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Liquidity resilience in the UK gilt futures market: evidence from the order book

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Abstract

We analyse liquidity dynamics in the UK long gilt futures market. We use a novel order book dataset to assess liquidity resilience to sources of pressure such as policy operations or episodes of financial distress. Our results provide evidence in favour of resilience. We further show that this resilience does not come at the expense of a negative liquidity trend. These findings mitigate the potential trade-off faced by policy makers such as regulators in maintaining an adequate level of liquidity in the UK long gilt futures market.

Key words: Gilt future, liquidity, order book, resilience.

JEL classification: G10, G14, G18.

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1 Introduction

The concept of market liquidity is not a new one. By the 1930s, elements of volume, timing and transaction cost were considered key in defining liquidity (Fernandez, 1999). In a more recent definition, Liu (2006) suggests that liquidity in an asset market is the "...ability to trade large quantities quickly at low cost with little price impact".

While clearly important for those actively trading, market liquidity is related to financial liquidity in a broader sense. The liquidity of markets is linked to funding liquidity — the ability of solvent institutions to make payments on time. While we may think of banks when we worry about funding liquidity, Nikolaou (2009) notes that the same issues can arise for firms, investors and traders. From a central bank's point of view, policymakers have been keen to emphasize that "market liquidity has economic benefits where it is reliable and resilient to stress" (Bank of England, 2016a).

Perhaps the most notable facet of market liquidity is that it can be elusive. There is much evidence of markets being liquid during normal conditions, only for liquidity to dry up when traders need it most. As such there exists a substantial empirical literature looking at liquidity resilience during periods of market stress. In Bouveret et al. (2015), for example, IMF staff describe how a sudden reduction in the depth of order books seems to have led to the October 2014 "Flash Rally" in US Treasuries. Adrian et al. (2016) present three case studies: the 2013 US "taper tantrum", in which fixed income markets sold off in anticipation of the Fed tapering its asset purchases; the October 2014 "Flash Rally"; and the liquidation of Third Avenue's Focused Credit Fund in December 2015.

A further concern is that market liquidity may have deteriorated in certain markets due to interventions such as the 2010 Dodd-Frank Act and the Basel III regulatory framework (Adrian et al., 2016). These regulatory interventions may make the financial system more resilient to stress at the expense of reducing liquidity in normal times. Policy makers may thus face a potential trade-off, the extent of which needs to be evaluated.

This paper contributes to the literature on market liquidity events by studying liquidity resilience in the UK gilt futures market. To the best of our knowledge, this topic has not received attention by the literature. We address two policy questions: whether market liquidity is resilient to stress; and whether resilience comes at the cost of deterioration in liquidity during normal times. This paper is therefore unique in terms of market of interest and provides previously missing information from a policy standpoint. Our work comprises four sequential building blocks: the UK gilt futures data; the choice of liquidity measure; the overall empirical evidence on market liquidity; and the study of specific episodes.

We measure liquidity in the UK gilt futures market through limit order book data. This makes our study different from the majority of existing contributions, which use less informative transaction-level data to construct liquidity metrics (see Goyenko et al. (2009) and Schestag et al. (2016), and references therein). Our work relates to Gomber et al. (2011) and Şensoy (2015), which both employ order book data. The former studies liquidity in the German equity market and the latter looks at the Turkish stock exchange.

As in Gomber et al. (2011) and Şensoy (2015), our data allow us to gauge market liquidity using the full depth of the order book. We motivate the selection of our preferred metric by comparing it to other measures applicable to order book data (Roncalli and Zheng, 2014). Through appropriate statistical tools, we empirically show that neglecting the information from the full order book may lead to inaccurate evaluation of market liquidity resilience.

Using our preferred metric, we provide an overview of liquidity dynamics over the period of interest. This allows us to assess whether liquidity has deteriorated in normal times. We describe liquidity level and liquidity risk (Adrian et al., 2016), and we measure the degree of comovement between market liquidity and funding liquidity (Brunnermeier and Pedersen, 2008).

Finally, we conduct a series of case study analyses to assess liquidity resilience in the UK gilt futures market. We do so by considering two classes of event. The first comprises Asset Purchase Facility (APF) gilt auctions. Christensen and Gillan (2016) investigates how the Federal Reserve's second Quantitative Easing (QE) programme affected market liquidity over its entire duration. We are interested in how UK long gilt futures market liquidity behaves around selected auctions. The second class of event relates to specific episodes of financial market stress that occurred during the time period covered by our data. Namely, the Swiss franc de-peg and the UK European Union membership referendum. To the best of our knowledge, no existing study has looked at the links between these events and the UK gilt futures market.

Our results can be summarised as follows:

- We show that long gilt futures liquidity does not worsen over the period of interest. This result is in line with the conclusions of Financial Conduct Authority (2016) in relation to UK corporate bonds.
- We document that a diminishing level of market liquidity is generally accompanied by an increase in liquidity volatility Adrian et al. (2016).
- Based on the theoretical motivation advanced in Brunnermeier and Pedersen (2008), we provide empirical evidence that market liquidity and funding liquidity are positively correlated, the latter being measured as in Bicu et al. (2016). This is relevant for

policymakers; Bank of England (2014) views market liquidity and funding liquidity from a macro-financial perspective as potential causes of systemic risk.

