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The market liquidity of interest rate swaps

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Abstract:

This paper studies market liquidity in interest rate swaps (IRS) before and during the global tightening of monetary policy. IRS constitute the single largest derivatives segment globally. Banks and Pension Funds extensively rely on IRS to hedge interest rate risk. Hence, providing an understanding of this market and the drivers of market liquidity is a key research question in the current market context. We use price and volume data from around 338.000 trades in the most active long-horizon swap contract denominated in EUR to construct seven liquidity measures. Taking a comprehensive approach, we apply linear regressions to determine the drivers of variation in liquidity. Our liquidity measures are significantly related to monetary policy, market-wide fixed income liquidity, EURIBOR rate volatility and Dealer behaviour. Indicators for generic market stress such as VIX which are often documented in the literature are not strongly connected to IRS trading conditions.

Key words: Fixed income, market structure, liquidity, swaps;
JEL code: G12, G15

1. Introduction

The liquidity in fixed income markets has recently attracted significant attention among policy makers and researchers. Market liquidity is usually understood as the ease with which a trader can buy or sell an instrument at a price close to the observed market price prior to the current transaction in a standard size (cf. IMF, 2015). Smooth trading of fixed income instruments depends on the availability and robustness of market liquidity (cf. Adrian et al., 2018). During a dislocation of trading conditions, investors withdraw from the market because they are no longer able to adjust their positions to changes in economic fundamentals. Possible direct consequences are a "Dash for cash", lost hedges and mark-to market losses. Over the last decade, major fixed income segments have seen several stress events, peaking in the Covid dislocation in March 2020 (Duffie, 2020) and most recently in UK Gilts (Pinter, 2023).[1]

We study market liquidity in the largest fixed income derivatives contract, interest rate swaps (IRS),[2] before and during the global tightening of monetary policy. At around US$ 406 trillion (H2:2022) of global outstanding notional,[3] IRS represent the largest segment of the global derivatives market, with EUR-denominated IRS accounting for around 27% in the second half of 2022.

IRS are traded over-the-counter (OTC) without centralised price-formation mechanisms,[4] such as Central Limit Order Books (CLOB) used on exchanges. Swaps are traded on several platforms and using a variety of trading protocols. To mitigate the costly frictions in this decentralised trading, "Dealers" have emerged. They intermediate between buyers and sellers and execute trades with smaller or less-active market participants (e.g., asset managers). Dealers typically try to run matched positions because their business model is oriented toward earning revenue from market-making rather than outright risk retention on their balance sheets. The analysis of IRS trading therefore provides unique insights into the mechanics of

[1] Other major stress events were the Treasury flash crash in October 2014, the Bund tantrum in May 2015 or the US$ Repo stress in September 2019 (cf. Scheicher, 2023).

[2] For the scope of this paper, this acronym applies only to interest rate swaps and should not be confused with the US Internal Revenue Service (which is often associated with 'IRS').

[3] Notional value as of December 2022 (BIS, 2022).

[4] Due to this decentralised and fragmented process buyers and sellers negotiate terms privately, often in ignorance of the prices currently available from other potential counterparties and with limited knowledge of trades recently negotiated elsewhere in the market. This induces sequential trade of assets by search and bargaining and high opacity: Clients request quotes bilaterally or on electronic platforms, with limited post-trade price transparency. One effect of these bilateral trading protocols and the corresponding "frictions" is a potentially significant price dispersion which we will study in our empirical analysis. See Friewald and Nagler (2019) for an empirical quantification of frictions.

intermediation in a major fixed income instrument, which has not been extensively studied so far. As Dealers play a central role in managing demand-supply imbalances, their risk management and allocation of capital to trading units may also influence market liquidity as they determine how much space is available on their balance sheets to open new trades. This mechanism has been observed during the March 2020 US Treasury dislocation (Duffie et al., 2023).

Unprecedented global tightening of monetary policy since June 2022 has forced market participants to adjust their trading strategies and positioning in a short period of time. Together with bonds, swap trading was an epicentre of the market adjustment. Given the benchmark function of IRS, liquidity stress in swaps might also influence conditions in other fixed income segments and is therefore of particular interest for monitoring the resilience of systemic market segments of the OTC market (cf. FSB, 2022).

We use price and volume data from around 338.000 trades in the most active swap contract denominated in EUR outside the money market, the EURIBOR six-month (6M) swap with 10-year maturity (EURIBOR 6M 10Y). Our sample covers the period from January 2018 to November 2022, hence it includes a period of major monetary policy tightening, which strongly affected pricing, volatility, and activity in fixed income markets. Swap contracts are typically traded bilaterally on multiple electronic platforms. Most swap transactions are nowadays cleared in Central Counterparties (CCPs).[5] To ensure consistency in the characteristics of the instruments we focus exclusively on CCP-cleared trades, hence our sample is representative of the predominant part of IRS trading and consists of fully standardised contracts with margining managed by the CCP.

Although the concept of market liquidity is straightforward to define, its measurement raises several major challenges. The simplest measure is the bid-ask spread which represents the difference between buyer and seller transactions or quotes, typically calculated at the close of trading. This measure is however not very informative about liquidity in an OTC environment, where trades are negotiated and executed bilaterally. Therefore, we calculate a broad range of liquidity measures covering activity, depth, and trading costs of swap trading. We discuss their evolution before and during global monetary policy tightening. We then study the correlation of these liquidity measures to better understand their information content for liquidity.

[5] In 2022, roughly 80% of EUR IRS were cleared in CCPs (BIS, 2022). The European Market Infrastructure Regulation (EMIR) established a requirement for EU- (and certain non-EU-) counterparties to clear standardised IRS (including EUR swaps) contracts, if they exceed certain exposure thresholds (the “Clearing Obligation”).

In the main part of our paper, we focus on the two key drivers identified in previous market dislocations, rate behaviour and Dealer activity. We also study the impact of monetary policy. Ultimately, we develop a simple framework for the interpretation of potential drivers of liquidity and use reduced-form econometric analysis to find the drivers of their variation and check their economic significance. In this context, we regress daily changes of the main liquidity measures on interest rate variables, monetary policy information, proxies for Dealer positioning and leverage, global risk appetite, global bond liquidity and Dealer funding costs.

We find that swap liquidity is significantly related to monetary policy events, market-wide fixed income liquidity, EURIBOR rates and Dealer behaviour. We document six key results, none of which have so far been discussed in the empirical literature. First, price dispersion rises around ECB monetary policy press conferences. Second, when swap trading volume rises, also the price impact and price dispersion of swap trades increase. Third, IRS liquidity is directly linked to German government bond price-based liquidity ("commonality in liquidity"). Fourth, rising rate volatility (proxied by squared rate changes) reduces market liquidity. Fifth, we illustrate a co-movement between initial margins and our core liquidity measure, which indicates a funding channel for trading conditions. Finally, increasing Dealer net-notional raises price dispersion. This last finding can be linked to the concept of "Dealer capacity" recently developed by Duffie et al. (2023) for the US Treasury market.

Our paper is connected to three areas of research, which have all been steadily growing over the last decade.[6] First, the last few years have seen extensive research on market liquidity in OTC markets, which account for the bulk of financial market activity: We contribute to this area as we study the largest OTC derivatives market using seven liquidity measures and investigating their covariates.[7] So far, interest rate swap liquidity has only been studied in the context of US-UK CCP fragmentation but there is no in-depth study of the evolution and drivers of liquidity in general. Second, we investigate the role of Dealers in swap market functioning. As

[6] The main pricing model for IRS has been introduced by Duffie and Singleton (1997). They propose a multi-factor econometric model of the term structure of IRS yields which allows for counterparty default risk, as well as different liquidities of the US Treasury and IRS markets. Recent empirical analysis of swap pricing, in particular swap spreads, is provided by Klingler and Sundaresan (2018), who focus on the role of demand for duration from underfunded pension plans in the US.

[7] The literature on OTC trading has grown strongly over the last few years, partly due to wider availability of transaction data. See Bessembinder et al. (2020) for a survey on OTC trading in bond markets and FSB (2022) for a policy discussion. As regards recent empirical research, US Treasury bonds are studied by Adrian et al. (2022), US corporate bonds by O'Hara and Zhou (2021), UK Gilts by Pinter et al. (2022), Euro area government bonds by Poli and Taboga (2021) and CDS by Schoenemann (2022).

OTC trading is dealer-run,[8] Dealer participation is vital in delivering intermediation in particular during high-volatility periods. The Covid market dislocation has led to an extensive discussion on policy measures to alleviate Dealer-induced constraints in intermediation during stress periods (cf. Duffie et al., 2023). We investigate whether market liquidity deteriorates with rising Dealer exposures and rising Dealer leverage.[9] Third, we shed light on market functioning during macro stress, in particular due to Covid in spring 2020 but also during the recent and still ongoing monetary policy tightening, which has led to a sharp repricing of many fixed income instruments as illustrated by the evolution of the EURIBOR rate (see Figure 2).

The rest of the paper is organised as follows: Section 2 describes our data and our methodology. Section 3 summarises the evolution of our measures of swap liquidity. Section 4 presents our main econometric results. Section 5 summarises robustness analysis and further empirical results. We conclude in Section 6.

2. Sample and liquidity estimation

2.1. Background on IRS trading

An IRS is a contractual agreement to periodically exchange fixed-rate payments for an agreed maturity and on a specified notional for a stream of payments which is calculated by using a floating rate of interest ("fixed-for-floating IRS"). This floating rate typically is the 6-month EURIBOR, whereas the maturity for swap contracts typically is five or ten years. The payments are computed on a notional amount defined in the contract, which is not exchanged, but used to calculate the payments from the fixed and floating rates. Economically, a swap represents a levered portfolio in plain vanilla coupon or floating-rate bonds. For the case of paying fixed, the swap represents a short position in a fixed rate bond and a long position in the floating rate bond of the same horizon and notional.

The European Market Infrastructure Regulation (EMIR), which was launched in 2012, provides the regulatory framework for swap trading in Europe. Most importantly, EMIR introduced a range of requirements to strengthen risk management practices and transparency pertaining to derivatives trading. This includes, (i) a reporting requirement for all derivatives transactions (incl. IRS) to authorised trade repositories, (ii) the mandatory obligation to clear most

[8] Dealers are still predominantly banks, but the market structure is evolving due to the growth of electronic trading. See Scheicher (2023) for a discussion of the role of non-bank Dealers and electronic trading.
[9] Kondor and Vayanos (2019) provide a theoretical framework.

IRS transactions denominated in EUR for EU- (and certain non-EU-) counterparties which exceed certain clearing thresholds, as well as (iii) requirements aiming at strengthening risk management practices (e.g. requiring timely/electronic trade confirmations). In parallel, granular data on IRS transactions have become available to supervisors and central banks via Trade Repositories, which provide the underpinning for our data set.

The trading of swaps takes place in a decentralised "over-the-counter" (OTC) market structure and relies on the market making of large banks matching IRS buyers and sellers. The core of this market consists of a small group of Dealers (typically large globally active banks), which trade IRS with other Dealers, other banks, as well as non-banks such as asset managers, sometimes using their balance sheets to warehouse or hedge exposures to clients. In practice, Traders use multiple platforms: According to ESMA,[10] 15 trading platforms are available in the EU, some of which use the Multilateral whereas others use the Organised Trading Facility setup.[11]

For maturities above one year, Euro area banks are particularly active in IRS referencing the EURIBOR. Euro area banks (for example firms facing fixed rate cashflows from their mortgage books) typically buy floating rate payments, hedging the risk from their fixed-rate loan books. Swaps on the EURIBOR 6-Month rate with a 10-year maturity are among the most actively used instruments. We will analyse pricing, activity, and trading conditions of this contract in detail in the following three sections (based on a sample of transactions covering the period from January 2, 2018, to November 28, 2022). In addition, we will use a sample of contracts with five-year maturity for robustness exercises.

2.2. Transaction data preparation

As indicated above, one main novelty of our paper is the ability to use updated EMIR data, as well as other relevant data sources, which allow us to investigate liquidity in the EUR-IRS market from a granular perspective. Our sample of time-stamped and fully identified IRS

[10] https://www.esma.europa.eu/sites/default/files/library/public_register_for_the_trading_obligation.pdf

[11] Under MiFID II, a Multilateral Trading Facility (MTF) is a multilateral system operated by an investment firm or market operator, which brings together multiple third-party buying and selling interests in financial instruments in the system, in accordance with non-discretionary rules. An Organised Trading Facility (OTF) is a system that is not a regulated market or MTF and in which multiple third parties can buy and sell bonds, derivatives, or other instruments.

transactions covers the period from January 2, 2018, to November 28, 2022, and comprises 1246 active trading days.[12]

We estimate all liquidity variables from the granular transaction data obtained from Trade Repositories. According to Jahan-Parvar and Zikes (2021) intraday estimation of trading conditions is more precise than estimation based on daily variables (e.g., daily highs and lows).

Our sample consists exclusively of CCP-cleared and therefore fully standardised trades,[13] hence we omit bilaterally cleared trades due to their different margining regime and collateral requirements (cf. Boudiaf et al., 2023).

Following the approach of Abad et al. (2013), Dalla Fontana et al. (2019) and Benos et al. (2018), we start with extensive filtering and cleaning of the raw transaction data set. To describe the procedures in place, Annex 1 shows the steps in our algorithm for the last sample day, 28/11/2022. After filtering, our sample contains 338.215 trades. In our econometric analysis we focus on the daily frequency.

2.3. Calculation of liquidity measures

Market liquidity is usually understood as the ease with which a trader can buy or sell an instrument at a price close to the observed market price prior to the transaction (cf. IMF, 2015). The following five dimensions are typically captured by empirical research of market liquidity:[14]

- Tightness reflects the direct transaction costs incurred when trading financial instruments.
- Depth captures the number of orders in an order book –the higher the number of orders, the more liquid trading is.
- Breadth refers to the volume of orders –in a liquid market large orders should not have a significant impact on prices.
- Resiliency measures the reaction of prices to imbalances driven, for instance, by new information about fundamentals.

