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ASSESSING THE LIQUIDITY PREMIUM IN THE ITALIAN BOND MARKET

by Maria Ludovica Drudi† and Giulio Carlo Venturi*

Abstract

This paper studies the effects of time-varying liquidity in the market for Italian government bonds and proposes a new methodology to estimate the liquidity premium implicit in bond prices. After adjusting for different maturities and coupon rates, we compute a yield spread between on- and off-the-run ten-year BTPs and regress this quantity on seven well-established liquidity metrics, explicitly distinguishing between current and future liquidity. We find that higher liquidity is indeed reflected in higher prices. Based on these results, we obtain a novel estimate of the liquidity premium, according to which the liquidity deterioration that occurred during the sovereign debt crisis lasted longer, but was of a smaller magnitude than that recorded during the Covid-19 pandemic.

JEL Classification: G12, G14.
Keywords: liquidity, sovereign bonds, liquidity risk, market microstructure.
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Contents

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1 Introduction[1]

The concept of market liquidity is elusive and multi-faceted, although of paramount importance for the well-functioning of financial markets. It can be defined as the ability to trade an asset immediately, with low transaction costs and with minimal impact on the price (Kyle 1985, Constantinides 1986, Amihud and Mendelson 1989, Engle and Lange 2001, Foucault et al. 2013). Liquidity is fundamental for traders as it reduces the execution or immediacy risk, i.e. the risk of delays in order execution due to the absence of counterparts on the opposite side of the market. Depending on individual needs, traders might monitor different measures of liquidity. Those willing to transact large quantities might, for example, track measures of market depth, while others willing to quickly execute trades might focus on measure of market activity.

Although it is intuitive that asset prices shall reflect the degree of liquidity, it is difficult to isolate the liquidity premium of different securities, because they typically differ not only in the degree of liquidity, but also in the market and credit risk. Moreover, the empirical literature usually focuses on the analysis of current liquidity, assuming that current liquidity will persist over time. However, building on the theoretical model in Amihud and Mendelson (1989), we show that securities' prices depend on expected future liquidity over the entire life of the asset and we are able to empirically test this result.

Governments issue bonds on a regular schedule to finance national debt. The newly issued bond is called "on-the-run" and typically attracts the majority of trades, while older bonds are called "off-the-run". On-the-run bonds are more sought-after and liquid; hence, they should have higher prices and lower yields. We follow the approach of Goldreich, Hanke and Nath (2005) and exploit this predictable pattern of liquidity throughout the

[1]We are indebted for comments or useful conversations to Marcello Pericoli, Marco Taboga, seminar participants at the Bank of Italy and an anonymous referee.

life cycle of the Italian 10 years BTPs, in order to elicit the impact of liquidity on prices. Intuitively, an on-the-run bond shall differ from the first off-the-run only in terms of market liquidity, after correcting for potentially different maturities and coupon rates. In order to proxy for the degree of liquidity of a bond, we compute seven different liquidity measures, which are well-established in the literature and capture different aspects of liquidity.

This empirical framework is able to disentangle current from future expected liquidity. The value of a liquidity measure at time t is a measure of current liquidity, while the average of the liquidity measure from time t up to maturity proxies expectations of future liquidity conditions by an investor with perfect foresight. Regressing the adjusted yield differential between on- and off-the-run bonds on our different measures of current and future liquidity, we find that future expected liquidity is a driver of the yield differential, while current liquidity is not. Our results suggest that higher future expected liquidity raises prices and lowers yields.

We are able to estimate the liquidity premium in bond yields through the coefficient associated with each liquidity measure in the regression analysis. Multiplying the coefficient by the liquidity measure we obtain an estimate of the increase in yields with respect to a perfectly liquid bond and we average the impact over the seven different measures, in order to obtain a comprehensive estimate of the liquidity premium with respect to a theoretically perfectly liquid bond. Thus, we are able to decompose the yield of on-the-run securities into a return component and a liquidity premium. The time-series of our estimated liquidity premium for the Italian bonds shows three important peaks: during the global financial crisis, the sovereign debt crisis and the Covid-19 pandemic. In line with the empirical findings of Poli and Taboga (2021), we find a significant difference between the liquidity deterioration occurred during the sovereign debt crisis and that during the Covid-19 pandemic: the former lasted for more than two years, while the latter, although greater in magnitude, was quickly re-absorbed. The most likely driver for this difference is the immediate and bold ECB intervention after the Covid-19 outbreak.

To understand the role of monetary policy on the estimated liquidity premium, we perform an event study analysis following the identification of the monetary policy surprises proposed by Altavilla et al. (2019). Their approach allows to condition on the size and sign of the surprises, rather than only on a binary variable that signals when a monetary policy announcement took place. We identify a Target surprise as the change in the 1-month OIS rate during the press release window and the Forward Guidance and Quantitative Easing surprises as the change in the 2-year and 10-year OIS rates, respectively, during the entire monetary policy window. We find that between 2014 and 2021 monetary policy improved liquidity conditions in the Italian sovereign bond market mainly through surprises about the current setting of the policy rates (Target surprises) and its policy communication (FG surprises), while the effect of quantitative easing was not statistically significant.

The remaining of this paper is organized as follows. In section 2, we summarize the related literature. In section 3, we briefly present the theoretical background; section 4 focuses on the data and the liquidity measures definition. Section 5 describes the results obtained with different model specifications. In section 6, we propose our liquidity risk premium estimator and section 7, finally, concludes.

2 Related literature and contribution of the paper

This work fits two strands of literature: one studying the effects of liquidity on asset prices, and one evaluating different aspects of liquidity.

The first stream comprehends studies on the effects of liquidity on asset prices, focusing on ex-post equity returns (Amihud and Mendelson, 1989; Eleswarapu and Reinganum, 1993; Brennan and Subrahmanyam, 1996; Barclay, Kandel and Marx, 1998; Eleswarapu, 1997; Chordia, Roll and Subrahmanyam, 2001; Datar, Naik and Radcliffe, 1998; Pastor and Stambaugh, 2001 and Amihud, 2002), bonds and notes expected returns (Amihud and Mendelson, 1991; Warga, 1992; Daves and Ehrhardt, 1993; Boudoukh and Whitelaw, 1993; Kamara, 1994; Krishnamurthy, 2002 and Strebulaev, 2002) and currency options (Brenner, Eldor and Hauser, 2001). A vast number of contributions proved the existence of liquidity risk premia in different asset classes, particularly for the US markets (e.g. Amihud 2006 and Ang et al. 2014). Amihud and Mendelson (1991) and Kamara (1994) investigated the market for US Treasury securities and, comparing yields on identical Treasury notes and bills, showed the presence of a liquidity/immediacy risk premium. Longstaff (2002) compared yields on notes issued by the US Treasury and by different US Government agencies, and found positive and statistically significant yield premiums on the latter caused by lower liquidity. Vayanos (2004) found that liquidity premia tend to increase in periods characterized by high volatility. Beber et al. 2009 and Schwarz 2019 focused on euro-area government bond markets and found that yield spreads highly depend on liquidity, especially during crises. A part of this literature focused on repo markets, studying the effect of liquidity on the specialness of sovereign bonds, i.e. the difference between the general collateral repo rate and the special collateral repo rate (see e.g. Jordan and Jordan, 1997; Buraschi and Menini, 2002). With this respect, it is worth mentioning the seminal paper by Duffie (1996), which shows that, given the total supply of an asset, its specialness increases with demand for short positions and with liquidity of the instrument. According to Krishnamurthy (2002) on-the-run bonds in the U.S. repo market tend to trade at lower yields, due to their liquidity premium.