- Finally, gilt futures market liquidity shows evidence of resilience during the episodes we consider: it is not affected by APF auctions; the effect of the Swiss franc de-peg lasted only for a few hours; and the pressure induced by the outcome of the EU referendum disappeared within two trading days. Although these episodes may not be ideal tests — a flash crash might reveal more — they are informative about market liquidity resilience to adverse shocks.

Our results lead to the conclusion that liquidity in the UK long gilt futures market is resilient to the adverse shocks we consider. This resilience does not come at the expense of a negative liquidity trend. We find no evidence of a trade-off between liquidity provision during episodes of distress and during normal times. Although we did not formally analyse causality, from our results we conjecture that market liquidity resilience is the result of adequate funding liquidity.

The remainder of the paper is organised as follows. Section 2 provides an introduction to the UK long gilt futures market. Section 3 describes the data. Section 4 motivates the choice of the liquidity measure used throughout the paper. Section 5 provides results about liquidity trends and liquidity risk over the available sample period. Section 6 looks at the linkages between market liquidity and funding liquidity. Section 7 assesses the effect of calendar trading on market liquidity. Section 8 presents case studies on market liquidity events. Section 9 concludes.

2 The UK long gilt futures market

This section introduces the UK long gilt futures market. Sections 2.1 to 2.4 describe the order book, the exchange on which futures are traded, the contract specification, and calendar spread trading, respectively.

2.1 Limit order books

Financial futures are contracts that oblige the buyer to purchase an asset at a predetermined future date and price. Likewise, the seller is obliged to take the other side of the trade. Futures may result in physical delivery or cash settlement. They may be traded in the secondary market so that any obligation is transferred to another party.

A future may be thought of as a standardised forward contract. It is this standardisation that allows futures to be traded on exchanges — effectively a marketplace and central counterparty between buyers and sellers. Intentions of buyers and sellers are represented on the exchange as orders to trade. These orders are aggregated by the exchange and form a *limit order book*. An algorithm matches orders based on price and time priority so that trades may occur. Figure 1 shows a schematic illustration of a limit order book.[1]

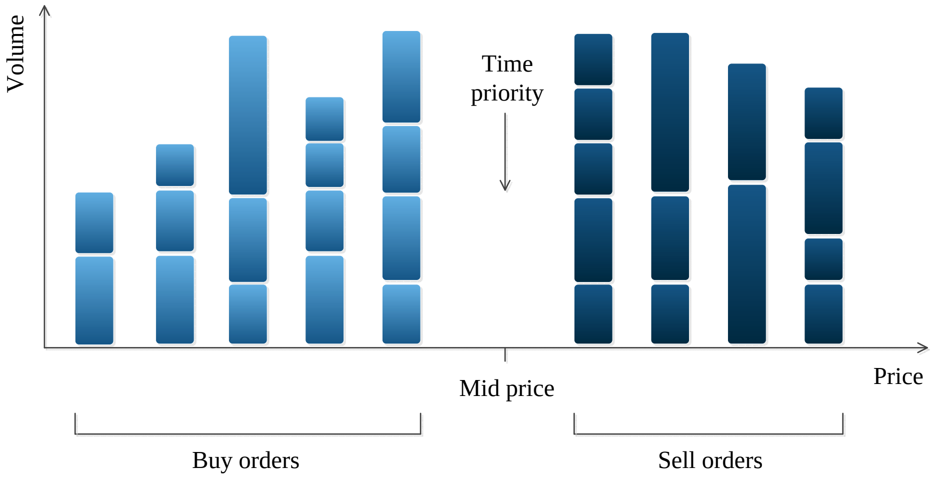


Figure 1: Schematic illustration of a limit order book.

2.2 Intercontinental Exchange

We examine long gilt future contracts traded through Intercontinental Exchange (ICE). ICE is an American business and financial firm; it owns exchanges and clearing houses for financial and commodity markets. ICE Futures Europe, the London-based Recognised Investment Exchange, is supervised by the UK Financial Conduct Authority (FCA). The Bank of England regulates ICE Clear Europe, one of the four central counterparties located in the United Kingdom.

2.3 Long gilt future contract specifications

In this section we provide some information about the future contracts we focus on.[2] We look at deliverable future contracts on UK gilts with maturities of 8 years and 9 months to 13 years: this is the criterion that defines the contracts of interest. Details of the contract specification can be found in Table 1.

2.4 Calendar spread trading

So far we have considered the market in individual long gilt future contracts. A trader may, for example, wish to take a position in the September contract. If the trade is to be kept open,

[1]Price and time priority are not always strictly enforced. EURIBOR futures for example are subject to a form of pro-rata allocation.
[2]Further information may be found at https://www.theice.com/products/37650336/Long-Gilt-Future.

