower (higher) the liquidity in the market. The last two liquidity proxies combine elements from both the tightness and depth liquidity dimensions and thus are regarded as hybrid liquidity measures. The higher the value of the quote slope measure the lower the liquidity in the market, whilst the higher the value of the MQI measure the higher the liquidity.

All the aforementioned liquidity measures are constructed using intraday 5-minute intervals. We properly clean our dataset and discard pre-sessional and end-of-day quotations along with zero and negative bid-ask spreads. Our sample period covers the 11-23 March 2020 outbreak and a pre-COVID period that spans the dates from 2 January 2019 to 30 December 2019. We also use a post-dash for cash period that extends from 24 March 2020 to 24 April 2020. Our dataset also covers the euro-area debt crisis period from November 2011 to January 2012 and a pre-crisis period from January 2008 to October 2009.[5]

[4]The market quality index (MQI) has been proposed by Bollen and Whaley (1998) in order to measure the net effect on overall market liquidity. An increase in the market quality index corresponds to an increase in market quality.

[5]We consider November 2009 as the beginning of the euro-area sovereign debt crisis (see relevant discussions in Claeys and Vašíček, 2014, De Santis, 2014, and O'Sullivan and Papavassiliou, 2020).

4. Empirical findings and discussion

We divide our empirical findings into three sections. The first section presents statistics on the liquidity of 10-year benchmark bonds from Germany, France, and Italy during the peak of the COVID-19 crisis and offers comparisons with the peak of the euro-area sovereign debt crisis. The second section investigates commonality in liquidity in the euro-area sovereign bond market before and during the dash for cash. The third section compares liquidity and commonality in liquidity between the dash for cash and a monthly period immediately following the dash for cash.

4.1. Liquidity measures: COVID-19 crisis vs euro-area debt crisis

In this section we compare the liquidity of 10-year benchmark bonds from Germany, France, and Italy during the dash for cash episode with their corresponding liquidity levels pre-COVID and during the peak of the euro-area sovereign debt crisis period. Table 1 depicts the mean values of liquidity measures during the 11-23 March 2020 outbreak that are compared with those in the pre-COVID period (2 January 2019 to 30 December 2019). There is a clear deterioration in liquidity during the dash for cash episode across all liquidity measures and countries. The percentage changes in liquidity between the two periods are substantial and take on values as high as 236%, highlighting the adverse liquidity conditions in the euro-area bond market at the peak of the pandemic. All spread measures, regardless of how they are measured, increase substantially during March, especially for Italy, suggesting that liquidity provision was impaired. Quoted depth drops for France and Italy whilst it improves for Germany, pointing to an increased trading activity for the German benchmark. This can be explained by flight-to-quality episodes that took place at the time, as investors were rebalancing their portfolios by investing in German bonds that were supposed to be safer and more liquid than other euro-area bonds, commensurate with Germany being a "safe haven" and the strongest economy in the euro-area. The mean value of the quote slope proxy rises across all countries and the market quality index drops, both indicating a clear liquidity deterioration.

Table 2 depicts consistent results across all countries and liquidity measures during the peak of the sovereign debt crisis. Liquidity deteriorates substantially during the peak of the crisis compared with its pre-crisis levels. In fact liquidity was impaired by a higher amount during that period than in March 2020. Based on the market quality index, market quality weakened by a higher amount during the debt crisis than during March 2020, although differences are small. This is due to the fact that quoted depth decreases and spread increases during the debt crisis dominate those of the COVID-19 episode.

Comparing the findings from Tables 1-2, we can conclude that the impact of the dash for cash episode on liquidity was not as severe as the debt crisis impact. It is also apparent from this analysis that Italy was more adversely affected during the peak of the sovereign debt crisis than Germany and France, with percentage changes in its liquidity levels reaching values greater than 300%. Previous research has shown that the liquidity of periphery euro-area countries, so-called GIIPS countries at the time of the euro-area debt crisis, was more adversely affected than the liquidity of core euro-area countries (O'Sullivan and Papavassiliou, 2020; Papavassiliou and Kinateder, 2021)[6].