The second stream evaluates different aspects of liquidity, captured by different liquidity indicators. Elton and Green (1998) focused on the effect of volume on Treasury bond prices. Fleming (1997), Fleming and Remolona (1999) and Balduzzi, Elton and Green (2001) studied intraday evolution of bid-ask spreads and volumes. Fleming (2003) documents that price pressure is a good proxy for liquidity in the U.S. Treasury market over high frequency time intervals (five minutes), while Huang, Cai and Song (2002) find a relationship between liquidity and return volatility in the Treasury market. Amihud (2002) propose a simple low frequency estimate of price impact for the equity market. Building on the seminal paper of Roll (1984), many works propose other refined measures to estimate the bid-ask spread (Hasbrouck, 2009; Corwin and Schultz, 2012 and Abdi and Ranaldo, 2017). Darolles et al. (2015, 2017) develop a model to measure the liquidity portion of volume relying on a structural definition of liquidity frictions coming from the theoretical model of Grossman and Miller (1988), which studies the effects of liquidity shocks on the way in which information is incorporated into the trading process. Poli and Taboga (2021) aggregate several liquidity metrics to create a composite indicator of market liquidity. Catania et al. (2022) exploit the relationship between volumes and volatility, and propose a high-frequency proxy of liquidity.

Our contribution to this literature is threefold. We apply the methodology developed in Goldreich, Hanke and Nath (2005) in order to verify their findings for the Italian sovereign bond market. We extend this empirical framework with a new and different set of liquidity measures to proxy the liquidity costs faced by the marginal investor, thereby being able to capture better the multifaceted nature of liquidity. Finally, we propose a novel estimate of the liquidity premium implicit in Italian government bond prices.

3 Theoretical background

According to the literature, the price of a specific asset class provides information about its level of liquidity as investors usually require a risk premium to hold an illiquid asset. Consequently, less liquid securities tend to have higher returns to compensate for the higher expected trading costs charged to trade these securities. For this reason, the illiquidity of a security can be captured by the cost the investor face when trading it as a fraction of its value (c).

Following Amihud and Mendelson (1989) and Goldreich, Hanke and Nath (2005), we assume that investors trade only when hit by an exogenous liquidity shock, whose per-period probability is captured by the parameter λ_i. We compare a completely liquid bond with another bond with the same characteristics, but with a positive trading cost c and we assume that there exist in the market a risk-neutral investor m who is indifferent between the two securities and is hit by a liquidity shock with probability λ_m each period. In continuous time, assuming that f_t is the instantaneous forward rate and that both bonds mature at time T, the value of the less liquid bond is equal to:

$$P_t^I = e^{-\int_t^T (f_\tau + \lambda_m c) d\tau} = e^{-\lambda_m c (T-t)} P_t^L \tag{1}$$

where P_t^L is the value of the fully liquid security at time t. It is possible to rewrite this price equation in terms of yields. If we assume that y_L and y_I are the yields to maturity for the fully liquid and the less liquid bonds, respectively, the equation becomes:

$$P_t^I = e^{-y_t^I (T-t)} = e^{-(\lambda_m c + y_t^L)(T-t)} \tag{2}$$

Therefore, the yield of the less liquid security exceeds that of the liquid one by $\lambda_m c$, i.e. the trading cost times the per-period probability that the marginal investor is hit by a liquidity shock:

$$y_t^I = \lambda_m c + y_t^L \tag{3}$$

To generalize the setting, we can assume that both securities are illiquid to a certain extent and that there exist an investor who is indifferent between them. In this case, calling the securities A and B, the relationship that links the two yields becomes:

$$y_t^B = \lambda_m (c^B - c^A) + y_t^A \tag{4}$$

We can express the following equation in terms of spreads saying that the yield spread (YS_t) between the two securities is proportional to the difference in their trading costs:

$$YS_t = y_t^B - y_t^A = \lambda_m (c^B - c^A) \tag{5}$$

Since yields are computed over the entire life of the security, equation (5) can be further amended, acknowledging that trading costs can vary over time and that they should reflect the expectation of future average values:

$$YS_t = \lambda_m E_t (\overline{c}^B - \overline{c}^A) \tag{6}$$

where $\overline{c}$ is the average trading cost over the entire life of the bond.

4 Data and liquidity measures

The Italian Treasury issues by auction several types of bonds on a regular schedule, which is publicly disclosed at the beginning of each year in order to achieve the required levels of transparency and regularity. BOTs are zero-coupon bonds with maturity maturities between 3 months and 1 year. CTZs are zero-coupon bonds with maturity of 24 months. BTPs are coupon bonds paying fixed semi-annual coupons with maturities of 3, 5, 10, 15 and 30 years. BTP€i and BTP-Italia are coupon bonds paying floating coupons indexed to Euro-area and Italian inflation rates respectively with maturity of 5, 10 and 30 years. Our empirical analysis focuses on ten-year BTPs, which are by far the most liquid and the most actively traded in the market. These securities are usually issued through biweekly auctions scheduled at the beginning of each year.

In general, the bond issued more recently for each maturity is called "on-the-run" while older bonds are called "off-the-run". The life cycle of an Italian government bond can be ideally divided into four phases. In the early phase, the bond has just been issued, supply is limited but rapidly increasing and demand comes mainly from the roll-over of contracts written on the previous on-the-run security. During the second phase supply increases and the on-the-run bond becomes the benchmark security, consequently attracting the majority of trading activity and liquidity. As the Treasury issues a further new bond of the same maturity, the former looses on-the-run status and becomes the so-called first off-the-run bond. During this phase, supply is stable, although variations may occur due to re-tapping operations or buy backs, and trading volume generally decreases as a large quantities are held by final investors. Consequently, its liquidity also decreases in a predictable way. In the final phase, the bond "ages" falling behind younger on- and off-the-run securities and attracting reduced market interest.

The secondary market for Italian, and in general euro area, government bonds is fragmented across different markets and trading venues. Securities are usually traded on wholesale markets (e.g., MTS), retail markets (e.g., MOT), dealer-to-client platforms (e.g., Bondvision), and over-the-counter electronic or physical markets (e.g., Tradeweb). We rely on data disseminated by MTS through Bloomberg and collect daily bid, ask, high, low and close prices and yields, and volumes of all ten-year BTPs, which became benchmark between April 2000 and May 2023, obtaining a total of 41 securities (see Table 6 in the Appendix).

MTS is a secondary wholesale regulated market supervised by CONSOB and Bank of

Italy. We decided to rely on data coming from MTS for three main reasons. First, since only institutional investors are allowed to participate, MTS should reflect the behaviour of knowledgeable enterprises, thus reducing the noise produced by naive individual investors. Second, MTS is highly representative of the Italian sovereign bond market collecting a substantial market share (see Table 7 in the Appendix). Third, MTS disseminates through Bloomberg high quality data, with few reporting errors and deep historical coverage, possibly due to its highly institutional and supervised nature; the same cannot be said for other sources.

Empirically, it is not possible to compute directly the cost of liquidity c. Consequently, it must be proxied using some liquidity measures. It is well known in the literature that measuring market liquidity is a complex task, due to its multi-faceted nature (e.g. Lybek and Sarr 2002, Cao et al. 2013). For this reason, many authors proposed several measures that captures different aspects of liquidity. In this paper, following the choice of Poli and Taboga (2021), we will focus on the most established and classical ones. In this paper, we compute seven well-established measures: the bid-ask spread, the Roll's estimator (Roll, 1984), the Corwin and Schultz's estimator (Corwin and Schultz, 2012), the Abdi and Ranaldo measure (Abdi and Ranaldo, 2017), the Hui and Heubel estimator (Hui and Heubel, 1984), the Amihud illiquidity measure (Amihud, 2002) and the volume.

The first four measures proxy the cost of liquidity by estimating the bid-ask spread. The last three, instead, are based on trading volumes as the literature has shown that markets with elevated activity tend to be more liquid (e.g. Glassman 1987, Glosten and Harris 1988, Bessembinder and Seguin 1993, Brennan and Subrahmanyam 1996, Nemes et al. 2012).