ICE Long gilt future	
Underlying	Notional gilt with 4% coupon[a]
Maturities	8 years and 9 months to 13 years
Nominal value	GBP100,000
Delivery date	Any business day in delivery month (at seller's choice)
Delivery months	March, June, September, December[b]
Quotation	Per GBP100 nominal
Tick size and value	0.01 (GBP10)[c]
Last trading day	Two business days before last business day of delivery month
Last trading time	11:00
First notice day	Two business days before the first day of the delivery month[d]
Last notice day	First business day after last trading day[e]

[a] A list of eligible bonds and their conversion factors is available from the exchange.
[b] The nearest three delivery months are available for trading at any one time. The contract with expiration date closest to the current date known as the "front" contract.
[c] The tick size is the minimum price movement.
[d] The first notice day is the day after which an investor who has purchased a futures contract may be required to take physical delivery of the contract's underlying.
[e] The last notice day is the final day on which a notice of intent to deliver the underlying may be issued.

Table 1: ICE long gilt future contract specification.

however, the position will eventually need to be rolled into the next contract. This is necessary because each future has a clearly defined expiry date.

In practical terms, it is the first notice day that is most important in determining when open positions are rolled (Table 1). This is because most market participants prefer not to physically deliver or receive the contract's underlying. As a result, a surge of rebalancing activity occurs leading up to the first notice day.

Those wishing to roll their contracts face the potential problem of slippage costs: there is no certainty that the buy and sell trades in the two contracts can be executed at exactly the same time. Many traders therefore choose to roll their positions by trading a calendar spread. Because the spread instrument is quoted on the basis of a price difference between the nearby and next contract, the effect is that of trading both legs simultaneously.

We will see in Section 7 that the preference for spread contracts around the first notice day becomes apparent in measures of single-contract liquidity.

3 Data

The data we use come from ICE Futures Europe. The original dataset consists of tick-by-tick order book observations, and it covers the period from October 20th, 2014 to April 19th, 2017. The start date was constrained by the transfer of trading from one exchange (London International Financial Futures and Options Exchange) to another (ICE). Data for dates prior to the change of trading venue were not easily recovered by the data provider. The endpoint of the sample coincides with the beginning of the project.

The large size of the original tick-by-tick dataset raises a data processing issue.[3] As in Gomber et al. (2011), we sample the data at one-minute frequency. This results in a manageable dataset yet retains the relevant information needed to build the liquidity measures detailed in Section 4. We start our analysis on November 4th, 2014, avoiding some initial noisy observations that coincided with a migration between trading exchanges. In this way, we end up with 223,191 order books over a 30 month period.[4]

Table 2 provides summary statistics for the bid and ask sides of the order books that we analysed. On the bid side, order books on average have 132.65 price levels. The lowest volume available at a bid price level averages GBP30,000 across all order books and the equivalent maximum volume is GBP46.63 million. On the ask side, the mean number of price levels is 146.76. The average minimum and maximum volumes per ask price are GBP70,000 and GBP65.51 million respectively.

	Mean	SD	Min	$Q_{0.25}$	Median	$Q_{0.75}$	Max
Bid side							
Price levels per book	132.65	29.28	35.00	113.00	129.00	149.00	298.00
Minimum volume at level[a]	0.03	0.05	0.00	0.00	0.00	0.10	0.20
Median volume at level	0.73	0.49	0.00	0.40	0.60	1.00	6.20
Maximum volume at level	46.63	31.88	5.00	24.10	35.10	55.10	516.70
Ask side							
Price levels per book	146.76	29.79	56.00	126.00	145.00	166.00	308.00
Minimum volume at level	0.07	0.05	0.00	0.00	0.10	0.10	0.30
Median volume at level	1.14	0.72	0.00	0.70	1.00	1.40	6.80
Maximum volume at level	65.51	33.60	7.60	41.80	52.80	85.40	161.10

[a] Volumes in million GBP.

Table 2: Descriptive statistics for 223,191 order books from the period 4 November, 2014 to 19 April, 2017 inclusive.

4 Choice of liquidity measure

In the literature, there is no general consensus on how to measure liquidity in bond markets (Schestag et al., 2016). For our analysis of the bond future order book we follow Gomber and Schweickert (2002) and use a measure that exploits information from the whole set of prices and volumes. We thus build a direct measure rather than rely on less informative proxies such

[3] To provide an idea of the order of magnitude, one hour of order book information can amount to approximately a gigabyte of data.

[4] Sampling the dataset means that we are not able to say anything about the resilience of liquidity to new orders. That is, we have not been able to test whether algorithmic traders immediately withdraw liquidity if a large market order is submitted. The resilience of liquidity to new orders is a question that we plan to address in future research.

as the bid-ask spread.

In this section we motivate our choice by running a comparison with other measures mentioned in the literature. Section 4.1 presents the liquidity measures, including the one we use for the empirical analysis. Section 4.2 provides descriptive statistics. Section 4.3 analyses the pairwise correlations between the measures. Section 4.4 studies the time series dynamics of the measures. Section 4.5 discusses the choice of the liquidity measure that we use in the empirical analysis.

4.1 Liquidity measure

In this section we describe several liquidity measures that differ from each other by the amount of information they incorporate (Schestag et al., 2016). We construct measures of increasing complexity, adding additional information from the order book at each step. We consider the bid-ask spread, order book volume at best limit, order book depth, instantaneous price impact and the Xetra liquidity measure. The measures are detailed in turn in Sections 4.1.1 to 4.1.5.