[12] Holidays and days with fewer than 25 transactions or less than USD 1 billion total notional are omitted. Regression sample size may be smaller due to data availability for explanatory variables.
[13] EURIBOR IRS are cleared in LCH LTD and Eurex. The market share of LCH LTD in the middle of our sample period was around 90% (see https://www.clarusft.com/latest-eur-swaps-market-share-for-ccps-and-sefs/).
[14] Schestag et al. (2016) offer a comprehensive "horse-race" analysis of liquidity measures using transaction data on US Corporate bonds.

- Immediacy represents the speed of execution in a market segment. A key driver of this speed is the activity of market makers who quote the prices at which other market participants can trade.

PROXY	DESCRIPTION	DEFINITION
TOTAL NOTIONAL PER DAY	Sum of new transaction volume during the trading day	$Tot.Notional_t = \sum_{k=1}^{N_t} Notional_k$
NUMBER OF TRANSACTIONS PER DAY	Count of newly executed trades	N_t
AVERAGE NOTIONAL OF A TRANSACTION PER DAY	Total notional per day divided by number of transactions	$Avg.Notional\ _t = \frac{1}{N_t}\sum_{k=1}^{N_t} Notional_k$
AVERAGE TIME DIFFERENCE BETWEEN TWO TRADES DURING THE TRADING DAY	Average time in minutes between two consecutive trades during German trading hours[15]	$TimeDiff\ _t = \frac{1}{N_t}\sum_{k=1}^{N_t}(Time_{k,t} - Time_{k-1,t})$
NUMBER OF ACTIVE COUNTERPARTIES PER DAY	Number of distinct traders executing a new trade	$Nr.Counterparties_t = \sum_{k=1}^{N_t} Cpties_k$
ROLL MEASURE OF BID-ASK (ROLL, 1984)	Bid-ask spread approximated as two times the square root of the negative covariance of returns and their lags[16][17]	$Roll_t = \frac{2}{N_t}\sum_{k=1}^{N_t}\sqrt{-cov(\Delta p_{k,t}, \Delta p_{k-1,t})}$
PRICE DISPERSION DURING A TRADING DAY (CF. JANKOWITSCH ET AL., 2011 AND BENOS ET AL., 2018)	Intuitively, a highly liquid (illiquid) market is characterised by negligible (significant) deviations of traded prices from their market valuations[18]	$Disp_t = \sqrt{\sum_{k=1}^{N_t}\frac{Vlm_{k,t}}{Vlm_t}(P_{k,t} - \overline{P_t})^2}$
PRICE IMPACT DURING A TRADING DAY (CF. AMIHUD, 2002, LOON AND ZHONG, 2016)	Single (sizeable) transactions have a high impact on market prices in illiquid markets[19]	$Impct_t = \frac{1}{N_t}\sum_{k=1}^{N_t}\frac{\lvert P_{k,t} - P_{k-1,t}\rvert}{Vlm_{k,t}}$

[15] We therefore omit transactions from US and Asian IRS trading hours which are much less active. We also do not consider the opening and closing trades for these metrics.
[16] We aggregate the intra-daily covariances between the rates of two trades to a daily measure by taking the average.
[17] A key assumption is that the asset value follows a random walk. Furthermore, buy and sell orders are assumed to be equally likely.
[18] Higher dispersion can reflect trading conditions where the flow of new trades is absorbed with larger price adjustments. For investors these deviations indicate rising costs of trading and therefore make hedging or investing more expensive.
[19] Measure based on the average ratio of absolute return of swap contract to its volume for a given day.

Based on this framework, we calculate eight complementary metrics on a daily horizon based on intraday observations for the underlying sample period. Figure 1 shows how these eight measures relate to the five dimensions outlined above. Despite the limitations of our dataset, in particular the lack of quotes,[20] we therefore cover the most important dimensions of liquidity identified in the literature.

While Jankowitsch et al. (2011) use Reuters closing values to proxy for the market valuations in the price dispersion formula, we are using the daily weighted average fixed rate instead. This approach is less biased with high intra-day volatility as end-of-day prices might be very different to the average during the day (Benos et al., 2018) and provided more reliable results throughout our sample. In particular, we compared multiple versions of the price dispersion measure using either Reuters closing rates, the average daily fixed rate or the volume-weighted average fixed rate. Since our data cleaning uses a range of Reuters quotes to define plausible prices and filter out any faulty observations, the weighted average fixed rate is in the range between Reuters highest and lowest quote on each day. Additionally, we deviate from Jankowitsch et al. (2011) by using the absolute difference between the price of the respective transaction and the market valuation because with relative differences price dispersion would be skewed by denominator effects with average prices very close to zero. The same reasoning holds for our price impact measure.

3. Evolution of swap market liquidity

In our sample period (time series plotted in Figure 2), the pricing of EURIBOR swap contracts reflects two distinct periods of inflation and corresponding monetary policy stance (highlighted by the vertical bars in Figure 2):

- From 2018 to 2021: Low inflation and accommodative monetary conditions with large-scale asset purchase programs ("quantitative easing") and policy rates close to zero:[21] In this period the swap rate first declined and then hovered around zero.

[20] Due to the absence of a centralised order book (use of multiple trading platforms), there is no consolidated source of quoting data for swaps.

[21] In this period, the ECB decreased the interest rate on the deposit facility by 10 basis points to -0.50% as of 12 September 2019 and restarted net bond purchases at a monthly pace of €20 billion from 1 November 2019.

- Late 2021 and 2022: Tightening of monetary policy by a global increase in policy rates in 2022 (ECB hikes starting in July 2022) led the swap rate to rise from zero to around 3%.

Since 2021, activity in EURIBOR-denominated IRS has increased (time series plotted in Figure 3), reflecting a broader trend in IRS (BIS, 2022). An indication is provided by the growth in notional volume (Figure 3, first row). A decomposition of the volume shows that the overall growth is driven by larger average trade size and increasing participation in swap trading (Figure 3, first and second rows).

Daily average notional volume in the last month of our sample, November 2022, stood at around EUR 20 bn, based on more than 370 trades newly executed per day in that month. The average trade size was EUR 54 mn and 54 traders were active on average during November 2022. In contrast, in the low rates period of July 2020, average daily notional volume amounted to EUR 6.8 bn with slightly less than 180 trades executed per day by around 35 market participants. Particularly strong market activity has been observed on a few days starting in late 2021 and continuing until the end of our sample, when 60 or more Clearing Members were active in this contract.[22]

The number of active banks provides an indication of the swap market's depth: The EUR swap market is deeper than US corporate bond trading but less deep than benchmark US Treasuries (cf. Scheicher, 2023). Immediacy of swap trades can be gauged through the time span between subsequent transactions during a trading day. As Figure 3 shows, the time difference closely follows other activity measures in the trend of steadily growing market activity. It starts at around five minutes in early 2018 and moves to below three minutes, albeit with considerable volatility (peaks of around seven minutes in middle of 2018 and 2020).

For the entire sample period (descriptive statistics summarised in Table 1), total notional amounts to EUR 12 bn on average, with 271 trades among 43 active counterparties. Average trade size equals around EUR 45 mn. As also shown in Figure 3 variation in the sample period is high, with total notional fluctuating between EUR 2 bn and 37 bn, average notional fluctuating between EUR 20 mn and EUR 100 mn and between 12 and 108 active Clearing Members.

A comparison with the evolution of trading conditions in the world's most important fixed income segment, US Treasuries,[23] shows similar patterns, with a deterioration indicated

[22] According to analysis by Coulier et al. (2023) using EMIR and bank balance sheet data, the use of interest rate derivatives differs by bank type, with higher heterogeneity among larger banks. Furthermore, banks are typically paying the fixed-rate in IRS.

[23] For US Treasuries, we use a price -based measure based on Hu et al. (2013) and obtained from Bloomberg.

since 2021 (Figure 4).[24] Such patterns are not surprising, as market participants had to process large amounts of new information related to the geopolitical environment, the macroeconomy and the impact on monetary policy.

Figure 4 also allows us to study the impact of the Covid-shock on IRS liquidity. Both measures for IRS spiked, with a stronger increase for price dispersion rather than price impact. Among all three measures plotted, the highest increase is observed for the US Treasury market. The general fragility of market liquidity in fixed income markets (cf. FSB, 2022) has been highlighted by the dislocation in US fixed income markets in March 2020 (first spike in the noise measure of US Treasuries in Figure 4)[25] and more recently by stress in UK Gilt trading in September 2022, due to a surprise change in UK fiscal policy. We will return to the analysis of common factors in liquidity in the next section.

Figure A.1 offers additional insights into the information content of our liquidity measures relative to the Bid-ask series as published by Reuters. For the bulk of our sample period, the Reuters bid-ask spread oscillates in a very narrow band[26], hence it hasn't reacted to the change in the monetary policy stance. In Figure A.2, we take a cross-sectional perspective and illustrate the variation of trading conditions across CMs.[27] We observe that smaller Clearing members face – in absolute terms –higher bid-ask spreads. This pattern may indicate benefits of centrality for major Dealers.[28]

Table 1: Descriptive statistics of levels of swap liquidity measures

VARIABLES	Mean	Median	Min.	Max.	StDev.	Skewness	Kurtosis
Price dispersion	0.018	0.012	0.003	0.097	0.015	2.366	9.215
Price impact	0.0009	0.0006	0.0001	0.016	0.001	4.989	46.414
Roll estimator	0.093	0.046	0.000	0.876	0.121	2.650	11.318
Total Notional	12.047	10.866	1.945	37.202	5.617	1.071	4.399
Nr. Transactions	271.400	246.000	48.000	742.00	117.4	0.868	3.463
Avg. Time Difference	4.481	4.115	1.100	15.898	1.922	1.244	5.804
Avg. Notional	44.780	43.790	19.270	106.06	9.780	0.998	5.626
Nr. Counterparties	43.620	43.000	12.000	108.00	11.827	0.495	3.528
Nr. Observations	1246						

Note: Average time difference is measured in minutes, total notional in billion EUR and avg. notional in million EUR.

[24] The recent global co-movement also provides indirect evidence for the high information content of our dataset despite the need for large-scale filtering.
[25] See O'Hara and Zhou (2023) for further discussion.
[26] The Reuters Bid-Ask spread is at 1 basis point especially in the last three years (with overall 850/1246 Reuters reported BA spreads equal to 0.01).
[27] For confidentiality reasons we aggregated the individual CMs to two groups. Group 1 contains smaller banks or banks with low daily activity, while Group 2 comprises Dealers.
[28] See Di Maggio et al. (2017) for analysis on the benefits of relationships in US corporate bond trading.

As we use daily changes in our regression analysis, we briefly summarise the corresponding descriptive statistics in Table 2. The descriptive statistics for the daily changes of swap liquidity measures behave as expected, with daily changes on average hovering around 0 for most variables. The main exception is the evolution of changes in total notional, which increased materially over the past two years, as described above. We also note considerable positive skewness and kurtosis in the case of price impact.

4. Econometric analysis of swap market liquidity

In this section we apply correlation, principal component, and regression analysis to understand the drivers of the variation in liquidity. We start with an overview of the hypotheses which we will test.

4.1. A framework for interpreting potential drivers of market liquidity

Variation in market liquidity is driven by changes in supply and demand in the market, with any imbalances to be managed by intermediaries such as bank dealers stepping up their trading activity.

Overall, our set of six hypotheses can be seen as broadly guiding our empirical analysis and allowing us to empirically investigate the evolution and drivers of trading activity and liquidity in the EUR IRS market. We do not build on a single unifying theoretical framework but base our hypotheses on theoretical and empirical research on OTC markets and fixed

Table 2: Descriptive statistics of daily changes of swap liquidity measures

VARIABLES	Mean	Median	Min.	Max.	StDev.	Skewness	Kurtosis
Price dispersion	3.80E-05	0.0001	-0.073	0.057	0.011	-0.295	8.588
Price impact	3.60E-06	-3.00E-06	-0.012	0.014	0.001	0.413	43.499
Roll estimator	0.0003	0.0004	-0.684	0.621	0.103	-0.339	13.430
Total Notional	0.009	0.139	-19.688	22.514	5.683	0.018	3.898
Nr. Transactions	0.200	0.000	-361.00	498.00	95.618	0.209	4.227
Avg. Time Difference	-0.003	0.011	-9.997	9.467	2.153	-0.049	5.057
Avg. Notional	0.002	0.540	-50.674	57.777	12.337	-0.104	4.621
Nr. Counterparties	0.010	0.000	-60.000	67.000	11.474	0.123	5.215
Nr. Observations	1245						

Note: Average time difference is measured in minutes, total notional in billion EUR and avg. notional in million EUR.

income instruments more broadly,[29] all of which are traded outside centralised exchanges. A key restriction is that all transactions in our sample have a CCP on one side and a Clearing Member

as counterparty, thus we are unable to calculate the network variables commonly used in empirical research e.g., on corporate bonds (such as Dealer centrality measures, or Interdealer vs Dealer-Client segmentation). Our use of transaction data also rules out the analysis of quotes and the corresponding "effective" bid-ask spreads as used with in the analysis of TRACE corporate bond data.

Hypothesis I. The co-movement between activity and price-based measures of liquidity changes in cross-section.

As explained in the previous subsection, we calculate a wide range of liquidity measures which are derived from transaction prices and volume. The literature offers multiple studies on the co-movement and information content of these measures. Among OTC segments, Anderson and Stultz (2016) show that for US corporate bonds, after the GFC, some price-based liquidity metrics have improved whereas activity as measured by turnover has declined. We test the co-movement of our measures by means of correlation and principal component analysis, also expecting that some correlations are not significant.

Hypothesis II. Macro fundamentals, in particular monetary policy, affect IRS activity and liquidity.