1. The bid-ask spread is a straightforward way to capture the liquidity of a traded asset. It is defined as the difference between ask and the bid prices or yields, i.e. prices or yields at which dealers are ready to sell and buy, respectively, a specific asset. The

literature has usually rationalized the existence of this spread acknowledging dealers' inventory costs and asymmetry of information.

$$S = bid_{yield} - ask_{yield} \tag{7}$$

2. Computation of the bid-ask spread requires access to the best bid and ask quoted prices, but market fragmentation might complicate this task. Roll's bid-ask bounce model (Roll, 1984) addresses this issue showing that under some simplifying assumptions [2] the spread can be estimated using a measure of serial correlation in price changes:

$$S_R = 2\sqrt{-Cov[\Delta P_t, \Delta P_{t-1}]} \tag{8}$$

where ΔP_t is the price change observed in two consecutive time periods. In particular, the auto-covariance is expected to be negative. Indeed, one important assumption of the Roll's model is that the bid-ask prices do not move in the absence of of shifts in the intrinsic value. Consequently, the the bounce between the bid and the ask generates this negative correlation in prices.

3. Another way to approximate the bid-ask spread is Corwin and Schultz's estimator (Corwin and Schultz, 2012), which uses daily high and low prices assuming that the size of the high-low range depends both on the true value volatility and on the bid-ask spread:

[2] The most important assumptions are: the true value of the asset follows a random walk and it is affected by public news that reach the market but not by the trading process, information is homogeneous, buy and sell orders are equally likely and the probability of continuation of buy or sell orders is equal to that of reversals.

$$S_{CS} = \frac{2(e^{\alpha} - 1)}{e^{\alpha} + 1} \tag{9}$$

with

$$\alpha = \frac{\sqrt{2\beta} - \sqrt{\beta}}{3 - 2\sqrt{2}} - \sqrt{\frac{\gamma}{3 - 2\sqrt{2}}}$$
$$\beta = \sum_{j=0}^{1} \left[ln \left(\frac{H_{t+j}}{L_{t+j}} \right) \right]^2$$
$$\gamma = \left[ln \left(\frac{H_{t,t+1}}{L_{t,t+1}} \right) \right]^2$$

where H_{t+j} and L_{t+j} are daily high and low prices and $H_{t,t+1}$ and $L_{t,t+1}$ are high and low prices observed in two consecutive days.

4. Combining the Roll's and Corwin and Schultz's estimators, Abdi and Ranaldo (2017) computed the cost of liquidity

$$S_{AR} = 2\sqrt{E[(P_t - \eta_t)(P_t - \eta_{t+1})]} \tag{10}$$

where P_t is the closing price and η_t is the arithmetic average between high and low prices. We estimate the expected value using a 20-day rolling average.

5. Hui and Heubel (1984) suggested to estimate the cost of liquidity with a price impact measure:

$$I_{HH} = \frac{\frac{H_t - L_t}{L_t}}{T_t} \tag{11}$$

where H_t and L_t are the daily high and low prices and T_t is a measure of turnover. In this paper, we replace turnover with trading volume.

6. Amihud (2002) proposes to measure illiquidity through a price impact indicator considering that, for given a level of trading volume, a security is more illiquid the higher is the price movement generated:

$$I_A = E\left[\frac{|r_t|}{V_t}\right] \tag{12}$$

where r_t and V_t are price return and trading volume. Expectation are estimated with a 20-day rolling average.

7. Trading volume is a straightforward measure of trading activity. However, more volumes are usually associated with better liquidity, so to consider them as a cost, we compute their reciprocal:

$$I_V = \frac{1}{Volume_t} \tag{13}$$

5 Methodology

The objective of this empirical analysis is to isolate the portion of the difference between the yields of the on-the-run and off-the-run securities that depends on liquidity and relate it to the various liquidity measures identified in the previous section.

We employ the methodology proposed by Goldreich, Hanke and Nath (2005) and pairwise compare each new on-the-run bond with the first off-the-run security. For each pair, we compute liquidity measures and differences in yields on a daily basis. Since our goal is to isolate the effect of liquidity on bond yields, pairwise comparison shall eliminate time fixed effects affecting liquidity. However, we need to make each pair homogeneous in terms of bond characteristics, so that any remaining yield differential between two artificially identical securities can be attributed to different liquidity conditions only. In order to do this, we need to acknowledge that each off-the-run bond might differ along two dimension from its on-the-run companion.

First, coupon rates usually differ and we need to adjust off-the-run yields to account for this. The adjustment in the coupon that must be added to the off-the-run yield is computed as the difference in yields between two hypothetical securities of the same maturity as the off-the-run bond but with different coupons (one equal to the off-the-run coupon and one equal to the on-the-run one). To compute the yields of the hypothetical bonds, we used the zero coupon bond yield curve.

Second, off-the-run securities always mature before their on-the-run companions and, provided that the yield curve is not flat, yields will differ even in the absence of liquidity costs. Off-the-run yields are adjusted to reflect this, adding the difference between two hypothetical yields implied by the zero coupon yield curve with maturities equal to those of the on-the-run and of the off-the-run securities, respectively.

After these adjustments, each pair is entirely identical in terms of underlying characteristics and any difference in yield shall reflect different liquidity conditions. According to equation (3), the yield of a generic bond is the sum of the yield of a perfectly liquid security and future trading costs. This theoretical result can be empirically tested through the following regression:

$$y_{i,t} = \alpha_t + \beta E_t[\bar{c}_i] + \varepsilon_{i,t} \tag{14}$$

Here, $y_{i,t}$ is the yield of generic security i a time t, α_t estimates the yield of a perfectly liquid security, the coefficient β estimates the probability that the marginal investor will be hit by a liquidity shock λ_m, and $E_t[\bar{c}_i]$ proxies the expected future trading costs over the lifetime of the security. Therefore, the yield difference between two securities i and j shall obey the following equation:

$$YS_t \equiv y_{i,t} - y_{j,t} = \beta E_t[\bar{c}_i - \bar{c}_j] + u_t \tag{15}$$

which is the empirical counterpart of equation (6). Assuming that security i and j are our off- and on-the-run bonds respectively, β is retrieved regressing the observed adjusted yield differences $y_{off,t} - y_{on,t}$ on the difference between expected future trading costs $E_t[\bar{c}_{off} - \bar{c}_{on}]$. In our empirical exercise, the trading costs are replaced by the liquidity measures presented in the previous section and expectations by averages from time t up to maturity since we do not assume any particular model for the expected trading costs.

6 Results

6.1 Baseline regression

Following the approach proposed by Goldreich, Hanke and Nath (2005), we construct a time series of 41 on-/off-the-run bond pairs and empirically evaluate the effect of expected future trading costs differentials on yield spreads. We run seven different regressions, one for each liquidity measure and we add a set of dummy variables, one for each pair of securities, to control for cross-sectional differences among the bonds that are unrelated with the liquidity cost. We estimate the following regression for each liquidity measure:

$$YS_t = \sum_{i=1}^{41} \alpha_i I_i + \beta(\bar{c}_{off,t} - \bar{c}_{on,t}) + u_t \tag{16}$$

Since we compute the expected future costs as the average of costs from time t up to maturity, we introduce a significant positive autocorrelation in the residuals. To overcome this problem, we estimate the regression through the Feasible Generalized Least Square

Table 1: Estimation of coefficient β with SE in parenthesis from equation (16)

	OLS	**HAC**	**FGLS**
Bid-Ask Spread	0.4751	0.4751	0.5200***
	(2.6596)	(2.3203)	(0.1384)
Roll	0.3445**	0.3445	0.3286***
	(0.1787)	(0.3717)	(0.0096)
Corwin and Schultz	2.1059**	2.1059*	2.1021***
	(0.9746)	(1.5178)	(0.0027)
Abdi and Ranaldo	0.1262	0.1262	0.1154***
	(0.3208)	(0.2316)	(0.0091)
Hui and Heubel	9.8531***	9.8531**	9.6185***
	(2.0658)	(5.5015)	(0.1789)
Amihud	8.7991***	8.7991**	8.6168***
	(2.5822)	(5.2405)	(0.1486)
Volume	1.1587***	1.1587***	1.1830***
	(0.2857)	(0.3861)	(0.0142)

Standard Errors in Parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

(FGLS) estimator, which allows to adjust for the residuals autocorrelation and through HAC.