4.1.1 Bid-ask spread

Let P^{BID} and P^{ASK} denote the bid and ask prices, defined as the highest price on the bid side and the lowest price on the ask side, respectively. As in Roncalli and Zheng (2014), the bid-ask spread of the order book is defined as

$$SP = P^{ASK} - P^{BID}.$$

By construction, the bid-ask spread has the same unit of measure as the underlying price change (i.e., GBP) and it tends move inversely with liquidity — the higher the former, the lower the latter. The bid-ask spread is therefore interpreted as a measure of *illiquidity*.

4.1.2 Order book volume at best limit

Let V^{BID} and V^{ASK} be the order book volumes corresponding to the bid and ask prices P^{BID} and P^{ASK}, respectively, as defined in Section 4.1.1. Define the quote midpoint QM as

$$QM = \frac{P^{BID} + P^{ASK}}{2}.$$

Following Roncalli and Zheng (2014), the average volume of the best limit is defined as

$$AV = \frac{1}{100}\left(\frac{V^{BID}+V^{ASK}}{2}\right)QM.$$

The average volume of the best limit measures the value of the average volume at the best prices on the bid and ask side. In our case, it is thus expressed in GBP. It moves in the same direction as liquidity — a higher average volume implies greater liquidity. It uses the information from the volumes V^{BID} and V^{ASK}, as well as that from the corresponding prices P^{BID} and P^{ASK}. This measure therefore adds information content versus the bid-ask spread which was concerned only with the best bid and ask prices.

4.1.3 Order book depth

Let P_{Bi} (P_{Aj}) be the sequence of prices on the bid (ask) side of the order book, and V_{Bi} (V_{Aj}) be the corresponding sequences of volumes. The order book depth for the bid and ask side, respectively, are defined as

$$Depth_B = \frac{\sum_i P_{Bi}V_{Bi}}{100}, \qquad Depth_A = \frac{\sum_j P_{Aj}V_{Aj}}{100}.$$

The total depth of the order book is defined as

$$Depth = Depth_B + Depth_A.$$

As was the case for the average volume of the best limit described in Section 4.1.3, the depth of the order book is measured in GBP. It is more informative than the order book volume at best limit as it employs the entire sequences of bid and ask prices and volumes. A greater depth is associated with greater liquidity.[5]

4.1.4 Instantaneous price impact measure

Let $P_A^{max}(V_A)$ denote the highest price at which a seller-initiated-order of given volume V_A could be immediately executed. Similarly, let $P_B^{min}(V_B)$ denote the lowest price at which a buyer's order for volume V_B could be executed without delay. We define the instantaneous price impact measures ${P_A}^{impact}(V_A)$ and ${P_B}^{impact}(V_B)$ for the ask and bid side of the order book as

$${P_A}^{impact}(V_A) = \frac{100 * |QM - P_A(V_A)|}{QM}, \qquad {P_B}^{impact}(V_B) = \frac{100 * |QM - P_B(V_B)|}{QM},$$

[5]Further details of simple volume-based liquidity measures can be found in Roncalli and Zheng (2014).

respectively. The total instantaneous price impact $P^{impact}(V)$ of the order book for a given volume V is

$$P^{impact}(V) = {P_A}^{impact}(V) + {P_B}^{impact}(V).$$

The instantaneous price impact measures the required liquidity (with respect to the mid quote QM) to immediately execute an order of volume V. Like the bid-ask spread, it moves inversely with liquidity and it is a measure of illiquidity. By construction, $P^{impact}(V)$ is measured as a percentage of the mid price QM. The proposed instantaneous price impact is more informative than the order book depth in that it depends on the underlying order volume V.

4.1.5 Xetra liquidity measure (XLM)

The Xetra liquidity measure was introduced by Deutsche Börse in 2002 (Gomber and Schweickert, 2002). Let LP denote a liquidity premium

$$LP = \frac{1}{2}\frac{P^{ASK} - P^{BID}}{QM} = \frac{1}{2}\frac{SP}{QM}.$$

Define the *weighted-average* prices at which a buyer-initiated and a seller initiated order of given volume could be immediately executed as

$$\bar{P}_B\left(V_B\right) = \frac{\sum_i P_{Bi} V_{Bi}}{V_B}, \qquad \bar{P}_A\left(V_A\right) = \frac{\sum_j P_{Aj} V_{Aj}}{V_A},$$

respectively, where $\sum_i V_{Bi} = V_B$ and $\sum_j V_{Aj} = V_A$. The adverse price movements for the bid and ask side are defined as

$$APM_B\left(V_B\right) = \frac{P^{BID} - \bar{P}_B\left(V_B\right)}{QM}, \qquad APM_A\left(V_A\right) = \frac{P^{ASK} - \bar{P}_A\left(V_A\right)}{QM},$$

respectively. The execution costs for a sell and a buy order respectively are

$$XLM_{\ B}\left(V_B\right) = 10000\left[LP + APM_B\left(V_B\right)\right], \qquad XLM_{\ A}\left(V_A\right) = 10000\left[LP + APM_A\left(V_A\right)\right].$$

The $XLM_{\ RT}\left(V\right)$ measure as the cost of a round-trip transaction for a given volume V is

$$XLM_{\ RT}\left(V\right) = XLM_{\ B}\left(V\right) + XLM_{\ A}\left(V\right).$$