In general, news about fundamentals directly affect the term structure. As a consequence, traders have to adjust their positions.[30] Our sample period is characterised by an unprecedented tightening of monetary policy which was still ongoing at the time of writing. Earlier research has also documented the empirical interaction of market liquidity and monetary policy for major fixed income segments.[31] Due to the complex and changing macroeconomic conditions, one distinguishing feature in this tightening cycle is uncertainty among market participants

[29] As Karnaukh et al. (2015) argue in the case of FX liquidity, it is "*difficult to obtain empirical factors that isolate supply side and demand-side sources of liquidity*".
[30] Eijffinger and Pieterse-Bloems (2022) offer a recent study on the pricing of euro government bonds.
[31] See Altavilla and Motto (2020) for analysis of the information flow to the yield curve on monetary policy decision dates. Pelizzon et al. (2016) study Italian government bond trading, highlighting the impact of ECB interventions on bid-ask spreads during the euro crisis.

about the path of rates and the "terminal policy rate".[32] Overall, we expect that monetary policy events, which we capture by means of announcement day dummies, increase IRS trading activity, but may not necessarily affect price dispersion.

Hypothesis III. IRS activity and liquidity are driven by interest rate risk hedging.

Changes in interest rates affect the value of banks' assets relative to their liabilities. Higher rates reduce the present value of assets with fixed payments, including government bonds and many mortgages. Therefore, interest rate risk is an inherent part of banking (Hoffmann et al., 2017 or Grassi et al., 2022). Banks convert some of their fixed rate assets into floating rate assets to match their floating rate liabilities by using IRS, where they pay a fixed rate and receive a floating rate that is linked to market interest rates. In the euro area, household mortgages, which are the largest interest-rate sensitive asset category for most banks, show significant differences in their cash-flow structure (with a predominance of fixed rates e.g., in Germany, whereas EURIBOR floating mortgages are most common e.g. in Spain).[33] In addition to rate changes, also their volatility should affect liquidity. Such a channel was notably documented by Duffie et al. (2023) for market liquidity of US Treasuries. We use EURIBOR rate changes (both the underlying six-month rate as well as the 10-year swap rate), squared changes and conditional rate change volatility (GARCH-estimated) as proxies for hedging demand. We expect that higher rate changes and volatility increase activity. Sudden large increases in demand for hedging may overwhelm intermediation capacity and therefore lead to temporary declines in market liquidity, which we also test.

Hypothesis IV. Higher funding costs reduce market liquidity.

Comprehensive margining of Clearing Member (CM) positions in CCPs is a major element of the post-GFC reform process. CCP risk management foresees two types of margins: Initial margins (IM) are collected to protect the CCP against future changes in the market value of swap contracts following a Clearing Member's default and is model driven. Variation

[32] In decentralised financial markets, Dealer willingness to intermediate is in general affected by the impact of asymmetric information (cf. Kyle, 1985). Dealers posting stale quotes face the risk of aggressive trading by informationally rich market participants. This scenario is less likely in the IRS market where – in contrast to corporate bonds or CDS – publicly available macroeconomic data is the main input to pricing.
[33] See Hofmann et al. (2017) for a discussion.

margin (VM) covers day-to-day changes in the market value of swap contracts.[34] Similar mechanisms are in place for bilateral clearing outside CCPs.

Margin calls can lead to high cash pressures on CMs and provide a practical link between funding and market liquidity (see Brunnermeier and Pedersen (2009) for theoretical modelling of the links between funding and market liquidity). In recent stress episodes, CCPs' margin calls reached unprecedented levels, raising liquidity risk for some market participants in Europe and US. For example, during the Covid Crisis in March 2020 an additional volume of US$ 300 bn of IM was called (see BCBS, CPMI and ISOCO, 2022). This episode has led to concerns about procyclicality of CCP margining, which implies that model-driven margin calls may exacerbate systemic stress by causing severe increases in (funding) liquidity risk.

CMs typically fund their margin payments to CCPs via unsecured or secured borrowing, hence these margins provide a direct drain on CMs' liquid resources. We will study the margin-liquidity co-movement in a qualitative approach (due to data restrictions). For our econometric analysis, we measure Dealer funding costs through the EUR repo rate as secured borrowing now exceeds unsecured interbank borrowing. We include the rate on repo contracts with "general collateral" and expect that higher funding costs – ceteris paribus - reduces activity.

Hypothesis V. IRS activity and liquidity are linked to Dealer behaviour.

According to some commentators[35] regulatory reforms in the aftermath of the global financial crisis may have increased the costs of intermediation in those fixed income markets which particularly depend on dealer trading and inventory capacity. For instance, Dealer conditions have been shown to affect trading conditions in US corporate bonds (Adrian et al., 2017; impact via Dealer leverage), CDS (Siriwardane, 2019; impact via Dealer leverage) and US Treasuries (Duffie et al., 2023; via utilization of Dealers' balance sheets). More generally He et al. (2016) show that Dealer leverage affects the cross-sectional variation in expected returns of equity and government bond market portfolios, as well as corporate bonds, derivatives, commodities, and currencies.[36] There could be several mechanisms for how a bank's capital and

[34] See Boudiaf et al. (2023) for an overview of CCP margining.
[35] See CGFS (2016) for further details on the discussion about the role of dealer metrics and Dealer behaviour.
[36] The theoretical model of Huang and Stoll (1997) emphasises inventory as a major determinant of bid-ask spreads in addition to an adverse selection element and order processing costs.

funding liquidity ratio might affect liquidity. A bank's RWA[37]-based capital position (defined as CET1 relative to risk-weighted assets) is a common determinant of a bank's rating and its counterparty risk in general (for a general discussion, see Acharya et al. (2016)). From a risk management perspective, market participants might prefer a counterparty that is well-capitalised and therefore more resilient to market shocks. Over the past years, mandatory central clearing for IRS should have reduced the relevance of this type of counterparty risk channel. Nevertheless, the leverage ratio which is defined as capital relative to total assets (i.e., with equal risk weights of 100% for all instruments irrespective of their risk) continues to be relevant. Introduced globally by the Basel III framework and in the EU via CRD IV,[38] the leverage ratio requires more capital against derivatives exposures, which have low market risk. We expect that lower leverage, i.e. higher capitalisation of Dealers (proxied by the market value of equity via the Euro STOXX Banks stock index) allows more active intermediation and therefore better liquidity.

We also expect that the net-gross ratio has a detrimental effect on liquidity. Our motivation for this linkage is based on the Dealer balance sheet utilization documented by Duffie et al. (2023) for US Treasury liquidity. Duffie (2023; section 4) provides a theoretical framework for the impact of Dealer limits in their intermediation capacity on market liquidity[39]. Empirically, CDS Dealer efforts to run flat books generate a complex network of exposures with a "flow of risk" centred on core Dealers.[40] As a result, Dealers' net exposures are very low compared to their gross exposures. Any deviations from target levels prescribed by bank risk management rules lead to more trading activity, which often takes place in the inter-Dealer market. Indeed, CDS volume between strongly connected Dealers represents about 60–90% of traded CDS notional (Battiston et al., 2018). The imbalance between buyers and sellers has also been shown to drive daily CDS liquidity (proxied by price dispersion and volume) by Aramonte and Szerszen (2020). Dalla Fontana et al. (2019) document this structural feature of swap markets for a snapshot of IRS exposures. These findings from CDS and IRS leads us to expect that

[37] Under the CRD framework EU banks have to comply with two capital requirements: One is applied to the bank's risk-weighted-assets (RWA; calculated e.g., via internal risk models) and one for the bank's total assets ("leverage ratio", using an equal risk weight of 100%) for all the bank's positions.

[38] CRD IV is in force since January 2018, hence banks' adjustment to the new regulatory regime should largely have been concluded during our sample period. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32013L0036

[39] Dealer bid-ask spreads are highly sensitive ("bend down") to Dealer inventory holdings once the inventories rise to a certain limit.

[40] The CDS market shows a high degree of intermediation (cf. Battiston et al., 2018). Major dealers do not fully retain underlying credit risk in their CDS portfolios, often redistributing it to other market participants.

Dealer positioning affects liquidity, whereby we measure Dealer positioning via the net-to-gross notional ratio (which is also used as a metric in the Basel framework).[41]

Hypothesis VI. IRS activity and liquidity are linked to global investor sentiment and liquidity in related markets.

We use VIX implied volatility as proxy for market-wide investor sentiment. As Tang and Yan (2017) show, CDS trading reacts significantly to VIX changes. We expect that higher implied volatility increases activity but decrease liquidity, due to risk limits and risk aversion.

Extrapolating from the previous hypothesis, we also investigate how IRS liquidity reacts to trading conditions in globally relevant markets, such as US Treasuries or German Bunds. This is based on results from international asset pricing, in particular on covered interest rate parity [42] and the fact that the major Dealers are globally active. Finally, the two major European CCPs, Eurex Clearing AG and LCH LTD, clear both EUR and USD contracts, which allows for low-cost trading of IRS across the major currencies. We expect positive co-movement of price-based liquidity with global factors. In this context, we also test for volatility spillovers between German government bonds and swaps. As these two instruments represent two key euro area fixed income markets, we expect co-movement of liquidity – also due to the role of Dealers – particularly in stress periods.

Table 3: Summary of hypotheses and related explanatory variables

Hyp. Nr.	VARIABLES	Definition	Expected Reaction
H1	-	Interaction activity – liquidity	Negative corr.
H2	Mon. Policy Decisions	Dummy for Mon. Pol. Decision days of ECB & Federal Reserve	Activity +
H3	EURIBOR 6M Rate	Fixed rate on EURIBOR 6M (and 10 Year)	Activity + Liquidity +/-
H3	Rate Volatility	GARCH estimate for EURIBOR 6M changes or squared changes	Activity + Liquidity -
H4	Repo rate	EUR overnight repo rate	Activity - Liquidity -
H5.A	EURO STOXX Banks	Closing price EURO STOXX Banks	Liquidity +
H5.B	Dealer Net-gross ratio	Dealer Net exposure / Dealer gross	Liquidity -
H6.A	VIX	Implied Volatility of S&P 500	Activity + Liquidity -
H6.B	DE / US Treasury liquidity	Bloomberg price “noise” measure	Liquidity +

[41] For instance, in the netting of Potential Future Exposure of derivatives which feeds into the numerator of the bank’s leverage ratio.
[42] See Du et al. (2018).

Our econometric approach follows Hu et al. (2013), Karnaukh et al. (2015) or Adrian et al. (2022). To test the six hypotheses summarised in Table 3, we use regression analysis with heteroskedasticity robust standard errors and covariances. Regressions are estimated in first differences, i.e. daily changes. We plot the main explanatory variables in Figure 5. Again, the impact of the changed monetary policy stance is clearly visible in all rate-related variables.

4.2. Correlations and principal components

We start with the analysis of contemporaneous co-movement in levels and changes (corelations of levels are shown in Annex 2). The highest correlations are observed for activity and liquidity-related metrics. In the first category, correlation between number of trades and notional is highest with a value of .87. In the second category, correlation between price dispersion, price impact and the Roll measure is between .67 and .87. Across the two categories, correlation between number of traders and the three price-based measures is between .32 and .41. These somewhat low correlations show that the number of active CMs captures a broader set of information than purely activity.

Results from corporate bonds[43] indicate that the network structure may affect liquidity. Using the number of active traders to represent the network density, we find that higher density correlates with higher notional, higher number of transactions and shorter time lags between new trades.

Correlations among the changes of the eight liquidity measures are shown in Table 4 and Figure 6. We find that the activity and the liquidity groups are each strongly correlated but correlation across the two types of measures is lower. In particular, the highest correlation is observed between changes in total notional and number of transactions with a value close to .8. Correlations of changes in total notional with average notional and time difference of trades are .61 and -.47 (due to the construction of the latter variable). The linear co-movement with price difference is slightly below .30. The correlation of this measure with the time variable is below -.20. The Roll measure shows a high (above .6) correlation with the two price-based measures, which have a bivariate correlation of .35. This comparatively weaker correlation indicates that price impact and price difference capture different dimensions of market liquidity although both are closely related to the Roll measure.

[43] Di Maggio et al. (2017) document how dealers' trading relations shape their trading behaviour in US corporate bonds

To summarise the information contained in the liquidity variables, we turn to Principal Component analysis.[44] To avoid redundant information, we abstract from including average daily notionals (which is a linear combination of total notional and number of trades) in this analysis, which leaves us with seven input measures. This allows us to study the joint dynamics of activity and liquidity. We extract the first, second and third principal components computed from the singular value decomposition of the 1244* 7 matrix of changes in liquidity measures.

Table 4: Contemporaneous correlations of daily changes of swap liquidity measures

	Price disp.	Price impact	Roll	Total Notional	Nr. Transactions	Avg. Time Diff.	Avg. Notional	Nr. Cpties
Price dispersion	1.000							
Price impact	0.352	1.000						
Roll estimator	0.682	0.620	1.000					
Total Notional	0.285	0.020	0.263	1.000				
Nr. Transactions	0.282	0.108	0.239	0.795	1.000			
Avg. Time Difference	-0.197	-0.038	-0.179	-0.475	-0.559	1.000		
Avg. Notional	0.128	-0.051	0.154	0.611	0.079	-0.090	1.000	
Nr. Counterparties	0.174	0.101	0.117	0.438	0.625	-0.280	-0.047	1.000

Note: Average time difference is measured in minutes, total notional in billion EUR and avg. notional in million EUR.

The first three factors account for 43%, 25% and 10% of total variation, hence in sum they are close to 80%. In the subsequent analysis we will therefore concentrate on these three variables. The weights of the seven liquidity variables in PC 1, PC2 and PC3 are provided in Table 5 and their time series are plotted in Figure 7.