4.2. Commonality in liquidity

In this section we study commonality in liquidity in the euro-area sovereign bond market before and during the dash for cash liquidity episode. We use PCA to show that common factors exist in liquidity levels as measured by spread-based and depth-based liquidity proxies. PCA is applied to standardised series of spreads and depths decomposing the sample covariance matrix, following Hasbrouck and Seppi (2001). Table 3 presents the empirical results on commonality. Panel A of the table presents the results for spread-based liquidity measures, i.e. best spread, quoted spread, and relative spread. The cumulative proportion of liquidity variation explained by the first two factors

[6]The acronym GIIPS was popularized during the euro-area sovereign debt crisis and refers to the financially distressed economies of Greece, Ireland, Italy, Portugal and Spain.

increases for best spread from 68.63% pre-crisis to 84.02% during the dash for cash episode. Similar result is documented for the relative spread with an increase from 68.83% pre-crisis to 83.87% during the COVID-19 outbreak. The cumulative proportion of liquidity variation explained by the two PCA factors drops for the quoted spread from 69.73% pre-crisis to 68.13% during the dash for cash episode (a small drop of 2.29%), however, still remains at high levels.

Panel B of the table presents the results for depth-based liquidity measures, i.e. quoted depth. There is an increase in the amount of liquidity variation explained by the first two PCA factors from 73.28% pre-crisis to 75.71% during the dash for cash period (an increase of 3.32%). The aforementioned results show that both spread-based and depth-based liquidity commonality strengthens during the COVID-19 outbreak confirming previous findings by Hameed, Kang, & Viswanathan (2010) and Karolyi, VanLee, & Dijk (2012) who document that commonality in liquidity increases during periods of market declines and exhibits a positive relationship with market volatility. The average realized volatility for Germany, France, and Italy pre-crisis is 0.24%, 0.27%, and 0.68% respectively, whereas the corresponding volatility during the dash for cash reaches 0.73%, 0.76%, and 2.85%, respectively, confirming the positive relationship between commonality in liquidity and market volatility. This finding can be explained by changes in volatility that affect systematic liquidity via correlated trading patterns that take effect among market makers, impacting on the supply side of liquidity (Chordia, Roll, & Subrahmanyam, 2000; Coughenour and Saad, 2004). As Kamara, Lou, & Sadka (2008) argue, during periods of stress the capital available to market makers and portfolio managers is reduced forcing them to reduce their holdings which increases commonality in liquidity. Similar explanations are provided by the theoretical model of Brunnermeier and Pedersen (2009) who find that during periods of increased volatility the funding liquidity of financial intermediaries is adversely affected leading to reduced liquidity supply which increases commonality in liquidity.

Overall, we find stronger commonalities in both spread and depth liquidity proxies during the COVID-19 outbreak than pre-COVID, indicating that

the euro-area sovereign bond market was vulnerable to extreme market-wide liquidity dislocations and that variation in liquidity was not completely idiosyncratic. The strengthening of liquidity commonalities indicates that the susceptibility of the financial system to liquidity squeezes is enhanced across sovereign benchmark bonds. Commonality in spread-based liquidity appears to be higher than commonality in depth-based liquidity, however, differences are not so dramatic.

4.3. Liquidity measures and commonality in liquidity: dash for cash vs post-dash for cash

To better understand the magnitude and duration of liquidity deterioration during the dash for cash, it is worth examining how much of the spike in illiquidity is eventually reversed in the period immediately following the dash for cash. We use a post-dash for cash period that spans the dates from 24 March 2020 to 24 April 2020. We deem that one month of data is sufficient to shed light in that regard.

Table 4 depicts the mean values of liquidity measures during the dash for cash that are compared with those in the post-dash for cash period. We find a clear improvement in liquidity during the post-dash for cash across all liquidity measures and countries. All spread measures drop by amounts ranging from 16 percent to 37 percent, while quoted depth increases for Germany and Italy by 20 and 54 percent, respectively, but drops for France only by a small amount of roughly 3 percent. Quote slope declines from 21 to 36 percent indicating liquidity improvements post-dash for cash, while the market quality index exhibits percentage increases that range from nearly 30 percent to 155 percent.

Panel A of Table 5 presents the empirical results on commonality for spread-based liquidity measures. The cumulative proportion of liquidity variation explained by the first two factors declines for all spread measures post-dash for cash evidencing that the risk of market-wide systematic liquidity breakdowns is lowered. Similar results are documented in Panel B of Table 5 for the quoted depth liquidity measure. These findings emphasize that within a month only from the extreme dash for cash liquidity episode,

the euro-area bond market successfully restored a substantial amount of its pre-COVID liquidity. Clearly, the ECB policy responses including the Pandemic Emergency Purchase Programme (PEPP) and the targeted longer-term refinancing operations, were successful in restoring market liquidity and increasing financial stability.