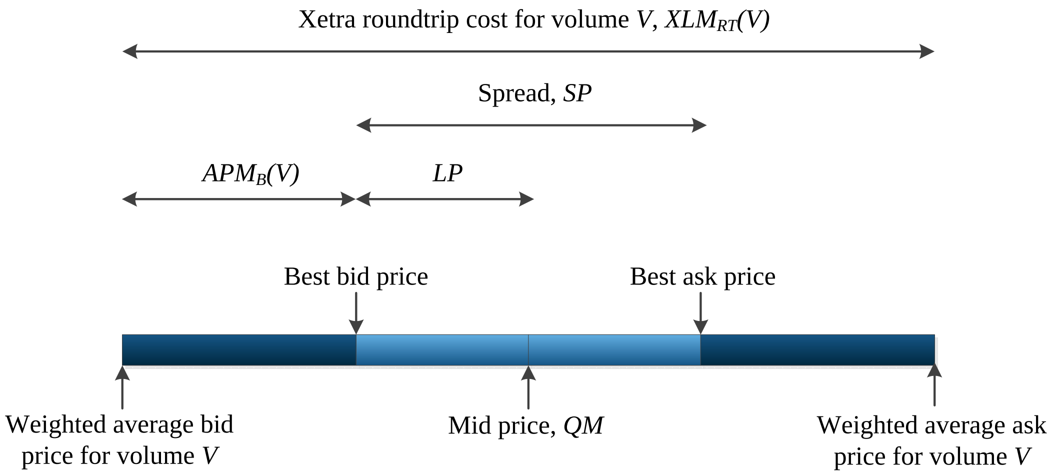


Figure 2: Schematic representation of the Xetra liquidity measure.

As it is defined, the $XLM_{RT}(V)$ measure is expressed in basis points of price (and not in basis points of yield) and it moves inversely with liquidity. It is more informative than the instantaneous price impact in that it uses the entire sequences of volumes that sum to V, along with the corresponding sequence of prices. Figure 2 shows a visual representation of the Xetra round-trip cost.

4.2 Descriptive statistics

In Table 3, we provide some descriptive statistics for the minute-by-minute liquidity measures described in Section 4.1.

Looking first at the bid-ask spread, the number of available data points (i.e., 223,191) matches the number of order books. That is, we were able to calculate this measure in all cases. However, the statistics show that the bid-ask spread may not be a very informative measure of liquidity. The mean, minimum and reported quantiles of the empirical bid-ask spread distribution all equal 0.01 — the minimum price increment for long gilt future contracts (Table 1).[6] The maximum value 0.15 occurs twice in the sample, at 09:30 on 17 June, 2015 and at 13:15 on 6 January, 2016. In both cases, the following value of the spread is back to normal levels, namely 0.01 and 0.02, respectively.

As extra information from the order book is included in the measures, more variation can be observed. The empirical distribution of both order book volume at best limit and order book total depth display more pronounced variation than the bid-ask spread. The two measures are

[6] Because the long gilt futures market is a relatively liquid one, the bid-ask spread is often as low as is allowed by the contract-specified tick size — when bid and ask prices cannot be any closer without being equal. This effective floor under the bid-ask spread limits its usefulness as a measure of liquidity.

thus likely to be more informative than the simple price spread measure.

We report instantaneous price impact measures for levels of volume equal to 50, 100 and 200 million GBP: as discussed in Section 4.1.4, the price impact measures the liquidity that is required to immediately execute an order of some volume V. At GBP50 million the number of observations is the same as the sample size, but as the volume increases, fewer observations become available as it becomes more difficult to fill the larger order. Liquidity thus decreases with volume. As expected, the value of all remaining descriptive statistics increases with volume.

Finally, for given levels of volume, the XLM has similar qualitative empirical behaviour to the price impact measure. To gain further information about the XLM measure, Figure 3 shows time series averages of round-trip market impacts for different volumes at 13:00. In line with the statistics in Table 3, the average XLM increases monotonically with volume.

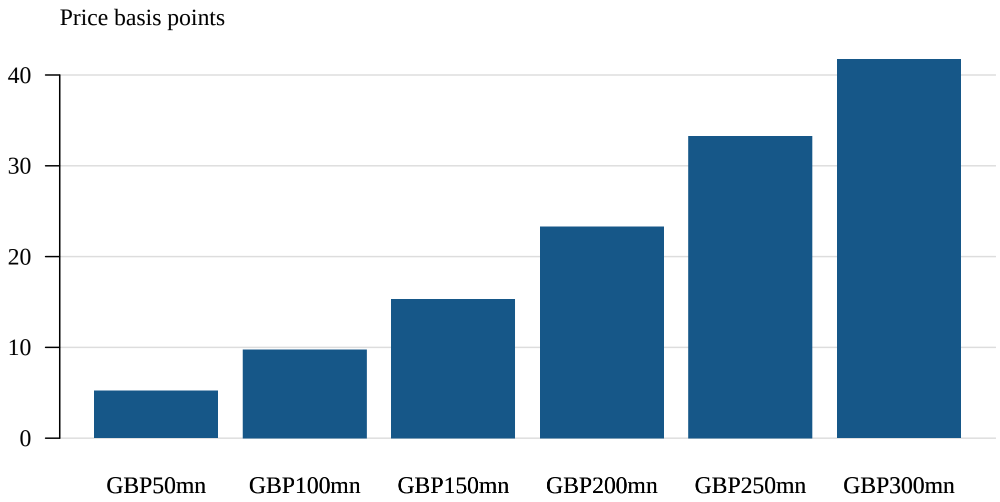


Figure 3: Average round-trip market impact (Xetra measure) for different trade sizes at 13:00.