Table 5.A: PCA loadings of daily changes of swap liquidity measures

VARIABLES	PC 1	PC 2	PC 3
Price dispersion	0.355	0.396	-0.235
Price impact	0.225	0.532	0.341
Roll estimator	0.355	0.523	-0.094
Total Notional	0.450	-0.274	-0.127
Nr. Transactions	0.488	-0.297	0.087
Avg. Time Difference	-0.359	0.240	0.550
Nr. Counterparties	0.359	-0.257	0.702

Note: All variables are standardized. Average notional was omitted as it is a linear combination of total notional and number of transactions. Dotted line indicates whether variable is a liquidity (top) or an activity (bottom) measure. Avg. time difference is measured in minutes and total notional in billion EUR.

[44] Principal components-based liquidity analysis is also used by Bicu-Lieb et al. (2020) for UK gilts, Poli and Tabogo (2021) for euro area government bonds and Duffie et al. (2023) for US Treasuries. In general, a dominant first principal component is found.

Table 5.B: PCA loadings of daily changes of swap liquidity measures – Sub-Samples according to MonPol environment

	(1) Before Mon. Policy tightening			(2) After Mon. Policy tightening		
VARIABLES	PC 1	PC 2	PC 3	PC 1	PC 2	PC 3
Price dispersion	0.257	0.601	-0.005	-0.417	0.316	0.580
Price impact	0.090	0.401	0.144	-0.658	-0.438	-0.534
Roll estimator	0.225	0.591	-0.023	-0.605	0.031	0.320
Total Notional	0.488	-0.129	-0.079	-0.095	0.551	-0.240
Nr. Transactions	0.541	-0.175	0.087	-0.101	0.470	-0.331
Avg. Time Difference	-0.436	0.180	0.677	0.050	-0.165	0.079
Nr. Counterparties	0.394	-0.221	0.712	-0.075	0.394	-0.320
# days/observations	1151	1151	1151	93	93	93

Note: First rate hike on 22nd July 2023 constitutes start of (2) After Mon. Policy tightening. All variables are standardized. Average notional was omitted as it is a linear combination of total notional and number of transactions. Dotted line indicates whether variable is a liquidity (top) or an activity (bottom) measure. Avg. time difference is measured in minutes and total notional in billion EUR.

From Table 5a we note that in the full sample PC1 has positive weights on the four activity measures (the time difference is by construction negatively related to liquidity as longer time lags between transactions imply lower activity). The weights on the three price-based measures are also positive. This pattern may be driven by the second part of the sample where activity increased, and price-based liquidity deteriorated.

In contrast, PC2 represents an average of the seven measures, as all notional measures show a negative relation and all price-based measures a positive weight. The third factor is a mix of the input variables with positive weights on the number of transactions and market participants as well as price impact. Further insights into the three factors are available from the time series plotted in Figure 7 (monthly averages, as for all other time series plots). The spikes in spring 2020 in the first and third factors relate to the market volatility observed around the outbreak of Covid. The first and second factors also show strong volatility in late 2022, possibly related to market uncertainty about the short-term path of monetary policy.

As a second step, we split our sample into two subperiods, before and after the monetary tightening in June 2022. This split strongly affects the relationship among the seven variables (Table 5.b). First, the overall results with respect to signs and magnitudes of the PCs are largely driven by the (much longer) zero-rate period, which dominates the sample period and provides 1151 out of a total of 1244 observations. Second, in the tightening period of 2022, the signs and magnitudes of the PCs change. The first PC estimated for 2022 has negative weights except for the immediacy and the second PC has negative weights on the price impact and time difference. Therefore, the interaction among the activity groups of variables also changes, although the general patterns in PC1 (from six "plus" signs to six "minus" signs) is preserved. We will return to the impact of the change in monetary policy stance in the regression analysis, where we will – motivated by the PCA – also present subsample results to test the robustness of our main findings.

Overall, the findings of correlation and principal components analysis confirm hypothesis 1. To comprehensively capture IRS liquidity, a broad set of seven measures provides a much richer picture than a narrow set of e.g., only bid-ask spreads or notional, and it shows limited overlaps among the different types of measures.[45] This structure of the information content is particularly valid for the quantitative tightening (QT) period.

4.3. The impact of monetary policy on swap trading conditions

To start the empirical analysis of liquidity drivers, we run regressions of ECB monetary policy indicators on the two main market liquidity metrics (i.e., price dispersion and total notional), using heteroskedastic SEs.[46] We find that ECB monetary policy decisions lead to significantly increased price dispersions and reduced notional on the day of the announcement, thus liquidity and activity both show a decline. This finding is consistent with earlier research on the impact of monetary policy on market liquidity.[47] In contrast, the impact of FED monetary policy decisions seems to have the opposite effect, although the results here show a lower statistical significance.

To investigate potential anticipatory or ex-post effects, we vary the time window around the event date by extending the event window to one day prior and/or one day after a respective monetary policy decision.[48]

[45] A similar finding of a *"disparate behaviour of the various measures"* is reported by Adrian et al. (2022, p.3).
[46] For the baseline regression, indicator is equal to one on the day of a monetary policy decision. To include some potential anticipation or delayed reactions we extend the event window to one day prior and/or one day after the decision.
[47] Fernández-Amador et al. (2013) find that an expansionary monetary policy of the ECB increases liquidity in German, French and Italian stocks and vice versa. Recently, researchers have extensively studied the impact of central bank purchase programs on bond market liquidity. Boneva et al. (2021) show that the Eurosystem purchase program for corporate bonds has led to deteriorated liquidity of older bonds but increased liquidity for newly placed bonds.
[48] This may indicate that traders anticipate the direction of the impact of the announcement.

Table 6: Regressions on Monetary Policy indicators

Daily Changes **in Price dispersion** regressed on Mon. Pol. Decision indicators

VARIABLES	(1)	(2)	(3)	(4)
ECB Mon. Policy decision day (t)	**0.005**			
	[3.12]			
FED Mon. Policy decision day (t)	**-0.003**			
	[-1.75]			
ECB incl. anticipatory effects (t-1 & t)		**0.002**		
		[2.01]		
FED incl. anticipatory effects (t-1 & t)		-0.001		
		[-0.77]		
ECB incl. ex-post effects (t & t+1)			**0.002**	
			[1.9]	
FED incl. ex-post effects (t & t+1)			**0.002**	
			[1.7]	
ECB full window (t-1, t & t+1)				0.001
				[1.4]
FED full window (t-1, t & t+1)				**0.002**
				[1.74]
Adj R^2 (%)	0.7	0.1	0.3	0.2
# days/observations	1245	1245	1245	1245

Daily Changes **in Total Notional (in bn EUR)** regressed on Mon. Pol. Decision indicators

VARIABLES	(1)	(2)	(3)	(4)
ECB Mon. Policy decision day (t)	**-2.066**			
	[-2.47]			
FED Mon. Policy decision day (t)	-1.003			
	[-1.37]			
ECB incl. anticipatory effects (t-1 & t)		-0.745		
		[-1.28]		
FED incl. anticipatory effects (t-1 & t)		0.958		
		[1.28]		
ECB incl. ex-post effects (t & t+1)			-0.641	
			[-1.1]	
FED incl. ex-post effects (t & t+1)			-0.624	
			[-1.12]	
ECB full window (t-1, t & t+1)				-0.224
				[-0.47]
FED full window (t-1, t & t+1)				0.561
				[0.97]
Adj R^2 (%)	0.3	0.1	-0.02	-0.07
# days/observations	1245	1245	1245	1245

Note: Explanatory variables are event dummies for monetary policy decisions. Standard errors are heteroskedasticity robust. T-values are expressed in brackets below. Bold coefficients are significantly different from 0 at the 10% level or higher.

Overall, our analysis using event day dummies[49] shows that ECB monetary policy events have a significant impact on both price dispersion (positive) and total notional (negative). This leads us to confirm hypothesis 2 about links between monetary policy and swap market liquidity: Monetary policy events reduce trading activity and lead to a deterioration of trading conditions. A possible explanation for these two findings could be that in the complex current environment market participants need to digest the new information and analyse how to adjust their forecasts of the "terminal rate"[50], thereby leading to worsened market liquidity.

4.4. EURIBOR rates and trading conditions

We now move to the analysis of the impact of hedging-cost-related explanatory variables on our two main liquidity measures. We first run regressions with the EURIBOR six-month underlying rate and the ten-year swap rate as key hedging-related variables to test for relationships between rates and market liquidity. Table 7 does not show any conclusive evidence of a linear relationship between hedging costs and market liquidity on a standalone basis, when measured via price dispersion. When coupled with a monetary policy decision dummy, hedging costs exhibit a significant impact on market liquidity by increasing price dispersion and reducing total national. Hence, liquidity reacts significantly to underlying squared rate changes only on monetary policy dates. Notional is also linked with second moments, via volatility rather than squared change. Rising volatility leads to a decline in notional. The strong importance of monetary policy for asset pricing is a stylised finding. For stock returns the "pre-FOMC announcement drift" has been documented by Lucca and Moench (2015). For bonds, Lou et al. (2022) document significant effects of MPC meetings on Gilt liquidity provision, in particular also via limits in Dealer risk-bearing capacity. This finding leads us to confirm hypothesis 3.

For a high-level analysis on IMs, we use public data on the time series of IMs at the EUREX OTC IRS segment as well as LCH Ltd. SwapClear. Eurex Clearing and LCH SwapClear both use VaR-based margin models.[51] Figure 8 indicates that rising margins over the last few years correlate with rising price dispersion.

[49] Using monetary policy shocks (cf. Pinter and Walker, 2023 for UK fixed income market) is beyond the scope of our exploratory analysis and left for future research.
[50] The peak of the policy rate.
[51] To illustrate the CCPs' margining methodology we refer to the PRISMA model of Eurex. Positions are first categorised into "Liquidation Groups" and portfolio margining is then applied to trades within the same

Table 7: Regressions on EURIBOR-related variables

Daily Changes **in Price dispersion** regressed on EURIBOR-related variables

VARIABLES	(1)	(2)	(3)	(4)
Δ EURIBOR 6M rate	-0.007			
	[-0.2]			
Δ EURIBOR 6M rate – squared		-0.655		
		[-1.42]		
Δ EURIBOR 6M volatility			0.005	
			[0.08]	
Δ Avg. fixed rate				0.001
				[0.06]
ECB Mon. Policy decision day (t)	**0.005**	**0.003**	0.002	**0.005**
	[3.15]	[2.28]	[1.4]	[3.05]
Interaction of rate measure with ECB MonPol decision dummy	0.370	**21.105**	0.304	-0.071
	[1.4]	[1.83]	[1.37]	[-0.73]
Adj R^2 (%)	0.6	1.1	0.7	0.5
# days/observations	1181	1181	1181	1181

Daily Changes **in Total Notional (in bn EUR)** regressed on EURIBOR-related variables

VARIABLES	(1)	(2)	(3)	(4)
Δ EURIBOR 6M rate	-1.670			
	[-0.12]			
Δ EURIBOR 6M rate – squared		-177.300		
		[-0.78]		
Δ EURIBOR 6M volatility			8.096	
			[0.41]	
Δ Avg. fixed rate				-5.478
				[-0.92]
ECB Mon. Policy decision day (t)	**-1.988**	**-1.576**	-0.527	**-1.997**
	[-2.36]	[-1.77]	[-0.54]	[-2.39]
Interaction of rate measure with ECB MonPol decision dummy	-85.041	-7386.000	**-195.571**	-48.403
	[-0.83]	[-0.75]	[-1.8]	[-1.19]
Adj R^2 (%)	0.2	0.4	0.6	0.4
# days/observations	1181	1181	1181	1181

Note: Continuous explanatory variables are measured as daily changes (Δ), where EURIBOR 6M rate is the floating interbanking market rate and Avg. fixed rate is the average daily swap rate. ECB Mon. Policy decision day is a dummy variable for days with ECB press conferences. Interactions are always between the respective continuous rate measure regressed in this column and the mon. policy dummy. Standard errors are heteroskedasticity robust. T-values are expressed in brackets below. Bold coefficients are significantly different from 0 at the 10% level or higher.

Liquidation Group and with the same holding period. Swaps are booked in the “Interest Rate Derivatives” category of Eurex and have a margin period of risk of five days. The initial margin takes a forward-looking perspective and in the case of OTC trades estimates the potential future exposure of CM portfolios for a 99.5% confidence level.

More detailed econometric analysis on the margin-liquidity interaction is beyond the scope of our paper as it requires firm-level data on the margins paid by major CMs at LCH LTD, which accounts for the bulk of swap clearing at the time of writing. These time series are not available to us due to data confidentiality restrictions.[52]

4.5. Linkages with Dealer variables and VIX

The relevance of Dealers for OTC market functioning has been discussed in the introduction. We start by testing the impact of Dealer funding costs via the repo rate in univariate regression analysis. Table 8 shows no significant coefficient in our linear[53] regression results in this respect; hence we cannot confirm hypothesis 4. Furthermore, market pricing may have undergone a structural break with the change in monetary policy. We therefore study subsample results in the multivariate analysis in the next subsection.

We now move to the Dealer-specific variables in our set of explanatory variables. As Table 8 shows, we find the expected signs in our regression results. Changes in the Dealer Net-Gross ratio are statistically significant for price dispersion although not for intermediary capital, pointing to a concrete relationship on a stand-alone basis for the Dealer exposure measure only. As regards total notional, an improved intermediary capital situation seems to have a positive effect on trading conditions. The coefficients for the Dealer Net-Gross ratio changes in the first regression remain positive when regressed together with the repo rate and the bank capital proxy, indicating a co-movement between price-based liquidity measures and Dealer exposure. This finding, which confirms hypothesis 5, is in line with existing analysis of the role of market making capacity for market liquidity (see Duffie et al., 2023 for further details for US Treasury trading).[54]

Motivated by findings of an exposure-liquidity relationship, we apply the Dealer capacity measure of Duffie et al. (2023) to examine the time series evolution. We apply the methodology of Duffie et al. (2023) to our dataset by calculating the Dealer balance sheet utilisation as the absolute value of Dealer net-notional divided by the maximum of its absolute value. Swap Dealer balance sheet capacity is proxied by how much of the historical maximum is currently consumed. Duffie et al. (2023) document that this approach, which they describe as "*revealed-*

[52] Under EMIR we can only access EU-related transaction or margin data.
[53] We will investigate non-linear effects of rate changes in the multivariate analysis.
[54] We also ran regressions using CDS spreads as a proxy for bank default risk. Coefficients were not significant.