Table 1 reports OLS, HAC and FGLS estimations of coefficient β in equation (16). Coefficients are consistent across different specifications, but FGLS is our preferred estimator due to its higher robustness and precision. All cost measures display positive and statistically significant coefficients, leading us to conclude that yield spreads depend on expected future trading costs regardless of the measure we select to proxy for them. This result confirms the evidence found by Goldreich, Hanke and Nath (2005) for 2-year US Treasury notes.

6.2 Contemporaneous and expected liquidity

In order to further disentangle the effect of future liquidity from current liquidity conditions, we compute contemporaneous and future expected trading costs. The former are denoted by c_t and are proxied by the liquidity measure at day t. The latter are denoted by $\overline{c}_{t+1}$ and are proxied by the average of the liquidity measure from time $t+1$ up to maturity. Both cost measures are standardised. Since, in principle, current liquidity captures expectations of future liquidity as well, future costs are orthogonalized with respect to contemporaneous costs and dummy variables, so that the coefficient of future costs summarizes the incremental effect of future liquidity beyond that of current liquidity. We estimate the following regression for each liquidity measure:

$$YS_t = \sum_{i=1}^{41} \alpha_i I_i + \beta(c_{off,t} - c_{on,t}) + \gamma(\overline{c}_{off,t+1} - \overline{c}_{on,t+1})^{orth} + u_t \tag{17}$$

Table 2 reports OLS, HAC, and FGLS coefficients and standard errors of contemporaneous and future trading costs. Estimates are consistent across estimators and, again, we focus on FGLS. Expected future liquidity displays positive and statistically significant coefficients, which are similar to those obtained from the baseline regression (16). Had contemporaneous liquidity been the main driver of yield differentials between liquid and illiquid bonds, we would have, instead, obtained statistically insignificant coefficients on orthogonalized cost measures. This suggests that future expected liquidity is the main driver of yield spreads above and beyond current liquidity.

6.3 Time and expected liquidity

The issuance schedule of government bonds is predictable and, as time passes, on- and off-the-run bonds become more similar. Thus, yield differentials might mechanically de-

Table 2: Estimation of coefficient β and γ with SE in parenthesis from equation (17)

	OLS		**HAC-OLS**		**FGLS**	
	Contemporaneous	**Expected**	**Contemporaneous**	**Expected**	**Contemporaneous**	**Expected**
Bid-Ask	0.0245	0.2265	0.0245	0.2265	0.0057	0.2262*
	(0.0534)	(2.6582)	(0.0311)	(2.3447)	(0.0096)	(0.1245)
Roll	0.0689	0.3660**	0.0689	0.3660	0.0673***	0.3683***
	(0.0554)	(0.1703)	(0.1740)	(0.3511)	(0.0098)	(0.0065)
C&S	0.1561***	1.8084**	0.1561	1.8084	0.1586***	1.6653***
	(0.0590)	(0.9789)	(0.2228)	(1.5086)	(0.0041)	(0.0854)
A&R	-0.4763***	0.4113	-0.4763***	0.4113**	-0.4715***	0.3995***
	(0.0604)	(0.3214)	(0.1738)	(0.2469)	(0.0035)	(0.0163)
H&H	-0.38644***	9.9378***	-0.38645**	9.9378**	-0.3877***	9.9337***
	(0.0674)	(2.0722)	(0.1710)	(5.3633)	(0.0061)	(0.1725)
Amihud	0.1099*	8.4543***	0.1099	8.4543**	0.1050***	8.3301***
	(0.0699)	(2.6182)	(0.2253)	(4.0213)	(0.0032)	(0.0860)
Volume	-0.0128	0.9727***	-0.0128	0.9727**	-0.0118***	0.9463***
	(0.0542)	(0.2856)	(0.0934)	(0.4184)	(0.0027)	(0.0253)

Standard Errors in Parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

crease over time and previous results might just hinge on this correlation. To rule out this possibility, we include a time trend τ_t, computed as the number of trading days since the issuance of the on-the-run bond (Goldreich, Hanke and Nath 2005). Expected future trading costs are proxied by standardized liquidity measures, and cost difference is orthogonalized with respect to the time trend and dummy variables. This procedure shall ensure that coefficients on trading costs capture the effect of future liquidity beyond that of time. We estimate the following regression for each liquidity measure:

$$YS_t = \sum_{i=1}^{41} \alpha_i I_i + \beta\tau_t + \gamma(\overline{c}_{off,t} - \overline{c}_{on,t})^{orth} + u_t \tag{18}$$

Table 3 reports OLS, HAC, and FGLS coefficients and standard errors of time trend and expected future trading costs. Time trends always display negative coefficients, confirming that the yield spreads mechanically decrease over time. However, coefficients on liquidity measures remain positive and statistically significant, with magnitudes similar to those of the baseline regression (16). We are, thus, able to rule out the possibility that previous results are just driven by time, and we further corroborate the pivotal role of future liquidity in determining yield differential between bonds of different liquidity profile.

6.4 Multiple expected liquidity measures

The liquidity measures proposed in this paper try to capture the theoretical cost of liquidity faced by the marginal investor. However, by regressing the yield spread on one measure at the time, we are only able to confirm that each liquidity measure is a driver of yield spreads between bonds of different liquidity profile. Since liquidity is a complex and multi-faceted concept, it is useful to understand which measures are more powerful drivers. In order to do this, we regress yield spreads on pairwise combinations of liquidity measures.

Since liquidity measures are correlated among each other (see Figure 2 in the Appendix),

Table 3: Estimation of coefficient β and γ with SE in parenthesis from equation (18)

	OLS		**HAC-OLS**		**FGLS**	
	Expected Liquidity	**Time Trend**	**Expected Liquidity**	**Time Trend**	**Expected Liquidity**	**Time Trend**
Bid-Ask	1.7413	-1.4480***	1.7413	-1.4480***	1.6958***	-1.4329***
	(2.6712)	(0.3427)	(2.3041)	(0.4281)	(0.0853)	(0.0120)
Roll	0.2727*	-1.4480***	0.2727	-1.4480***	0.2503***	-1.4289***
	(0.1793)	(0.3426)	(0.3742)	(0.4274)	(0.0105)	(0.0114)
C&S	3.0539***	-1.4480***	3.0539**	-1.4480***	2.9646***	-1.4707***
	(0.9925)	(0.3424)	(1.5653)	(0.4284)	(0.0379)	(0.0103)
A&R	0.3339	-1.4480***	0.3339*	-1.4480***	0.3357***	-1.4704***
	(0.3238)	(0.3427)	(0.2249)	(0.4278)	(0.0034)	(0.0178)
H&H	8.0971***	-1.4480***	8.0971*	-1.4480***	7.9277***	-1.4432***
	(2.1419)	(0.3422)	(5.6394)	(0.4266)	(0.1376)	(0.0050)
Amihud	10.2925***	-1.4480***	10.2925***	-1.4480***	10.2584***	-1.4443***
	(2.5961)	(0.3422)	(4.2264)	(0.4243)	(0.0765)	(0.0081)
Volume	0.92478***	-1.4480***	0.9248**	-1.4480***	0.9225***	-1.4446***
	(0.2938)	(0.3424)	(0.4317)	(0.4240)	(0.0188)	(0.0121)

Standard Errors in Parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

we orthogonalize the differences in the cost of liquidity under the second measure with respect to the differences under the first one. Doing so, coefficients on the second liquidity differential capture the incremental effect of the second liquidity measure on yield spreads on top of the effect of the first measure.

$$YS_t = \sum_{i=1}^{41} \alpha_i I_i + \beta(\overline{c}^{j}_{off,t} - \overline{c}^{j}_{on,t}) + \gamma(\overline{c}^{k}_{off,t} - \overline{c}^{k}_{on,t})^{orth} + u_t \tag{19}$$

where $k, j = 1, ..., 7$ indicate the different liquidity measures and $k \neq j$.