5. Conclusion

In this paper we study liquidity conditions in the euro-area sovereign bond market during the COVID-19 outbreak. We document a clear liquidity deterioration during the dash for cash episode compared to a pre-COVID period across a range of liquidity measures that capture different liquidity dimensions. The spikes in illiquidity are reversed quickly, within only a month that follows the dash for cash. We also find significant commonalities in liquidity that weaken after the dash for cash, highlighting the systemic nature of liquidity shocks during the pandemic.

The COVID-19 experience reinforces the importance of implementing post-crisis reforms that would protect the global financial system and enhance its resilience. This includes regulatory reforms and policy actions, such as analysing the drivers of bond market illiquidity, the role of margins, and the full implementation of the Basel III framework in light of the new standards that came into effect recently on market risk-related capital requirements.

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Table 1: Summary statistics.

Liquidity measures	**Countries**		
	Germany	**France**	**Italy**
Best spread (pre-COVID)	0.1156	0.1160	0.9880
Best spread (dash for cash)	0.1976	0.3443	2.6534
Percentage change (%)	70.93	196.81	168.56
Quoted spread (pre-COVID)	0.2071	0.1647	1.1504
Quoted spread (dash for cash)	0.2839	0.4163	3.8685
Percentage change (%)	37.08	152.76	236.27
Relative spread (pre-COVID)	0.0988	0.0939	0.8505
Relative spread (dash for cash)	0.1886	0.2720	2.8081
Percentage change (%)	90.89	189.67	230.17
Quoted depth (pre-COVID) (million €)	13.98	22.52	24.86
Quoted depth (dash for cash) (million €)	16.41	19.56	12.25
Percentage change (%)	17.38	-13.14	-50.72
Quote slope (pre-COVID)	0.0037	0.0036	0.0314
Quote slope (dash for cash)	0.0063	0.0107	0.0862
Percentage change (%)	70.27	197.22	174.52
MQI (pre-COVID) (million €)	90.61	157.21	103.58
MQI (dash for cash) (million €)	51.72	57.62	15.25
Percentage change (%)	-42.92	-63.35	-85.28

The table presents summary statistics (mean values) of liquidity measures for Germany, France, and Italy over the dash for cash (11-23 March 2020) and pre-COVID (January 2019 to December 2019) periods. Best spread is the difference between the best ask quote and the best bid quote. Quoted spread is defined as the difference between the average of the three best ask prices and bid prices. Relative spread is the best bid-ask spread divided by the quote midpoint. Quoted depth is the best bid size plus best ask size. Quote slope is defined as best spread divided by the logarithm of quoted depth. Market quality index (MQI) is defined as half of quoted depth divided by the relative spread.

Table 2: Summary statistics.

Liquidity measures	**Countries**		
	Germany	**France**	**Italy**
Best spread (pre-crisis)	0.1145	0.2476	0.2251
Best spread (during crisis)	0.1809	0.8199	0.7743
Percentage change (%)	57.99	231.14	243.98
Quoted spread (pre-crisis)	0.1567	0.3473	0.3001
Quoted spread (during crisis)	0.2169	0.9391	1.1186
Percentage change (%)	38.42	170.40	272.74
Relative spread (pre-crisis)	0.1108	0.2402	0.2263
Relative spread (during crisis)	0.1621	0.8341	0.9069
Percentage change (%)	46.30	247.25	300.75
Quoted depth (pre-crisis) (million €)	26.90	31.61	24.75
Quoted depth (during crisis) (million €)	14.74	21.93	11.46
Percentage change (%)	-45.20	-30.63	-53.69
Quote slope (pre-crisis)	0.0036	0.0077	0.0070
Quote slope (during crisis)	0.0058	0.0254	0.0250
Percentage change (%)	61.11	229.87	257.14
MQI (pre-crisis) (million €)	256.61	184.77	127.84
MQI (during crisis) (million €)	59.18	19.36	10.13
Percentage change (%)	-76.94	-89.52	-92.07

The table presents summary statistics (mean values) of liquidity measures for Germany, France, and Italy over the sovereign debt crisis (November 2011 to January 2012) and pre-crisis (January 2008 to October 2009) periods. Best spread is the difference between the best ask quote and the best bid quote. Quoted spread is defined as the difference between the average of the three best ask prices and bid prices. Relative spread is the best bid-ask spread divided by the quote midpoint. Quoted depth is the best bid size plus best ask size. Quote slope is defined as best spread divided by the logarithm of quoted depth. Market quality index (MQI) is defined as half of quoted depth divided by the relative spread.