Table 8: Regressions on Dealer-related variables

Daily Changes **in Price dispersion** regressed on Dealer-related variables

VARIABLES	(1)	(2)	(3)	(4)
Δ EUR Repo rate	0.003			0.004
	[0.23]			[0.26]
Δ Dealer Net-Gross ratio		**0.003**		**0.003**
		[2.71]		[2.73]
Δ EURO STOXX Banks			1.62E-05	7.91E-06
			[0.06]	[0.03]
Adj R^2 (%)	-0.06	0.5	-0.08	0.4
# days/observations	1181	1181	1181	1181

Daily Changes **in Total Notional (in bn EUR)** regressed on Dealer-related variables

VARIABLES	(1)	(2)	(3)	(4)
Δ EUR Repo rate	1.347			1.243
	[0.3]			[0.28]
Δ Dealer Net-Gross ratio		0.821		0.821
		[1.33]		[1.32]
Δ EURO STOXX Banks			**0.178**	**0.175**
			[1.76]	[1.73]
Adj R^2 (%)	-0.07	0.05	0.2	0.2
# days/observations	1181	1181	1181	1181

Note: Continuous explanatory variables are measured as daily changes (Δ), where EUR Repo rate is the daily European repo rate, dealer net-gross ratio is a net- to gross-notional ratio for major European dealers and EURO STOXX Banks are the daily closing prices of the sector index taken from Bloomberg. Standard errors are heteroskedasticity robust. T-values are expressed in brackets below. Bold coefficients are significantly different from 0 at the 10% level or higher.

preference", is a significant driver of US Treasury market liquidity in particular in stress periods. We plot the series in Figure 9, which indicates considerable variation with peaks in late 2019 and 2020. Recently, capacity utilisation of swap Dealers seems to be below historical peaks.

Finally, we investigate the impact of generic market stress (VIX) and liquidity commonality effects. In Table 9, we find that neither the VIX measure nor the US treasury liquidity yields any statistically significant results in this specification. The Bund liquidity, on the contrary, shows a significant positive relationship with the price dispersion measure which partly confirms hypothesis 6.

Table 9: Regressions with VIX and Bund Liquidity

Daily Changes **in Price dispersion** regressed on market volatilities			
VARIABLES	(1)	(2)	(3)
Δ VIX	-7.71E-06		
	[-0.05]		
Δ US treasury liquidity		0.002	
		[0.31]	
Δ Bund liquidity			**0.012**
			[2.09]
Adj R^2 (%)	-0.08	-0.06	1
# days/observations	1181	1181	1181

Daily Changes **in Total Notional (in bn EUR)** regressed on market volatilities			
VARIABLES	(1)	(2)	(3)
Δ VIX	0.006		
	[0.09]		
Δ US treasury liquidity		-0.936	
		[-0.41]	
Δ Bund liquidity			-1.982
			[-0.91]
Adj R^2 (%)	-0.08	-0.07	0.02
# days/observations	1181	1181	1181

Note: Continuous explanatory variables are measured as daily changes (Δ), where VIX is the implied volatility in the S&P 500 and US treasury/Bund liquidity resemble bond market liquidity measures taken from Bloomberg. Standard errors are heteroskedasticity robust. T-values are expressed in brackets below. Bold coefficients are significantly different from 0 at the 10% level or higher.

4.6. Multivariate analysis

Concluding the summary of our main econometric results of drivers of liquidity variation, we estimate multivariate regressions with all key explanatory variables, as well as an AR(1)-term to capture possible autocorrelation in the dependent variable. We focus on (changes in) total notional and price dispersion as dependent variables. We further compare the results with multivariate regressions using the first two factors from the principal components analysis described in section 4.2. This comprehensive approach allows us to examine the impact of interactions among explanatory variables and its impact on market liquidity drivers.

Our four multivariate regressions include changes in the EURIBOR 6 Month rate and its square to capture nonlinear effects (cf. section 4.3), the change in total notional to control for overall market activity, the change in the repo rate and changes in Bund liquidity and VIX to capture funding and global market conditions. To capture the positioning and market perception of Dealer banks, we include the changes in Dealer net notional, which were significant in our earlier analysis and bank stock prices rather than Dealer capitalisation which was insignificant. We estimate this specification using HAC standard errors and covariance matrix:

$$\Delta Y_t = \beta_0 + \beta_1\, \Delta EURIBOR6M + \beta_2 \Delta EURIBOR6M^2 + \beta_3\, \Delta TotalNotional + \beta_4\, \Delta RepoRate + \beta_5\, \Delta EUROSTOXXBanks + \beta_6\, \Delta BundLiquidity + \beta_7 \Delta NetGross + \beta_8\, \Delta VIX + \beta_9\, MonPolRegime + \beta_{10}\, \Delta Y_{t-1} + \varepsilon_t$$

$$where\ Y_t \in \{PriceDispersion, TotalNotional, PC1, PC2\}$$

The results are summarised in Table 10.

We find that the liquidity measures react in a nonlinear manner to rate changes and are impacted by Bund liquidity and Dealer positioning. First, price dispersion exhibits a significant negative reaction to squared rate changes. A similar, but statistically insignificant effect is found for price total notional.[55] Second, there is a strong positive relationship between price dispersion and the price-based Bund market liquidity measure also in the multivariate setting. Hence, we confirm commonality in liquidity[56] between two of the most important fixed income instruments in the euro financial markets. Third, also in the multivariate setup Dealer behaviour affects IRS liquidity via positioning also in the multivariate specification, as higher Dealer net notional increases price dispersion.[57] Fourth, total notional increases price dispersion, hence there is a link of liquidity with volume, which may be driven by the behaviour of our variables in 2022. Fifth, we find a significant AR(1) process in both direct measures of trading conditions, hence we observe some persistence in activity and liquidity. Finally, the R^2 coefficient for price dispersion changes exceeds the value for the regression on changes in total notional, indicating that the latter variable contains more noise unrelated to our covariates.

As a second step in our multivariate analysis, we use the first two principal components identified earlier as dependent variables to cross-check the multivariate regression results (Table 10). Overall, we confirm the main findings of rate impact, Dealer activity and commonality in liquidity. First, both PCs are strongly related to total notional. Second, the first PC shows a nonlinear dependence on EURIBOR rates via the significance of the squared change. Third,

[55] In this specification, using the ten-year swap rate instead of the underlying 6Month-EURIBOR rate reduces significance for the Dealer net notional to above 10% for the regression on price dispersion.
[56] See Chordia et al. (2000) for analysis of this concept for the US equity market. Flood et al. (2016) provide evidence of this mechanism in equity and US corporate bond markets.
[57] We also investigate economic significance. Given the results of Duffie et al. (2023), we focus on impact of Dealer positioning. Here, we find that an 1SD increase in changes of Dealer net-gross ratio leads to an increase in changes of price dispersion by around 4% of SD. This weak impact may be due to the short sample (4 years) and the linear regression specification.

Bund liquidity has a significant positive effect on both PCs. Fourth, Dealer activity has a direct effect on the second PC. Finally, the highest R^2 is observed for PC1 (.64), whereas the coefficient for the second factor is around .3. This also shows the benefits of aggregating the very heterogeneous information in our seven underlying liquidity measures into two series via principal component.

A comparison of our findings with the recent literature on liquidity determinants for bonds and CDS shows that many results are shared with other market segments. Feldhuetter and Poulsen (2018) also find that Dealer inventory is the most important driver of the variation in bid-ask spreads of US corporate bonds. Adrian et al. (2022) find that announcements, volatility, and activity of high-frequency traders[58] are correlated with US Treasury market liquidity. Finally, in an analysis of bonds and CDS, Aramonte and Szerszen (2020) highlight the importance of cross-market liquidity.

Table 10: Multivariate regressions

VARIABLES	(1) Price dispersion	(2) Total Notional	(3) PC 1	(4) PC 2
Δ EURIBOR 6M rate	0.024	17.739	2.804	-3.672
	[0.52]	[0.93]	[0.75]	[-0.87]
Δ EURIBOR 6M rate - squared	**-1.084**	-484.491	**-104.260**	-4.299
	[-1.66]	[-1.52]	[-1.75]	[-0.06]
Δ Total Notional	**0.0004**	-	**0.218**	**-0.082**
	[6.84]	[-]	[31.93]	[-12.57]
Δ EUR Repo rate	0.007	4.052	-0.182	-0.189
	[0.68]	[0.83]	[-0.17]	[-0.15]
Δ EURO STOXX Banks	0.000	0.170	0.003	0.006
	[-0.14]	[1.62]	[0.14]	[0.26]
Δ Bund liquidity	**0.015**	-1.474	**1.779**	**2.341**
	[2.84]	[-0.77]	[3.22]	[3.51]
Δ Dealer Net-Gross ratio	**0.002**	0.488	0.146	**0.246**
	[1.83]	[0.82]	[1.25]	[1.94]
Δ VIX	0.000	0.077	0.013	-0.013
	[0.56]	[1.04]	[0.91]	[-0.93]
MonPol environment dummy	0.002	0.519	0.124	0.090
	[0.92]	[0.6]	[0.56]	[0.3]
AR(1)	**-0.373**	**-0.400**	**-0.200**	**-0.414**
	[-7.2]	[-12.32]	[-7.8]	[-8.25]
# days/observations	1180	1180	1179	1179
Adj R^2 (%)	22.3	15.8	63.8	32.3

Note: MonPol environment is a dummy variable indicating the change of the mon. policy regimes with the first rate hike on the 22nd July 2023. AR(1) is an autoregressive term of the respective dependent variable. Standard errors are heteroskedasticity robust. T-values are expressed in brackets below. Bold coefficients are significantly different from 0 at the 10% level or higher.

[58] IRS trading is mostly conducted by banks rather than trading firms.

5. Robustness checks and further empirical results

5.1. Sub-sample analysis according to ECB monetary policy environment

We first divide the sample into two subperiods, before and after the ECB tightened monetary policy. As this change occurred in July 2022, our second subperiod is relatively short (89 days), whereas the first subperiod contains 1091 days. Nevertheless, due to the importance of monetary policy, as documented above, this subsample analysis can still shed light on the role of the different factors in the two monetary policy regimes. Table 11 contains the results for the two subperiods using changes in price dispersion as dependent variable.

Table 11: Multivariate regressions for two subsample periods

VARIABLES	(1) Sample: 1/09/2018 to 7/21/2022	(2) Sample: 7/22/2022 to 11/22/2022
Δ EURIBOR 6M rate	-0.002	0.047
	[-0.03]	[0.53]
Δ EURIBOR 6M rate - squared	-0.623	-1.198
	[-0.9]	[-0.98]
Δ Total Notional	**0.0004**	0.0002
	[8.31]	[0.81]
Δ EUR Repo rate	0.008	0.007
	[0.36]	[0.59]
Δ EURO STOXX Banks	0.0001	-0.003
	[0.32]	[-1.43]
Δ Bund liquidity	**0.010**	**0.023**
	[2.04]	[1.71]
Δ Dealer Net-Gross ratio	**0.002**	0.003
	[2.03]	[0.21]
Δ VIX	0.0001	**-0.003**
	[1.05]	[-1.69]
AR(1)	**-0.331**	**-0.482**
	[-5.41]	[-4.46]
Adj R^2 (%)	19.2	28
# days/observations	1091	89

Note: First rate hike on 22nd July 2023 constitutes start of (2) After Mon. Policy tightening. Standard errors are heteroskedasticity robust. T-values are expressed in brackets below. Bold coefficients are significantly different from 0 at the 10% level or higher.

The main differences in the two subsamples relate to the roles of total notional and Dealer net notional, both of which are significant in the first period, but not after the change in the monetary policy stance (albeit the time frame is relatively small). In the second period, the main significant covariate for price dispersion is Bund liquidity, confirming the commonality in liquidity across monetary policy conditions.

5.2. Tests for seasonality in the time series of liquidity

We further investigate whether market activity and liquidity measures would be affected by seasonal moves around typical reporting periods by regressing price dispersion and total notional on end-of-month, end-of-quarter or end-of-year indicator variables.[59] Neither activity, nor liquidity seem to be affected by seasonality as none of the coefficients in Table 12 are significant. However, all coefficients are negative, which implies that at typical reporting dates, market activity is actually lower.

5.3. Analysis for swaps with 5-year maturity

As mentioned above, trade data is subject to a considerable number of outliers and data errors due to misreporting. Therefore, we also construct the liquidity measures used above for a second actively traded contract, the EURIBOR 6M swap with a five year maturity. This contract is among the three key contracts outside of the money market and should, thus, be a useful counterfactual to the EURIBOR 6M 10Y swap rate.

In Table 13, we run a correlation analysis between the levels of activity and liquidity measures for contracts with 5 years and 10 years maturity. Table 14 shows the correlations between the daily changes of the measures for the two contracts. The levels of the metrics have a particularly high correlation with their 5-year maturity counterparts, indicating largely equivalent results. The pattern is similar in Table 14; however, with lower correlation values.

In Table 15 we repeat the multivariate regressions using the specification of Table 10 above. As lefthand side variables we use price dispersion and total notional. Results are slightly weaker than the ten-year analysis in terms of statistical significance. In particular, the squared rate has almost the same coefficient, but is no longer significant. A similar observation is valid

[59] See Du et al. (2018) who document that deviations from covered interest rate parity are particularly strong for forward contracts that appear on banks' balance sheets at the end of the quarter.

for Dealer net-gross ratios, while the opposite is true for bank stock returns (similar coefficient but significant in the 5 year specification).