Table 4: Estimation of coefficient β and γ with SE in parenthesis from equation (19)

	Bid-Ask spread	Roll's estimator	Corwin and Schultz estimator	Abdi and Ranaldo estimator	Hui and Heubel estimator	Amihud illiquidity measure	Volume
Bid-Ask spread		0.43*** (0.067) 0.25*** (0.020)	0.96*** (0.053) 1.81*** (0.007)	0.29** (0.110) 0.21*** (0.006)	0.62*** (0.101) 5.40*** (0.037)	1.37*** (0.080) 1.30*** (0.017)	1.29*** (0.116) 1.15*** (0.004)
Roll's estimator	0.30*** (0.023) 0.40*** (0.067)		0.68*** (0.007) 3.39*** (0.009)	-0.015 (0.015) 0.73*** (0.040)	-1.42*** (0.022) 5.50*** (0.053)	-0.04* (0.016) 1.28*** (0.005)	-0.50*** (0.014) 1.38*** (0.007)
Corwin and Schultz's estimator	1.88*** (0.008) 0.78*** (0.053)	3.14*** (0.010) -0.65*** (0.005)		2.29*** (0.055) 1.51*** (0.033)	-3.57*** (0.025) 6.51*** (0.024)	1.93*** (0.064) 1.18*** (0.016)	-0.26** (0.011) 1.20*** (0.010)
Abdi and Ranaldo's estimator	0.18*** (0.011) 0.30** (0.110)	0.36*** (0.026) 0.51*** (0.025)	-0.98*** (0.033) 3.39*** (0.072)		4.02*** (0.017) 8.20*** (0.028)	-0.12*** (0.016) 1.29*** (0.014)	0.297 (0.024) 1.16*** (0.003)
Hui and Heubel's estimator	5.38*** (0.037) 0.74*** (0.101)	5.37*** (0.052) 0.39*** (0.019)	4.03*** (0.024) 2.61*** (0.032)	7.29*** (0.026) -1.38*** (0.011)		5.71*** (0.064) -0.25*** (0.017)	3.27*** (0.063) 0.82*** (0.023)
Amihud illiquidity measure	1.33*** (0.018) 1.35*** (0.080)	1.23*** (0.008) 0.24*** (0.015)	1.54*** (0.018) 1.67*** (0.065)	1.29*** (0.014) -0.03*** (0.016)	-0.79*** (0.021) 5.69*** (0.063)		0.65*** (0.023) 1.16*** (0.011)
Volume	1.37*** (0.025) 1.06*** (0.116)	1.41*** (0.007) -0.39*** (0.014)	1.16*** (0.011) -0.39*** (0.010)	1.13*** (0.003) 0.40*** (0.024)	1.29*** (0.018) 3.15*** (0.065)	1.09*** (0.013) -0.10*** (0.026)	

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4 reports the results of the FGLS cross-regressions. Non-orthogonalized measures are reported on columns. In each cell, the first number is the estimate of β and second number of γ with standard errors in parenthesis. The inclusion of a second measure does not have a unique effect. In general, the inclusion of the bid-ask spread always adds explanatory power to the regressions. The Hui and Heubel's estimator, the bid-ask spread and the volume are never subsumed by the second orthogonalized measure. These results seem to suggest that, at least for our sample of 10-year Italian government bonds, these liquidity measures are the most powerful drivers of yield spreads. Table 8 in the Appendix shows the results obtained through the OLS.

7 Liquidity premium and perfectly liquid yield estimation

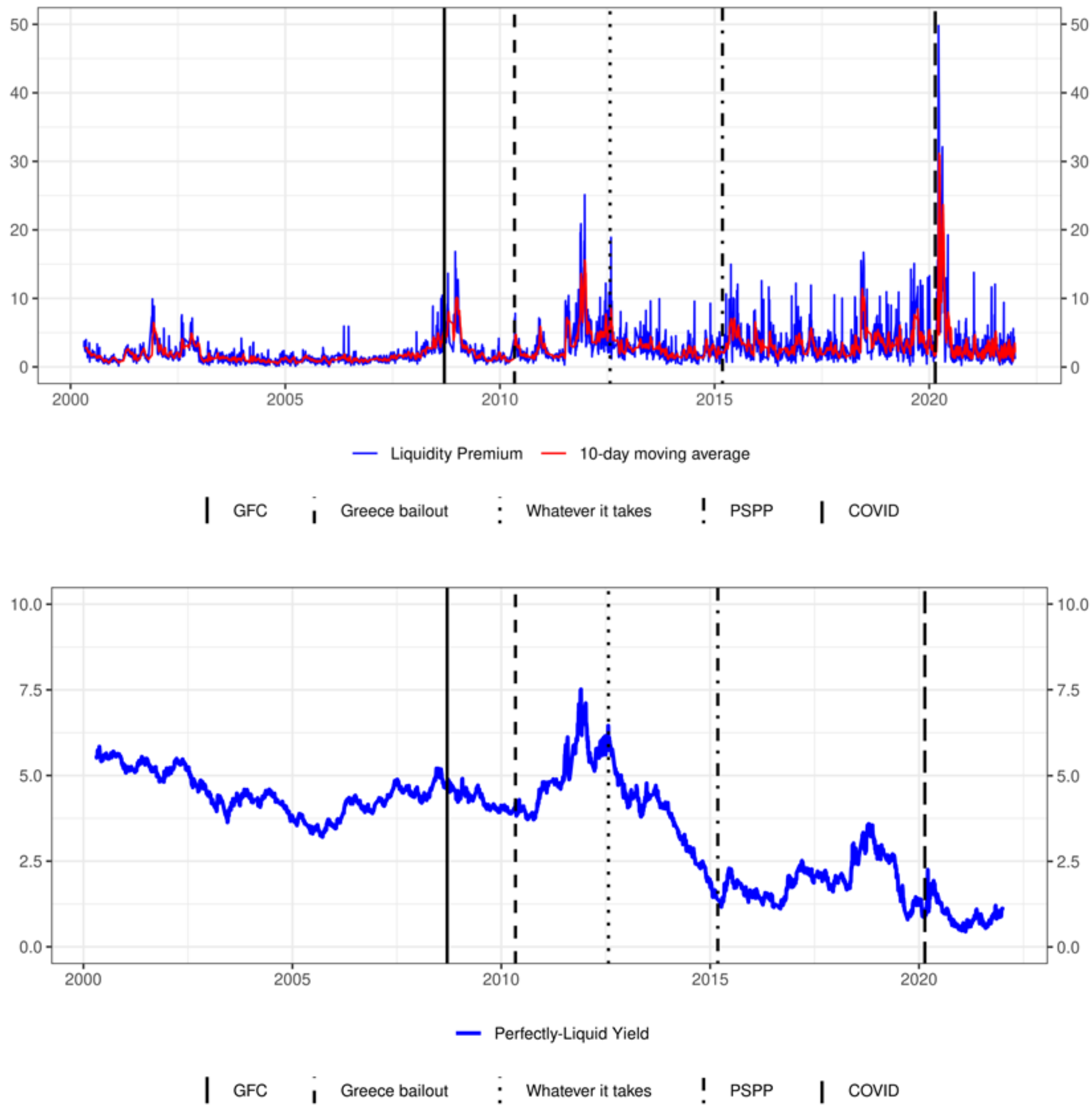
According to equation (3), generic bond yields are equal to a perfectly liquid bond yield plus an illiquidity term, given by the trading cost times the per-period probability that the marginal investor is hit by a liquidity shock:

$$y_t^I = \lambda_m c + y_t^L$$

Relying on the results of the previous empirical analysis, we can decompose observed yields into a perfectly liquid yield and a liquidity premium. Indeed, liquidity measures are a proxy for the trading costs c and estimates for β coefficients in regression (16) proxy for λ_m. Thus, for each on-the-run security we multiply each liquidity measure by the corresponding coefficient of table 1. Then, we aggregate estimated premia averaging across liquidity measures. It follows that perfectly liquid yields are the difference between observed yields and the estimated (averaged) liquidity premium. We concatenate all the available on-the-run securities in order to obtain a time series of the estimated liquidity premium and perfectly liquid yield, which are plotted in figure 1.