In conclusion, Table 3 provides a summary of the empirical distribution of the liquidity measures described in Section 4. Based on the available information, the bid-ask spread does not provide an accurate description of liquidity in the UK long gilt futures market as it does not display sufficient and meaningful time variation.

4.3 Correlation analysis

Table 4 collects pairwise correlations for the liquidity measures in Table 3. The liquidity measures that depend on volume levels are highly correlated, with values ranging between 0.56 and 0.97. Those measures are negatively correlated with the order book volume and the total market depth, but mildly positively correlated with the bid-ask spread. Order book volume at best limit and total depth are positively correlated; these two measures move in opposite directions with respect to the bid-ask spread, which is at odds given the interpretation of the bid-ask spread given in Section 4.1.1. The correlation analysis thus suggests that the bid-ask spread may not provide an accurate measure of liquidity.

	Unit	N	Mean	SD	Min	$Q_{0.25}$	Median	$Q_{0.75}$	Max
Bid-ask spread	GBP	223,191	0.01	0.00	0.01	0.01	0.01	0.01	0.15
Vol. at best limit	GBP bn	223,191	7.15	4.80	0.12	4.17	6.15	8.86	291.93
Total depth	GBP bn	223,191	1,387	444	277	1,013	1,346	1,735	3,137
Price impact$_{50}$	% of mid	223,191	0.09	0.08	0.01	0.06	0.08	0.10	2.14
Price impact$_{100}$	% of mid	222,843	0.19	0.20	0.03	0.12	0.15	0.21	12.16
Price impact$_{200}$	% of mid	220,008	0.61	0.95	0.07	0.25	0.38	0.66	14.82
XLM$_{50}$	price bp	223,191	5.02	3.61	0.80	3.47	4.37	5.61	109.26
XLM$_{100}$	price bp	222,843	9.40	7.31	1.83	6.14	7.92	10.52	267.62
XLM$_{200}$	price bp	220,008	22.30	24.55	3.81	12.01	16.63	24.99	708.32

Table 3: Descriptive statistics for liquidity measures.

	Bid-ask spread	Vol. at best limit	Total depth	Price impact$_{50}$	Price impact$_{100}$	Price impact$_{200}$	XLM$_{50}$	XLM$_{100}$
Vol. at best limit	0.19							
Total depth	-0.09	0.27						
Price impact$_{50}$	0.10	-0.30	-0.36					
Price impact$_{100}$	0.08	-0.26	-0.37	0.88				
Price impact$_{200}$	0.06	-0.21	-0.41	0.59	0.71			
XLM$_{50}$	0.12	-0.35	-0.37	0.97	0.83	0.56		
XLM$_{100}$	0.10	-0.33	-0.41	0.97	0.95	0.65	0.95	
XLM$_{200}$	0.07	-0.26	-0.43	0.73	0.86	0.93	0.69	0.80

Table 4: Correlation matrix for liquidity measures.

4.4 Market liquidity dynamics

In order to analyse liquidity dynamics over the entire sample period of 30 months, we first take daily averages of the liquidity measures described in Section 4.1, which were originally constructed at one-minute frequency (see Section 3).

4.4.1 Market liquidity and trading activity

Following Chordia et al. (2001), we investigate the joint evolution of market liquidity and trading activity. We measure daily trading activity through daily traded volumes. More recently, Bank for International Settlements (2016) discusses the potential linkages between fixed income market liquidity and trading activity. Figure 4 shows the time series of long gilt futures daily traded volume. The series displays a great deal of time variability, pronounced peaks and several troughs.[7] The average is about 181,662 traded contracts per day, with a standard deviation approximately equal to 71,514.

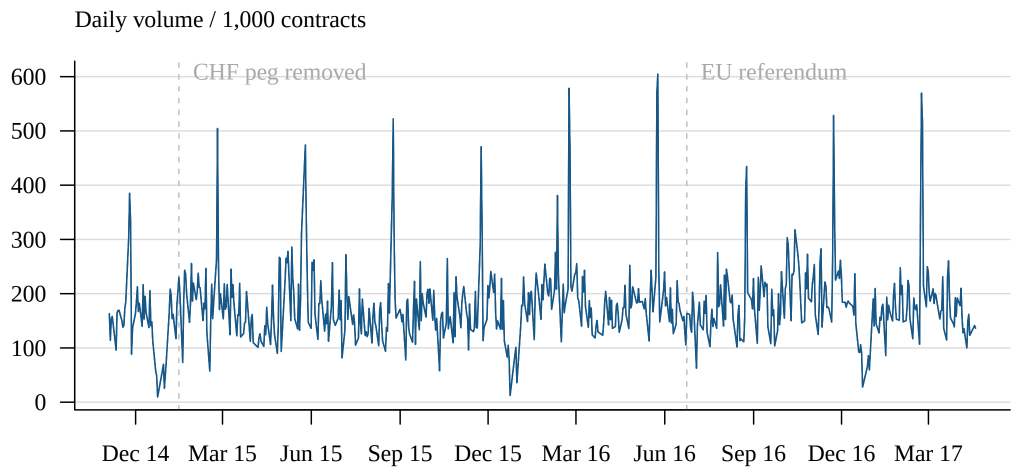


Figure 4: Long gilt futures daily traded volume.