Table 12: Seasonality regressions

Daily Changes **in Price dispersion** regressed on calendar dummies

VARIABLES	(1)	(2)	(3)
End-of-month indicator	0.0005		
	[0.34]		
End-of-quarter indicator		0.003	
		[1.18]	
End-of-year indicator			0.003
			[0.53]
Adj R^2 (%)	-0.07	0.02	-0.06
# days/observations	1181	1181	1181

Daily Changes **in Total Notional (in bn EUR)** regressed on calendar dummies

VARIABLES	(1)	(2)	(3)
End-of-month indicator	-1.097		
	[-1.39]		
End-of-quarter indicator		-1.209	
		[-1.02]	
End-of-year indicator			-3.917
			[-1.14]
Adj R^2 (%)	0.09	-0.01	0.1
# days/observations	1181	1181	1181

Note: All explanatory variables are dummies controlling whether a day is the last day of the month, quarter or year. Standard errors are heteroskedasticity robust. T-values are expressed in brackets below. Bold coefficients are significantly different from 0 at the 10% level or higher.

Table 13: Contemporaneous correlations – Levels

10y / **5y**	Price disp.	Price impact	Roll	Total Notional	Nr. Trans-actions	Avg. No-tional	Nr. Cpties
Price dispersion	0.874						
Price impact		0.705					
Roll estimators			0.839				
Tot. Notional				0.613			
Nr. Transactions					0.812		
Avg. Notional						0.279	
Nr. Counterparties							0.669

Note: Total notional is measured in billion EUR and avg. notional in million EUR. The seven measures on the top belong to the 10y maturity contract, while the variables at the left belong to the 5y maturity contract.

Table 14: Contemporaneous correlations – Differences

10y / **5y**	Price disp.	Price impact	Roll	Total Notional	Nr. Trans-actions	Avg. No-tional	Nr. Cpties
Price dispersion	0.604						
Price impact		0.561					
Roll estimators			0.634				
Tot. Notional				0.408			
Nr. Transactions					0.546		
Avg. Notional						0.199	
Nr. Counterparties							0.385

Note: Total notional is measured in billion EUR and avg. notional in million EUR. The seven measures on the top belong to the 10y maturity contract, while the variables at the left belong to the 5y maturity contract.

Table 15: Multivariate regressions - 5y Maturity contracts

VARIABLES	(1) Price dispersion	(2) Total Notional
Δ EURIBOR 6M rate	0.044	0.777
	[0.94]	[0.05]
Δ EURIBOR 6M rate - squared	-1.186	-204.700
	[-1.39]	[-0.71]
Δ Total Notional	**0.0003**	-
	[4.95]	[-]
Δ EUR Repo rate	-0.004	-0.340
	[-0.29]	[-0.07]
Δ EURO STOXX Banks	**0.000**	0.160
	[-1.82]	[1.57]
Δ Bund liquidity	**0.020**	0.265
	[3.38]	[0.16]
Δ Dealer Net-Gross ratio	0.000	-0.123
	[0.28]	[-0.3]
Δ VIX	0.000	0.045
	[-0.36]	[0.78]
MonPol environment dummy	0.001	-0.004
	[0.51]	[-0.00]
AR(1)	**-0.445**	**-0.407**
	[-8.35]	[-10.71]
# days/observations	1180	1180
Adj R^2 (%)	27.6	16.2

Table 16: Multivariate regressions with asymmetry dummies

VARIABLES	(1) Price dispersion	(2) Price dispersion	(3) Price dispersion	(4) Price dispersion	(5) Price dispersion
Δ EURIBOR 6M rate	0.036	0.028	0.029	0.031	0.029
	[0.69]	[0.62]	[0.63]	[0.68]	[0.64]
Δ EURIBOR 6M rate - squared	-0.952	-0.887	-0.887	-0.859	-0.901
	[-1.43]	[-1.43]	[-1.43]	[-1.37]	[-1.47]
Δ Total Notional	**0.0004**	**0.0004**	**0.0004**	**0.0004**	**0.0004**
	[6.92]	[6.92]	[6.92]	[6.72]	[6.94]
Δ EUR Repo rate	0.008	0.008	0.008	0.007	0.008
	[0.81]	[0.81]	[0.81]	[0.72]	[0.83]
Δ EURO STOXX Banks	-1.98E-05	-2.28E-05	-4.92E-05	-4.48E-05	-2.66E-05
	[-0.08]	[-0.06]	[-0.19]	[-0.18]	[-0.11]
Δ Bund liquidity	**0.015**	**0.015**	**0.015**	**0.015**	**0.015**
	[2.76]	[2.76]	[2.76]	[2.75]	[2.8]
Δ Dealer Net-Gross ratio	**0.002**	**0.002**	**0.002**	**0.002**	**0.003**
	[1.85]	[1.83]	[1.82]	[1.8]	[2]
Δ VIX	8.32E-05	8.14E-05	8.88E-05	8.29E-05	7.86E-05
	[0.6]	[0.58]	[0.64]	[0.59]	[0.57]
Indicator for pos. Δ EURIBOR 6M rate	-0.0004				
	[-0.55]				
Indicator for neg. Δ EURO STOXX Banks		2.03E-06			
		[0.00]			
Indicator for neg. Δ Intermediary capital ratio			-0.0002		
			[-0.3]		
Indicator for pos. Δ CDS itraxx EU Financials				-0.0002	
				[-0.29]	
Indicator for pos. Δ Buyer notional					-0.001
					[-0.95]
AR(1)	**-0.372**	**-0.372**	**-0.372**	**-0.369**	**-0.372**
	[-7.26]	[-7.29]	[-7.27]	[-7.17]	[-7.3]
# days/observations	1180	1180	1180	1180	1180
Adj R^2 (%)	22.1	22.1	22.1	21.3	22.1

5.4. Tests for asymmetric effects

In this subsection we test the responsiveness of liquidity to several asymmetric effects, namely:

- Increases in the EURIBOR 6M rate,
- Decreases in bank capital,

- Increases in funding costs,
- And increases in the share of buyers in our sample.

We do this by including dummy variables of the respective events in our multivariate specification and regressing them on price dispersion. We do not find any significant relationship between those events and price dispersion (Table 16). Additionally, the other explanatory variables are not impacted by including these indicator variables and the variance in price dispersion explained by the explanatory variables remains significant. Finally, Table 17 analyses robustness with Buyer - Seller Notional as an alternative explanatory variable to capture demand-supply imbalances. This measure of market positioning is positively linked to total notional and the first principal component (also a function of the former).

Table 17: Robustness with Buyer - Seller Notional

VARIABLES	(1) Price dispersion	(2) Total Notional	(3) PC 1	(4) PC 2
Δ EURIBOR 6M rate	0.027	17.080	4.429	-4.683
	[0.56]	[0.89]	[0.78]	[-1.1]
Δ EURIBOR 6M rate – squared	**-1.155**	-458.420	-153.150	23.986
	[-1.66]	[-1.41]	[-1.64]	[0.34]
Δ Buyer - seller notional	3.86E-13	**2.72E-10**	**7.18E-11**	6.61E-12
	[1.55]	[2.21]	[2.03]	[0.24]
Δ EUR Repo rate	0.007	3.854	0.507	-0.284
	[0.68]	[0.81]	[0.33]	[-0.24]
Δ EURO STOXX Banks	6.48E-05	**0.183**	0.042	-0.011
	[0.26]	[1.72]	[1.21]	[-0.5]
Δ Bund liquidity	**0.015**	-1.622	**1.439**	**2.496**
	[2.85]	[-0.85]	[2.36]	[3.35]
Δ Dealer Net-Gross ratio	0.001	-0.509	-0.017	0.145
	[0.55]	[-0.66]	[-0.08]	[0.83]
Δ VIX	0.0001	0.076	0.032	-0.018
	[0.76]	[1.02]	[1.26]	[-1.14]
MonPol environment dummy	0.002	0.501	0.173	0.064
	[0.97]	[0.59]	[0.68]	[0.2]
AR(1)	**-0.408**	**-0.396**	**-0.429**	**-0.429**
	[-7.79]	[-12.27]	[-13.53]	[-8.23]
# days/observations	1180	1180	1179	1179
Adj R^2 (%)	18.7	16.2	19.8	20.8

Table 18: Summary of results

Hyp. Nr.	Hypothesis	Empirical evidence
H1	The linkages between activity and price-based measures of liquidity change in the crossection.	Principal component analysis and weights of PCA factors 1, 2 and 3
H2	Monetary policy affects IRS activity and liquidity	Impact of monetary policy on activity
H3	IRS activity and liquidity are driven by interest rate risk hedging.	Impact of rates via interaction on price dispersion and PC1 with squared rate changes / volatility
H4	Higher funding costs reduce market liquidity	Not confirmed directly with regression analysis (but some indirect evidence of co-movement of IMs and price dispersion at a monthly frequency)
H5 A & B	IRS activity and liquidity are linked to Dealer behaviour	Confirmed via dependence of price dispersion on Dealer net notional
H6 A & B	IRS activity and liquidity are to global investor sentiment and liquidity in related markets	Confirmed via dependence of PC1, PC2 and price dispersion on Bund illiquidity measures

6. Conclusions

Overall, in our sample period, the activity and liquidity of EURIBOR IRS has exhibited material volatility and undergone significant changes, which are to large degree related to the changes in the monetary policy stance.

In our empirical analysis, we find that IRS liquidity deteriorates with monetary policy events and rising Dealer positioning, Bund illiquidity and squared absolute rate changes. Our detailed results are summarised below together with our six hypotheses outlined earlier. For the interpretation of the results, an important limitation of our analysis is the unbalanced size of the sample in the two subperiods, as the QT period accounts for a relatively short period of only 89 days.

Monitoring IRS activity and liquidity is critical for central banks, as both directly affect the ability of commercial banks to deal with the currently volatile interest rate environment. We believe that our work and the set-up can facilitate the establishment of such monitoring.

At the same time, a range of additional elements need to be in place in order to allow for a meaningful monitoring arrangement. In addition to general issues related to data quality and data availability, further key considerations to be taken into account are:

- The nature of the instrument (bond vs future CDS vs IRS), which affects the pay-off, margining and mark-to-market valuation,
- The market microstructure (OTC for bonds and swaps vs. CLOB for futures),

- The role of bank and non-bank Dealers and their willingness/ability to provide liquidity in stress,
- Liquidity dynamics (as measured e.g., by price dispersion or Roll) vs activity (as measured by notional or number of trades)

Against this backdrop, any interpretation of the evolution of market liquidity must consider the effects of both demand for market liquidity (which is largely driven by banks and asset managers who react to interest rate changes, bank risk appetite and overall demand for hedging) and supply, which is provided by Dealers (whose intermediation capacity is driven e.g., by their capital situation).

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Appendix

Table A. 1: Illustration of filtering for 28/11/2022

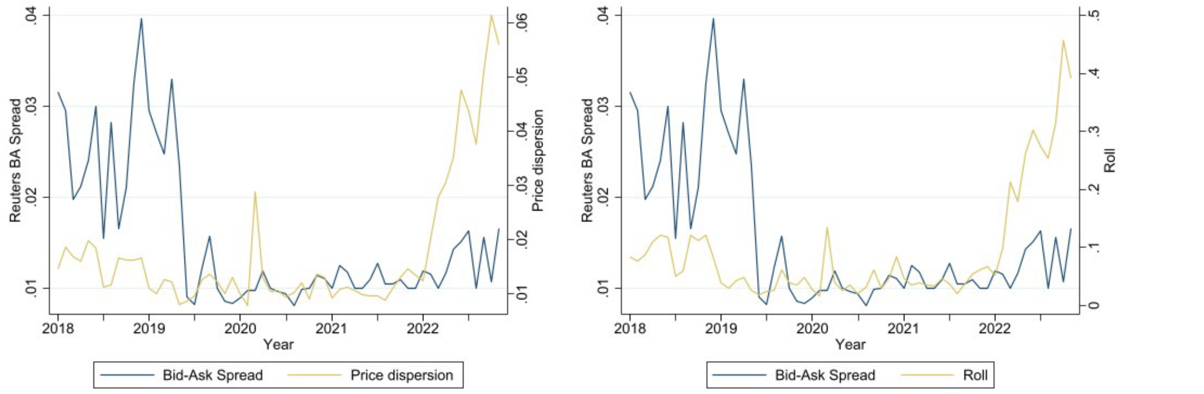
Filtering Stages	Nr. Observations
Start: EURIBOR 6M 10Y trades	968
Plausible LEIs (= 20 digits)	968
Plausible Notionals (EUR 500,000 <= Notional <= EUR 1 bn)	769
Plausible Maturity (Today <= Maturity < 2050)	769
Plausible Execution Date (1970 <= Execution < Today)	769
No intragroup transactions	760
Correct trade side classification	760
Price filtering (within daily quote range + 5% interval)	499
FINAL: CCP cleared transactions only	437

Table A.2: Contemporaneous correlations - Levels

	Price disp.	Price impact	Roll	Total Notional	Nr. Transactions	Avg. Time Diff.	Avg. Notional	Nr. Cpties
Price dispersion	1.000							
Price impact	0.676	1.000						
Roll estimator	0.875	0.814	1.000					
Total Notional	0.481	0.278	0.449	1.000				
Nr. Transactions	0.511	0.365	0.476	0.874	1.000			
Avg. Time Difference	-0.376	-0.234	-0.352	-0.660	-0.714	1.000		
Avg. Notional	0.018	-0.094	0.032	0.361	-0.093	-0.012	1.000	
Nr. Counterparties	0.411	0.320	0.366	0.636	0.773	-0.486	-0.173	1.000