Between 2000 and 2007, the Italian sovereign bond market liquidity premium hovered around the lowest values registered over the entire time horizon with little volatility. The premium significantly increased for the first time during the global financial crisis (GFC) without, however, any remarkable movement of the perfectly-liquid yield. The premium surged again during the sovereign debt crisis, peaking at the time when the ECB's President Mario Draghi pronounced the famous "Whatever it takes" speech. This time, the perfectly-

Figure 1: Estimated liquidity premium and perfectly liquid yield



liquid yield rose significantly signalling that bond yields were incorporating other risks, most notably country credit risk. Liquidity conditions improved immediately after the launch of the Outright Monetary Transactions (OMT), albeit the volatility of the premium never returned to the pre-crisis levels. Between 2012 and 2015, the perfectly liquid yield decreased in response to ECB interest rate cuts and mitigation of country credit risk.

From 2015 until the outburst of the pandemic, both the premium and the perfectly liquid yield remained rather stable, although the premium displayed significant volatility. During the second quarter of 2018, we can spot a moderate worsening of financial conditions linked to political uncertainty around the government formation. Finally, during the Covid-19 crisis, liquidity conditions in the Italian sovereign bond market severely deteriorated. The estimated premium reached its peak at roughly 50bps in March 2020 during the most acute phase of the crisis, while the perfectly-liquid yield increased little. Our decomposition, indeed, shows that the increase in bond yield observed during the pandemic crisis was mainly driven by a worsening in liquidity conditions.

In line with the empirical findings of Poli and Taboga (2021), we found a significant difference between the liquidity deterioration occurred during the sovereign debt crisis and that registered during the Covid-19 pandemic: the former lasted for more than two years, while the latter was quickly re-absorbed. The most likely driver of this difference is the immediate and bold ECB intervention after the Covid-19 outbreak. In particular, the introduction of the PEPP, which had an explicit market stabilization function and was extremely flexible across time, asset classes and jurisdictions, could have played an important role (Lane 2020a and 2020b; Bernardini and De Nicola, 2020).

To confirm that indeed the ECB monetary policy had a significant effect on our estimated liquidity premium we performed an event study analysis. We follow Altavilla et al. (2019) that propose a more sophisticated identification of the monetary policy surprises with respect to the traditional monetary policy dummy variable. In their paper, for each Governing Council meeting, Altavilla and co-authors exploited intraday data[3] to create event windows ranging between 10 minutes before the monetary policy press release and 10 minutes after the end of the monetary policy press conference and developed a Euro Area Monetary Policy Event-Study Database (EA-MPD). Using a principal component analysis on these data, they showed that euro area monetary policy surprises are multi-dimensional. Their approach allows to condition on the size and sign of the surprises, rather than only on a binary variable that signals when a monetary policy announcement took place. In this way, it is possible to understand the monetary policy effects in a more precise way and to distinguish between Forward Guidance (FG) and Quantitative Easing (QE) surprises. However, the EA-MPD has the drawback to cover only Governing Council meetings, not considering other interventions such as speeches or communications that may happen in other days, thereby losing some information.

Following their approach, we identified a Target surprise as the change in the 1-month OIS rate during the press release window and the FG and QE surprises as the change in the 2-year and 10-year OIS rates, respectively, during the entire monetary policy window (composed of both the press release and the press conference windows). Then, we regressed each of these monetary policy surprises individually on our estimated liquidity premium.

As shown in Table 5, the coefficients for Target and FG are statistically significant, signalling that monetary policy has indeed a significant effect on the Italian sovereign bond market liquidity. The coefficients are positive, meaning that an expansionary monetary policy surprise, which generates a decrease in the OIS rates, tends to decrease the sovereign bonds liquidity premium, easing liquidity conditions in the market. The fact that the

[3] The database contains changes in: OIS rates with 1, 3, 6 month, 1 to 10, 15, and 20 year maturities; German bund yields with 3 and 6 month, 1 to 10, 15, 20, and 30 year maturities, French, Italian, and Spanish sovereign yields with 2, 5, and 10 year maturities, the STOXX50E, the SX7E, and the exchange rate of the euro.

Table 5: Monetary policy surprises on the estimated liquidity premium

	Liquidity Premium
Target	1.011***
	(0.214)
Forward Guidance	0.526***
	(0.146)
Quantitative Easing	0.091
	(0.128)

Standard Errors in Parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

coefficient of QE is not statistically significant may signal that monetary policy was able to affect the sovereign bond market liquidity mainly through the setting of the policy rate and its communication about the future path of monetary policy and less through the purchase programs. This result may depend on different factors. First, it could be the case that the QE announcements had been largely anticipated by the market. Second, it could also be the case that for the QE the delayed effects that unfolded at the time when the purchases were made (so-called flow effects) prevail over the announcement effects. In both cases, our event study would not be able to capture the effect of QE on the liquidity premium.

Moreover, the growing literature that studies the effects of the asset purchases on market liquidity suggests that there is a trade-off between decreasing yields and maintaining good market liquidity conditions (Ferdinandusse et al. 2020). This trade-off depends on the supply channel of QE, i.e. high central bank bond holdings can lead to modestly more expensive trading costs for market participants. Indeed, if the central bank holds the bonds purchased in the context of its asset purchases programs, it is effectively reducing the amount of bonds available for trade to other investors. This scarcity problem is usually reported for sovereign bonds of core euro area countries (see e.g. Coeuré, 2017). Ferdinandusse et al. (2020) show that the effect of QE on market liquidity crucially depends on the share of preferred habitat investors in the market, the higher is this share the higher the reduction of yields, but also the negative effect of central bank purchases on market liquidity. They found that although the public sector purchase programme (PSPP) asset purchases were broadly symmetric across countries, there is a high level of heterogeneity among national sovereign bond markets. In particular, they report that the core countries tend to have higher share of preferred habitat investors, and consequently tend to suffer more for the unintended scarcity problem, while the peripheral ones tend to have a lower share.

To mitigate these scarcity problems, the ECB started to lend its holdings of securities purchased under the PSPP since 2 April 2015. Considering the period from 2014 to 2021 for the Italian sovereign bond market, we found no significant effect, neither positive nor negative, of QE on market liquidity possibly confirming that the ECB was mindful in designing its purchase programs, taking into account the potential disruptions coming from an excessive fast pace of purchases.

8 Conclusion

This paper studies the effects of time-varying liquidity on Italian sovereign bonds prices and estimates the liquidity premium implicit in government bond yields. We compare on- and off-the-run ten-year BTPs, whose liquidity evolves predictably over time, and we explicitly distinguish between current and expected future liquidity.

We use and aggregate seven different and well-established liquidity measures, in order to capture the different aspects of liquidity. All the selected measures significantly explain the difference between yields of off- and on-the-run bonds. Furthermore, we empirically validate for the Italian market the theoretical result that future liquidity is the driver of yield differences between bonds with different liquidity profiles.