Table 3: Principal component analysis (PCA).

Panel A: Spread liquidity measures			
		Pre-crisis	**Dash for cash**
Best spread	PCA 1	35.27%	48.51%
	PCA 1+2	68.63%	84.02%
Quoted spread	PCA 1	35.82%	35.90%
	PCA 1+2	69.73%	68.13%
Relative spread	PCA 1	35.59%	49.08%
	PCA 1+2	68.83%	83.87%
Panel B: Depth liquidity measures			
		Pre-crisis	**Dash for cash**
Quoted depth	PCA 1	42.51%	42.24%
	PCA 1+2	73.28%	75.71%

The table presents the results of principal component analysis (PCA) applied to spread-based and depth-based liquidity measures of 10-year benchmark bonds of Germany, France, and Italy. Best spread is the difference between the best ask quote and the best bid quote. Quoted spread is the difference between the average of the three best ask prices and bid prices. Relative spread is the best bid-ask spread divided by the quote midpoint. Quoted depth is the best bid size plus best ask size. The dash for cash refers to the period 11-23 March 2020 whilst the pre-crisis refers to the period from January 2019 to December 2019. The proportion of variation in liquidity explained by the first and second principal components is reported.

Table 4: Summary statistics.

Liquidity measures	**Countries**		
	Germany	**France**	**Italy**
Best spread (dash for cash)	0.1976	0.3443	2.6534
Best spread (post-dash for cash)	0.1526	0.2177	2.1055
Percentage change (%)	-22.77	-36.77	-20.65
Quoted spread (dash for cash)	0.2839	0.4163	3.8685
Quoted spread (post-dash for cash)	0.2381	0.2737	2.8322
Percentage change (%)	-16.13	-34.25	-26.79
Relative spread (dash for cash)	0.1886	0.2720	2.8081
Relative spread (post-dash for cash)	0.1412	0.1841	1.9382
Percentage change (%)	-25.13	-32.32	-30.98
Quoted depth (dash for cash) (million €)	16.41	19.56	12.25
Quoted depth (post-dash for cash) (million €)	19.75	18.93	18.92
Percentage change (%)	20.35	-3.22	54.45
Quote slope (dash for cash)	0.0063	0.0107	0.0862
Quote slope (post-dash for cash)	0.0048	0.0068	0.0678
Percentage change (%)	-23.81	-36.45	-21.34
MQI (dash for cash) (million €)	51.72	57.62	15.25
MQI (post-dash for cash) (million €)	76.47	74.75	38.97
Percentage change (%)	47.85	29.73	155.54

The table presents summary statistics (mean values) of liquidity measures for Germany, France, and Italy over the dash for cash (11-23 March 2020) and post-dash for cash (24 March 2020 to 24 April 2020) periods. Best spread is the difference between the best ask quote and the best bid quote. Quoted spread is defined as the difference between the average of the three best ask prices and bid prices. Relative spread is the best bid-ask spread divided by the quote midpoint. Quoted depth is the best bid size plus best ask size. Quote slope is defined as best spread divided by the logarithm of quoted depth. Market quality index (MQI) is defined as half of quoted depth divided by the relative spread.

Table 5: Principal component analysis (PCA).

Panel A: Spread liquidity measures			
		Dash for cash	**Post-dash for cash**
Best spread	PCA 1	48.51%	47.21%
	PCA 1+2	84.02%	78.54%
Quoted spread	PCA 1	35.90%	35.80%
	PCA 1+2	68.13%	68.02%
Relative spread	PCA 1	49.08%	49.05%
	PCA 1+2	83.87%	80.53%
Panel B: Depth liquidity measures			
		Dash for cash	**Post-dash for cash**
Quoted depth	PCA 1	42.24%	35.15%
	PCA 1+2	75.71%	68.46%

The table presents the results of principal component analysis (PCA) applied to spread-based and depth-based liquidity measures of 10-year benchmark bonds of Germany, France, and Italy. Best spread is the difference between the best ask quote and the best bid quote. Quoted spread is the difference between the average of the three best ask prices and bid prices. Relative spread is the best bid-ask spread divided by the quote midpoint. Quoted depth is the best bid size plus best ask size. The dash for cash refers to the period 11-23 March 2020 whilst the post-dash for cash refers to the period from 24 March 2020 to 24 April 2020. The proportion of variation in liquidity explained by the first and second principal components is reported.