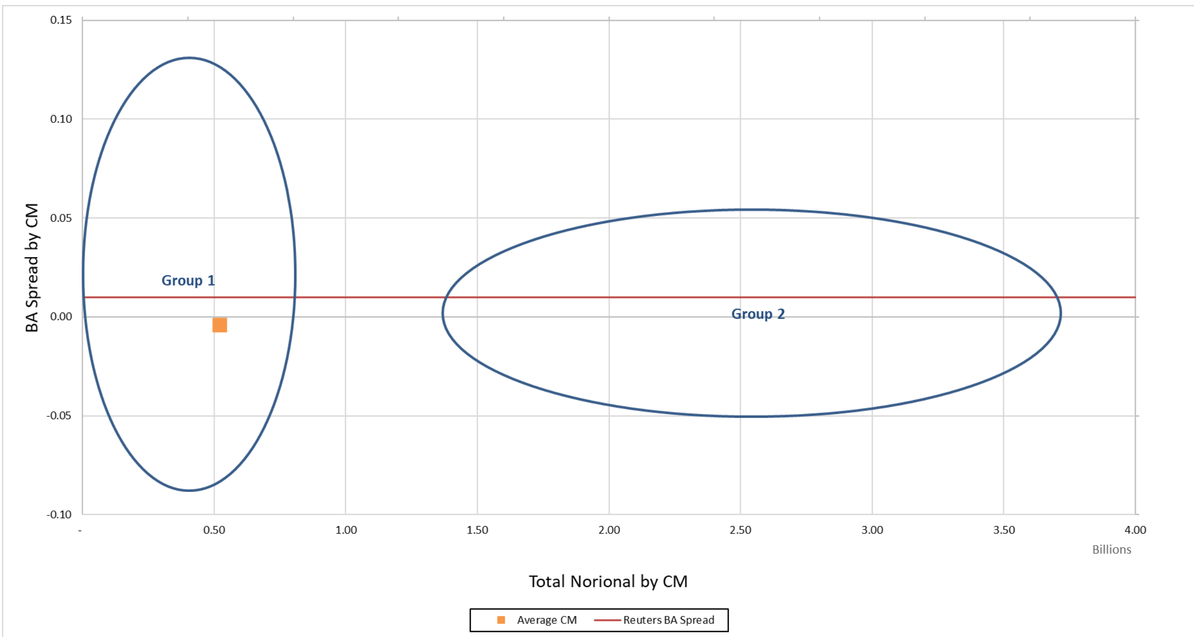
Note: Average time difference is measured in minutes, total notional in billion EUR and avg. notional in million EUR.

Figure A.1: Reuters Bid-Ask Spread in comparison with liquidity measures



Note: Monthly aggregation of daily EURIBOR 6M 10Y Bid-Ask spread from Reuters as well as the price dispersion and roll measure. Bid-Ask spread is calculated by subtracting the end-of-day bid price from the end-of-day ask price.

Figure A.2: Comparison of CM-level Bid Ask spreads to their trading volume



Note: Average Bid-Ask spread by CM in comparison to total daily notional by CM (date not shown due to data confidentiality). Average Bid-Ask spread is calculated by subtracting the average buy price from the average sell price for all 24 CMs that were active on both sides, i.e. that were selling and buying on that day. Due to data confidentiality, the individual CMs are aggregated to two groups. While Group 1 mostly includes smaller banks and banks with low activity on the respective day, Group 2 comprises a set of Dealers. The red line indicates the Reuters Closing Bid-Ask spread (1 bp). The average over all 24 CMs is included as additional benchmark in gold.

Figure 1: Summary of liquidity measures

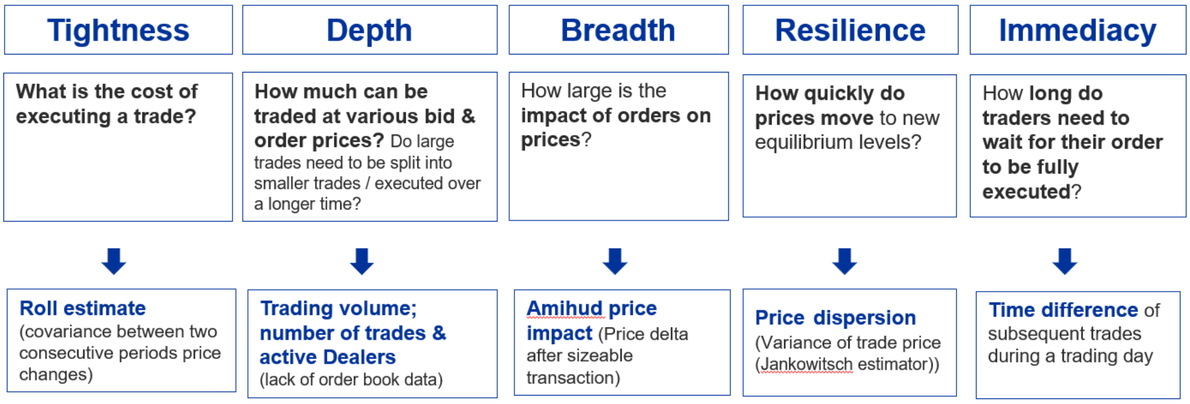
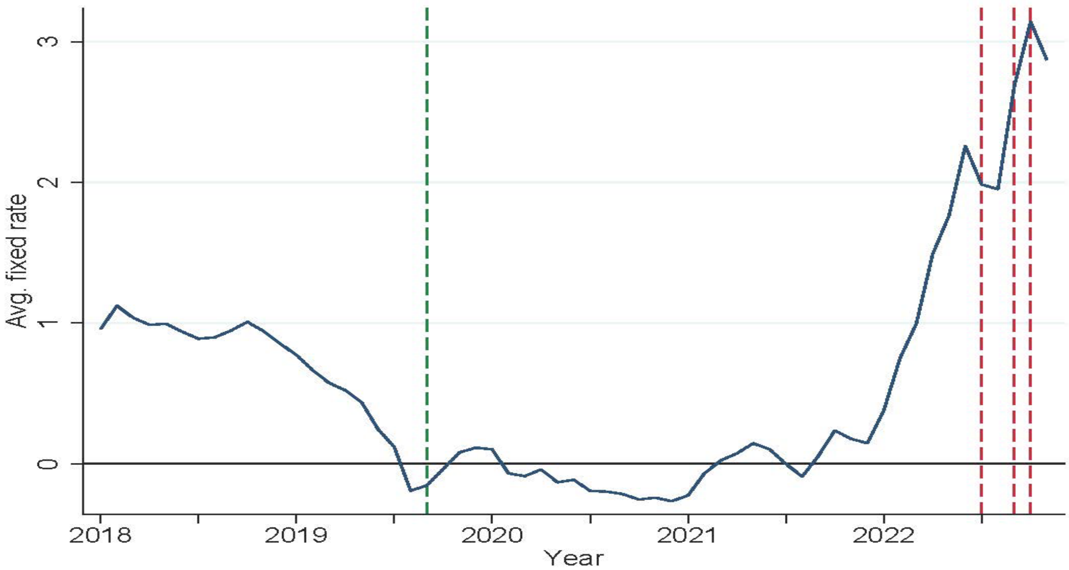
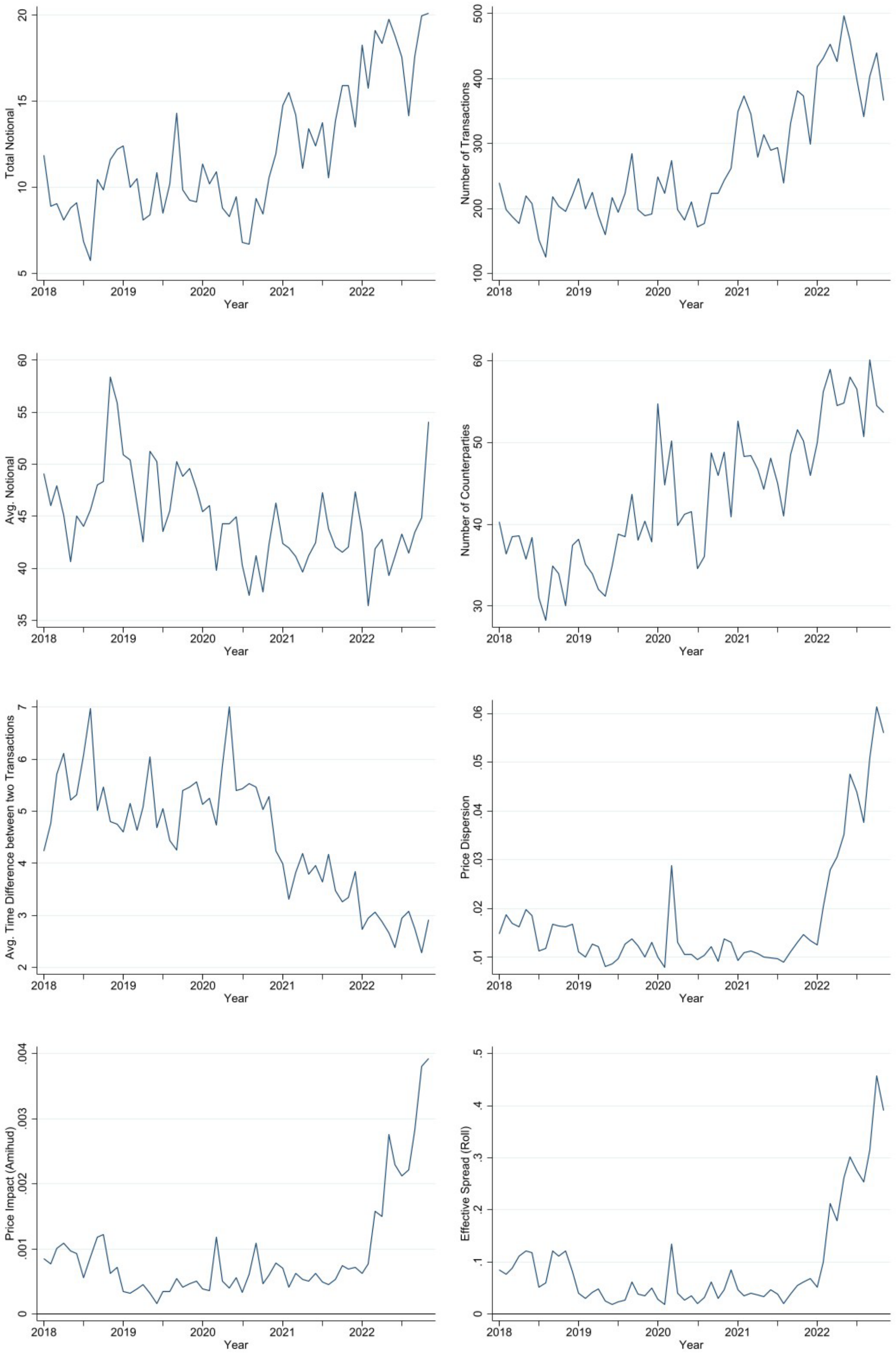


Figure 2: Time series of swap rate



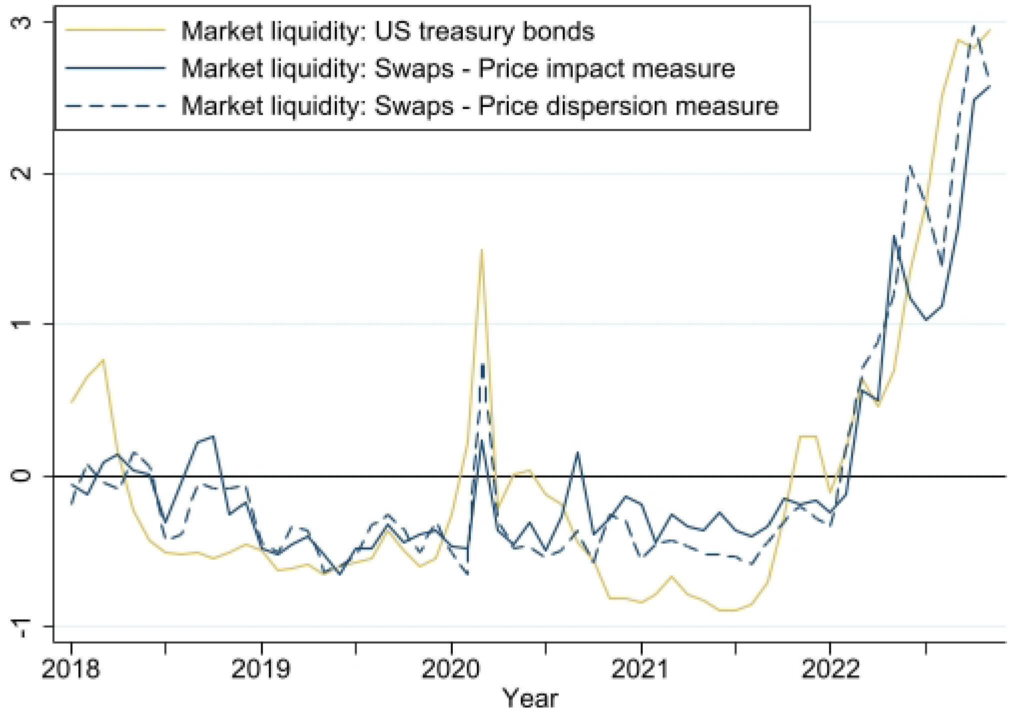
Note: Monthly aggregation; Red (green) vertical lines represent ECB monetary policy tightening (loosening).