Table 5 shows sample pairwise correlations between the sequence of daily volumes in Figure 4 and the liquidity measures listed in Tables 3 and 4. Market volume at best limit and total depth are measures of liquidity; as expected, they are positively correlated with trading volumes. On the other hand, instantaneous price impact and XLM move inversely with liquidity, and they are negatively correlated with daily volumes. Although the bid-ask spread is a measure of illiquidity, it is positively correlated with volumes. This casts further doubt on the validity of the bid-ask spread as a liquidity metric for our dataset.

[7] This series is available from Bloomberg.

	Correlation
Bid-ask spread	0.07
Vol. at best limit	0.20
Total depth	0.13
Price impact$_{50}$	-0.09
Price impact$_{100}$	-0.11
Price impact$_{200}$	-0.15
XLM$_{50}$	-0.09
XLM$_{100}$	-0.12
XLM$_{200}$	-0.17

Table 5: Correlation of liquidity measures with daily traded volume.

4.4.2 Granger causality

The liquidity measures described in Section 4.1 require different amounts of information from the limit order book. It seems natural, therefore, to test whether any of the measures can be used to predict any others. We do this by testing for Granger causality. Table 6 displays results from the test as applied to changes in the daily liquidity measures listed in Table 5.

For the purpose of discussion, we split the results into three groups. They correspond to the first three, middle three and last three columns of p-values in Table 6.

	Bid-ask spread	Vol. at best limit	Total depth	Price impact$_{50}$	Price impact$_{100}$	Price impact$_{200}$	XLM$_{50}$	XLM$_{100}$	XLM$_{200}$
Bid-ask spread		0.48	0.01	0.46	0.28	0.86	0.66	0.29	0.90
Vol. at best limit	0.13		0.38	0.47	0.59	0.35	0.40	0.58	0.60
Total depth	0.21	0.87		0.10	0.05	0.09	0.13	0.08	0.58
Price impact$_{50}$	0.09	0.34	0.00		0.11	0.00	0.50	0.42	0.00
Price impact$_{100}$	0.07	0.41	0.00	0.44		0.00	0.50	0.34	0.00
Price impact$_{200}$	0.00	0.14	0.01	0.41	0.21		0.59	0.26	0.00
XLM$_{50}$	0.17	0.26	0.00	0.05	0.01	0.00		0.06	0.00
XLM$_{100}$	0.03	0.37	0.01	0.49	0.47	0.00	0.56		0.00
XLM$_{200}$	0.00	0.09	0.01	0.01	0.00	0.00	0.03	0.00	

Table 6: Causality matrix for changes in daily average liquidity measures (p-values for row causing column). Shaded cells indicate values that are significant at the 5% level.

- *Bid-ask spread, order book volume at best limit and order book depth (columns 1–3)*

  Price impact and Xetra measures Granger-cause the bid-ask spread, with some test statistics significant at the 5 percent level. This is evidence that the most informative measures contain valuable information for predicting the bid-ask spread. Conversely, no liquidity measure Granger-causes the order book volume at best limit. The order book depth is Granger-caused by all measures except the order book volume.

- *Instantaneous price impact (columns 4–6)*

  Neither the bid-ask spread nor the order book volume Granger-cause the instantaneous price impact. The order book total depth only has a marginal effect. There appears to be some degree of Granger causality from the Xetra measure.

- *Xetra liquidity measure (columns 7–9)*

  Granger causality mainly arises from the instantaneous price impact and it is more pronounced for higher volumes.

The results from Granger causality analysis may be summarised as follows. Instantaneous price impact and Xetra measure Granger-cause bid-ask spread and total depth. The dynamics of the order book volume do not seem to be captured by any other measure. The more informative instantaneous price impact and Xetra measure are Granger-caused by neither the bid-ask spread nor the order book volume, whereas the total depth displays limited degree of predictive power.

In conclusion, the results suggest that instantaneous price impact and Xetra measure incorporate all information contained in bid-ask spread and total depth. The order book volume may include some amount of additional information. Therefore, although price impact and Xetra measure are the most informative liquidity measures we consider, they do not incorporate all of the information contained within the data.

4.4.3 Liquidity persistence

The main aim of our paper is to assess liquidity resilience. In order to understand how liquidity is likely to behave in response to a shock, we analyse the persistence of the liquidity measures we constructed. To this purpose, Figure 5 shows the autocorrelation function of the measures for order up to 21. Because we consider daily averages for our measures, the maximum lag order corresponds to a period of approximately one calendar month.

The measures that aggregate over volume levels (i.e., bid-ask spread, volume at best limit and total depth), display a high degree of persistence. Even after 21 days, the least persistent measure of the three (i.e., the order book volume) has autocorrelation above 30 percent. On the other hand, price impact and XLM have autocorrelations that become negligible after approximately 10 days for all volume levels. This result suggests that the amount of information used to construct liquidity measures influences the serial dependency of the measures. Less informative measures are more persistent — a fact that is relevant when assessing liquidity resilience to adverse shocks.