We decompose on-the-run yields into a return component and a liquidity premium finding that the liquidity deterioration occurred during the sovereign debt crisis lasted longer but with smaller magnitude than that occurred during the Covid-19 pandemic. Finally, our results show that monetary policy improved liquidity conditions mainly through surprises about the current setting of the policy rates and its policy communication, while the effect of quantitative easing was not statistically significant.

A natural development for future research will be to expand the set of maturities analyzed, in order to understand the robustness of our results along the maturity curve. On a different note, the analysis developed in this paper focuses on the cash segment of the MTS market. However, the on-/off-the-run cycle of government bonds is particularly linked to the specialness of these securities in the repo market. Future research shall, thus, analyse the effect of future liquidity on prices controlling for the specialness. Finally, a further development shall more deeply analyse the impact of unconventional monetary policies and asset purchases on sovereign bond market liquidity, for example, focusing on the flow effects in the spirit of Bernardini and De Nicola (2020).

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Appendix

Table 6: List of BTPs that became benchmark between Apr-2000 and May-2023.

ISIN	Issue	Maturity	Benchmark	Coupon	ON-Start	ON-End
IT0001338612	26-May-1999	01-Nov-2009	05-Oct-1999	4.25	–	–
IT0001448619	28-Mar-2000	01-Nov-2010	29-Jun-2000	5.50	25-Apr-2000	26-Feb-2001
IT0003080402	26-Feb-2001	01-Aug-2011	16-May-2001	5.25	26-Mar-2001	26-Oct-2001
IT0003190912	26-Oct-2001	01-Feb-2012	28-Nov-2001	5.00	23-Nov-2001	27-Aug-2002
IT0003357982	27-Aug-2002	01-Feb-2013	19-Sep-2002	4.75	27-Sep-2002	28-Apr-2003
IT0003472336	28-Apr-2003	01-Aug-2013	15-Jul-2003	4.25	27-May-2003	27-Jan-2004
IT0003618383	27-Jan-2004	01-Aug-2014	04-Feb-2004	4.25	24-Feb-2004	26-Aug-2004
IT0003719918	26-Aug-2004	01-Feb-2015	03-Dec-2004	4.25	23-Sep-2004	26-Apr-2005
IT0003844534	26-Apr-2005	01-May-2015	23-May-2005	3.75	24-May-2005	23-Feb-2006
IT0004019581	23-Feb-2006	01-Aug-2016	02-Mar-2006	3.75	23-Mar-2006	27-Dec-2006
IT0004164775	27-Dec-2006	01-Feb-2017	02-Mar-2007	4.00	25-Jan-2007	29-Aug-2007
IT0004273493	29-Aug-2007	01-Feb-2018	22-Nov-2007	4.50	26-Sep-2007	29-Apr-2008
IT0004361041	29-Apr-2008	01-Aug-2018	19-Aug-2008	4.50	29-May-2008	28-Oct-2008
IT0004423957	28-Oct-2008	01-Mar-2019	27-Jan-2009	4.50	27-Nov-2008	27-Apr-2009
IT0004489610	27-Apr-2009	01-Sep-2019	08-Jun-2009	4.25	27-May-2009	25-Sep-2009
IT0004536949	25-Sep-2009	01-Mar-2020	01-Oct-2009	4.25	23-Oct-2009	29-Mar-2010
IT0004594930	29-Mar-2010	01-Sep-2020	31-Mar-2010	4.00	28-Apr-2010	27-Aug-2010
IT0004634132	27-Aug-2010	01-Mar-2021	31-Aug-2010	3.75	24-Sep-2010	23-Feb-2011
IT0004695075	23-Feb-2011	01-Sep-2021	19-May-2011	4.75	23-Mar-2011	26-Aug-2011
IT0004759673	26-Aug-2011	01-Mar-2022	19-Dec-2011	5.00	23-Sep-2011	24-Feb-2012
IT0004801541	24-Feb-2012	01-Sep-2022	04-Jun-2012	5.50	23-Mar-2012	28-Aug-2012
IT0004848831	28-Aug-2012	01-Nov-2022	04-Oct-2012	5.50	25-Sep-2012	25-Feb-2013
IT0004898034	25-Feb-2013	01-May-2023	06-May-2013	4.50	25-Mar-2013	26-Jul-2013
IT0004953417	26-Jul-2013	01-Mar-2024	01-Oct-2013	4.50	23-Aug-2013	25-Feb-2014
IT0005001547	25-Feb-2014	01-Sep-2024	19-Jun-2014	3.75	25-Mar-2014	26-Aug-2014
IT0005045270	26-Aug-2014	01-Dec-2024	31-Oct-2014	2.50	23-Sep-2014	24-Feb-2015
IT0005090318	24-Feb-2015	01-Jun-2025	01-Apr-2015	1.50	24-Mar-2015	26-Aug-2015
IT0005127086	26-Aug-2015	01-Dec-2025	02-Nov-2015	2.00	23-Sep-2015	24-Feb-2016
IT0005170839	24-Feb-2016	01-Jun-2026	06-Jun-2016	1.60	23-Mar-2016	26-Jul-2016
IT0005210650	26-Jul-2016	01-Dec-2026	31-Oct-2016	1.25	23-Aug-2016	26-Jan-2017
IT0005240830	26-Jan-2017	01-Jun-2027	31-Mar-2017	2.20	23-Feb-2017	28-Jun-2017
IT0005274805	28-Jun-2017	01-Aug-2027	11-Oct-2017	2.05	26-Jul-2017	26-Jan-2018
IT0005323032	26-Jan-2018	01-Feb-2028	08-Mar-2018	2.00	23-Feb-2018	26-Jul-2018
IT0005340929	26-Jul-2018	01-Dec-2028	06-Sep-2018	2.80	23-Aug-2018	25-Feb-2019
IT0005365165	25-Feb-2019	01-Aug-2029	12-Apr-2019	3.00	25-Mar-2019	27-Aug-2019
IT0005383309	27-Aug-2019	01-Apr-2029	13-Dec-2019	1.35	24-Sep-2019	27-Feb-2020
IT0005403396	27-Feb-2020	01-Aug-2030	09-Jun-2020	0.95	26-Mar-2020	04-Jun-2020
IT0005413171	04-Jun-2020	01-Dec-2030	14-Sep-2020	1.65	02-Jul-2020	25-Sep-2020
IT0005422891	25-Sep-2020	01-Apr-2031	30-Oct-2020	0.90	23-Oct-2020	18-Feb-2021
IT0005436693	18-Feb-2021	01-Aug-2031	28-Apr-2021	0.60	18-Mar-2021	09-Jun-2021
IT0005449969	09-Jun-2021	01-Dec-2031	22-Oct-2021	0.95	07-Jul-2021	31-Dec-2021
IT0005466013	28-Oct-2021	01-Jun-2032	01-Feb-2022	0.95	01-Nov-2021	01-Aug-2022
IT0005494239	01-Aug-2022	01-Dec-2032	02-Aug-2022	2.50	03-Aug-2022	31-Jan-2023
IT0005518128	31-Jan-2023	01-May-2033	01-Feb-2023	4.40	02-Feb-2023	05-Apr-2023