Figure 3: Time series of activity and liquidity measures



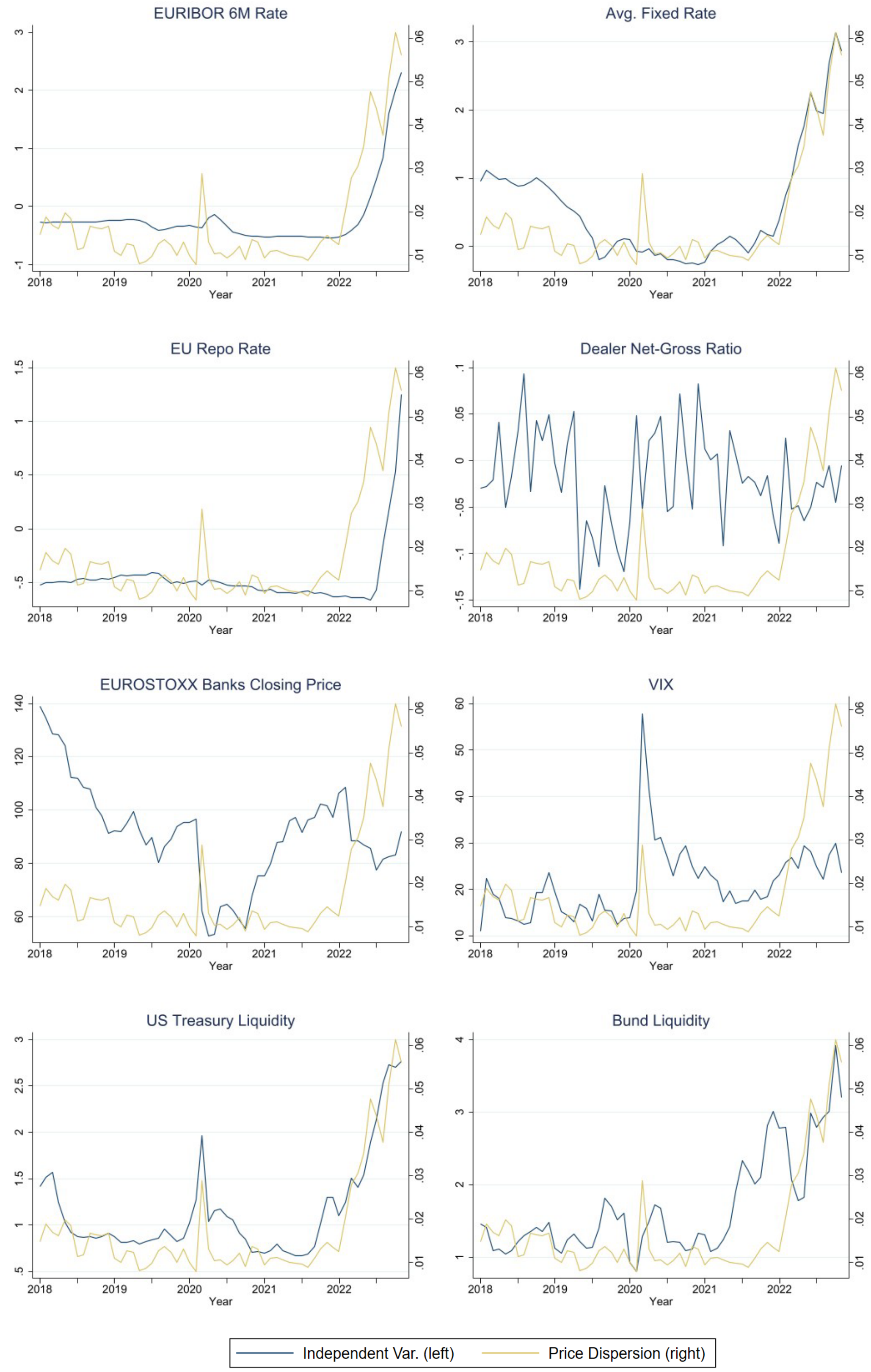
Note: Monthly aggregation of daily activity and liquidity measures. While total notional is measured in bln EUR, average notional is measured in mln EUR and average time difference between two transactions is measured in minutes

Figure 4: Comparison of price-based swap liquidity measures with US Treasury liquidity



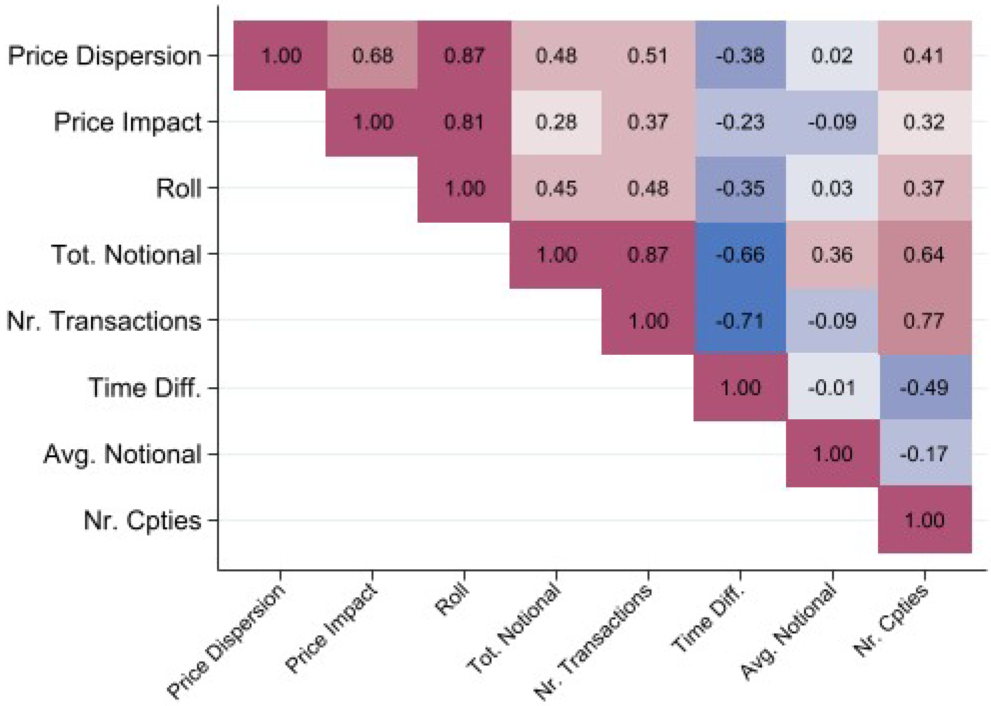
Note: This Figure shows the evolution of three market liquidity measures between 2018 and the end of 2022. Two measures (Price dispersion and price impact measure) illustrate market liquidity in the interest rate swap market (new trades in EURIBOR 6M - 10 year maturity swaps per business day). The third measure is a liquidity index for US Treasury government bonds. All measures are standardized, monthly averaged daily aggregations. Source: EMIR; authors calculation; Bloomberg

Figure 5: Time series of main explanatory variables



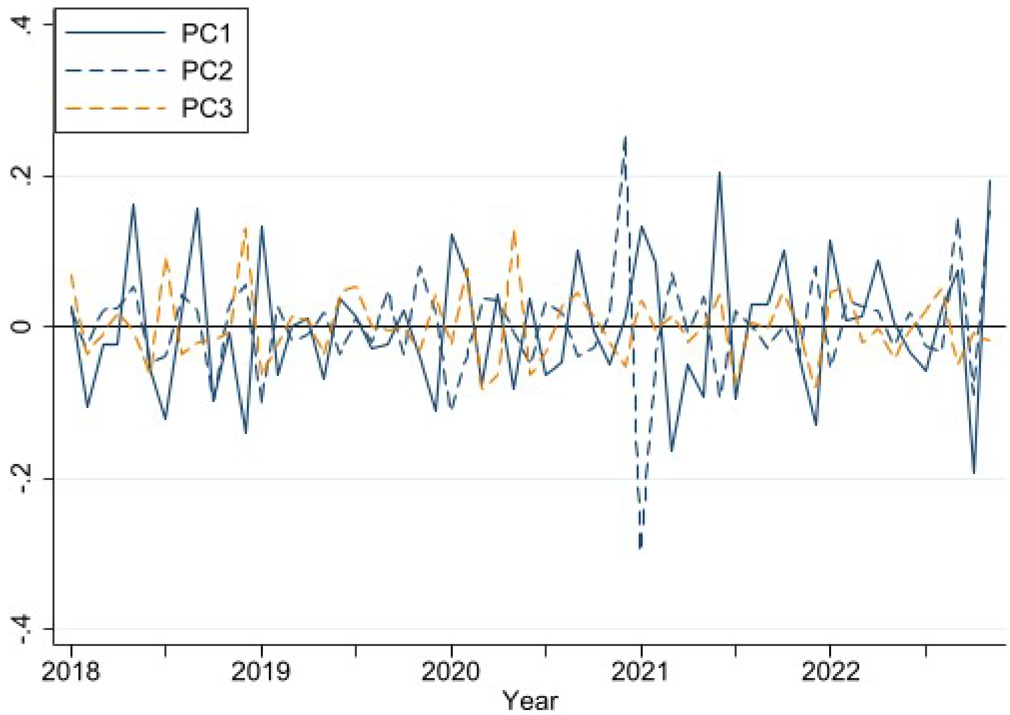
Note: Monthly aggregation of daily liquidity measures and other explanatory variables. The right axis is always dedicated to price dispersion (in yellow), while the left one describes the respective independent (right-hand side) variable. EURIBOR, the average fixed rate and the repo rate are all denominated in Percent.

Figure 6: Results of correlation analysis



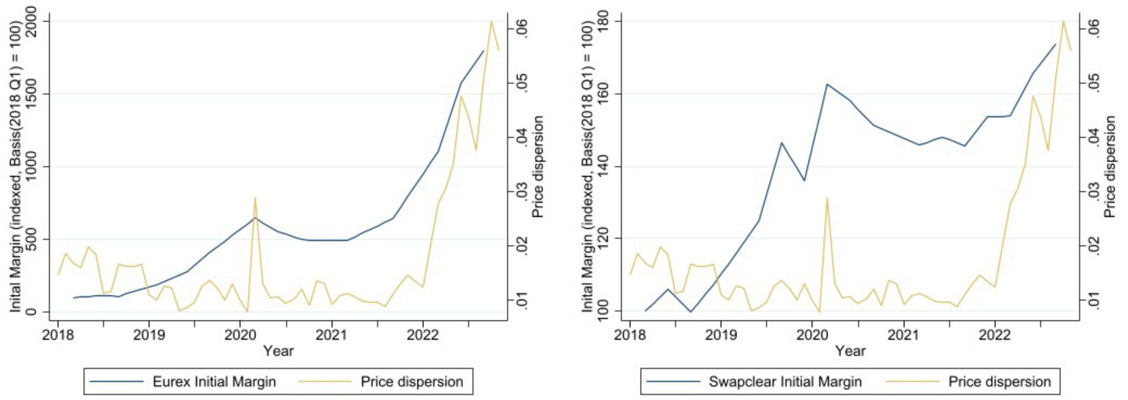
Note: The figure visualizes the correlation between the eight liquidity measures discussed in the main text. Red colouring depicts positive correlation while blue colours highlight negative correlation. Average time difference is measured in minutes, total notional in billion EUR and avg. notional in million EUR.

Figure 7: Time series of first three principal components



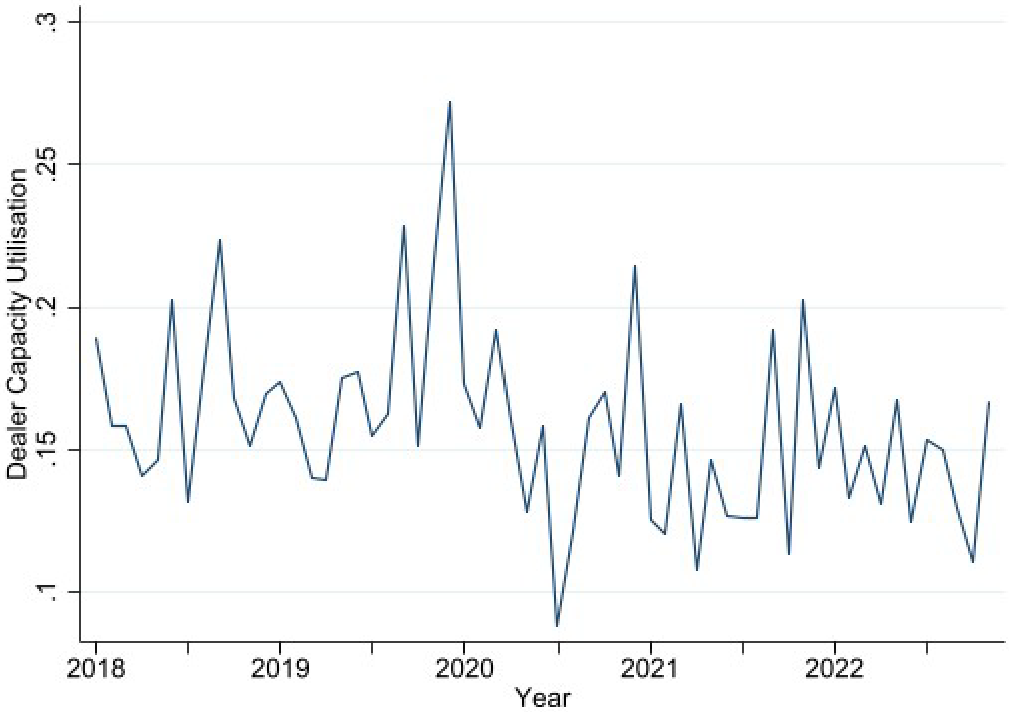
Note: Monthly aggregation of daily principal component values. Principal components are constructed from standardized day-over-day changes of seven activity and liquidity measures: Price dispersion and impact, Roll, total notional, avg. time difference between two transactions and the number of transactions as well as of counterparties.

Figure 8: Initial Margin requirements for two CCPs and price dispersion



Note: Time series of quarterly Eurex (left, OTC IRS segment only) and LCH Ltd. (right, Interest rates segment only) Initial Margin (IM) requirements is taken from the public quantitative disclosure data (Disclosure reference 6_1_1 Total figures) and interpolated to monthly values. For comparability, we indexed the IM evolution to Q1 2018 which we normalized to 100. Monthly aggregation of daily price dispersion data.

Figure 9: Evolution of Dealer capacity



Note: Monthly aggregation of daily dealer capacity utilisation. Dealer capacity utilisation is calculated by dividing daily absolute dealer net-notional by the maximum absolute dealer net-notional on a single day in our sample.

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