Table 7: MTS market share of benchmark BTPs

ISIN	Issue	Maturity	Benchmark	Coupon	MTS
IT0004695075	23-Feb-2011	01-Sep-2021	19-May-2011	4.75	59%
IT0004759673	26-Aug-2011	01-Mar-2022	19-Dec-2011	5.00	61%
IT0004801541	24-Feb-2012	01-Sep-2022	04-Jun-2012	5.50	60%
IT0004848831	28-Aug-2012	01-Nov-2022	04-Oct-2012	5.50	60%
IT0004898034	25-Feb-2013	01-May-2023	06-May-2013	4.50	49%
IT0004953417	26-Jul-2013	01-Mar-2024	01-Oct-2013	4.50	49%
IT0005001547	25-Feb-2014	01-Sep-2024	19-Jun-2014	3.75	44%
IT0005045270	26-Aug-2014	01-Dec-2024	31-Oct-2014	2.50	40%
IT0005090318	24-Feb-2015	01-Jun-2025	01-Apr-2015	1.50	38%
IT0005127086	26-Aug-2015	01-Dec-2025	02-Nov-2015	2.00	35%
IT0005170839	24-Feb-2016	01-Jun-2026	06-Jun-2016	1.60	33%
IT0005210650	26-Jul-2016	01-Dec-2026	31-Oct-2016	1.25	31%
IT0005240830	26-Jan-2017	01-Jun-2027	31-Mar-2017	2.20	29%
IT0005274805	28-Jun-2017	01-Aug-2027	11-Oct-2017	2.05	25%
IT0005323032	26-Jan-2018	01-Feb-2028	08-Mar-2018	2.00	15%
IT0005340929	26-Jul-2018	01-Dec-2028	06-Sep-2018	2.80	11%
IT0005365165	25-Feb-2019	01-Aug-2029	12-Apr-2019	3.00	10%
IT0005383309	27-Aug-2019	01-Apr-2029	13-Dec-2019	1.35	13%
IT0005403396	27-Feb-2020	01-Aug-2030	09-Jun-2020	0.95	22%
IT0005413171	04-Jun-2020	01-Dec-2030	14-Sep-2020	1.65	30%
IT0005422891	25-Sep-2020	01-Apr-2031	30-Oct-2020	0.90	23%
IT0005436693	18-Feb-2021	01-Aug-2031	28-Apr-2021	0.60	19%

Table 8: OLS comparison for Table 4

	Bid-Ask		Roll		C&S		A&R		H&H		Amihud		Volume	
Bid-Ask			0,64	(2,660)	1,06	(2,662)	0,43	(2,662)	0,66	(2,652)	1,62	(2,682)	1,53	(2,656)
			0,35*	(0,179)	1,89***	(0,537)	0,12	(0,321)	5,48***	(1,038)	1,38***	(0,436)	1,18***	(0,199)
Roll	0,42	(0,379)			0,72***	(0,210)	0,04	(0,237)	-1,45***	(0,368)	0,04	(0,205)	-0,49**	(0,228)
	0,60	(2,660)			3,25***	(0,953)	0,78*	(0,402)	5,82***	(1,046)	1,31***	(0,432)	1,41***	(0,242)
C&S	1,98***	(0,609)	3,04***	(0,853)			2,34***	(0,552)	-3,64***	(1,033)	2,03***	(0,538)	-0,22	(0,694)
	0,87	(2,659)	-0,55*	(0,317)			1,40***	(0,413)	6,63***	(1,063)	1,23***	(0,433)	1,26***	(0,265)
A&R	0,09	(0,399)	0,34	(0,331)	-1,07***	(0,403)			4,12***	(0,696)	-0,24	(0,341)	0,241	(0,320)
	0,44	(2,661)	0,61***	(0,224)	3,37***	(0,692)			8,59***	(1,330)	1,39***	(0,446)	1,20***	(0,200)
H&H	5,46***	(1,039)	5,66***	(1,040)	4,11***	(1,073)	7,58***	(1,180)			5,83***	(1,396)	3,29***	(1,190)
	0,78	(2,653)	0,47***	(0,180)	2,66***	(0,548)	-1,53***	(0,410)			-0,22	(0,565)	0,86***	(0,231)
Amihud	1,41***	(0,446)	1,24***	(0,435)	1,61***	(0,439)	1,40***	(0,453)	-0,77	(0,656)			0,65	(0,452)
	1,59	(2,680)	0,32*	(0,179)	1,76***	(0,538)	-0,13	(0,331)	5,81***	(1,361)			1,21***	(0,241)
Volume	1,44**	(0,588)	1,44***	(0,252)	1,22***	(0,220)	1,17***	(0,199)	1,33***	(0,207)	1,12***	(0,285)		
	1,29	(2,654)	-0,37***	(0,217)	-0,37	(0,714)	0,35	(0,322)	3,17***	(1,207)	-0,14	(0,523)		

Standard Errors in Parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

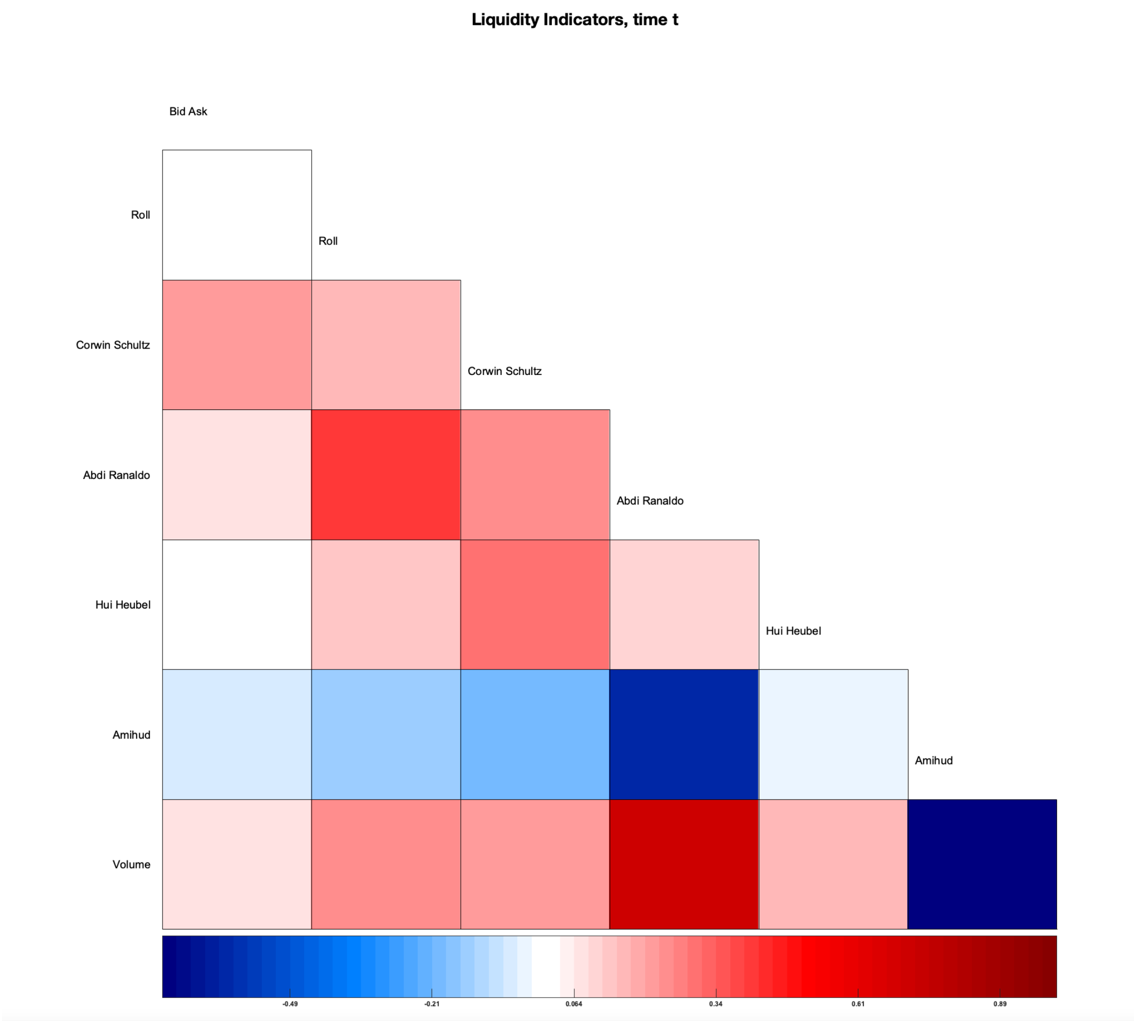

Figure 2: Correlation Matrix of Liquidity Measures