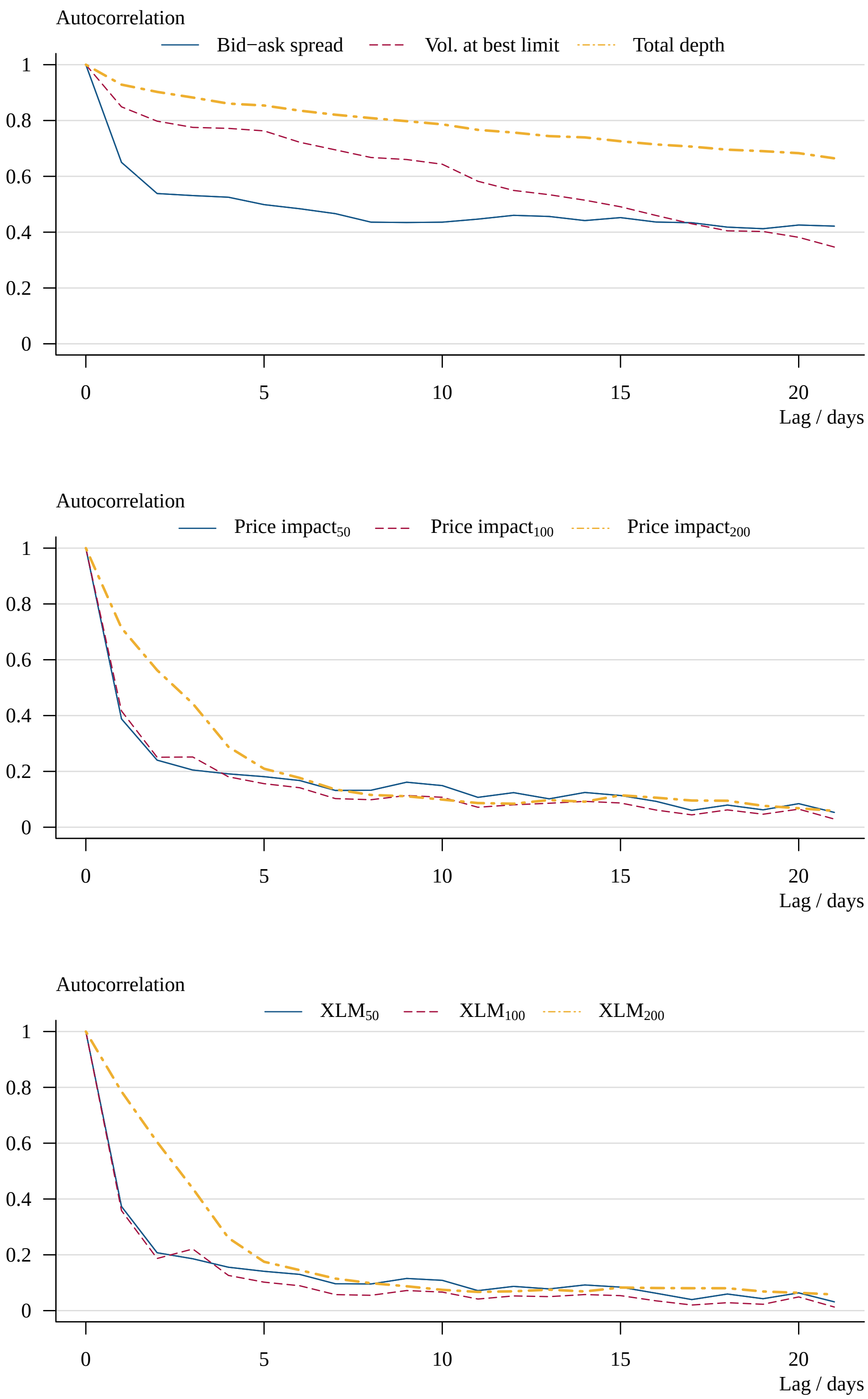


Figure 5: Autocorrelations for liquidity measures.

4.5 Discussion

The aim of Section 4 is to motivate the choice of the XLM measure as a liquidity metric for the UK long gilt futures market when the entire order book is available. Our empirical analysis shows that the bid-ask spread may not give a clear picture: it has very limited time variation; it may display counterintuitive time series dynamics; and the information it conveys may be included in the other liquidity measures we presented. The order book volume and depth may overestimate the impact of an adverse shock and thus not be informative about market liquidity resilience. The XLM does not suffer from any of these problems. At the same time, being the most informative liquidity measure, it embeds the features of the instantaneous price impact. The XLM thus is the liquidity metric we use in the empirical analysis that follows.

5 Liquidity trend and liquidity risk

In this section we study market liquidity over the entire sample period. This is the third building block of our paper and relates to the first research question we attempt to answer. We start by looking at liquidity trend in Section 5.1. Then, in relation to Adrian et al. (2016), we analyse liquidity risk in Section 5.2. Following the discussion in Section 4.5, we focus on the XLM measure presented in Section 4.1.5.

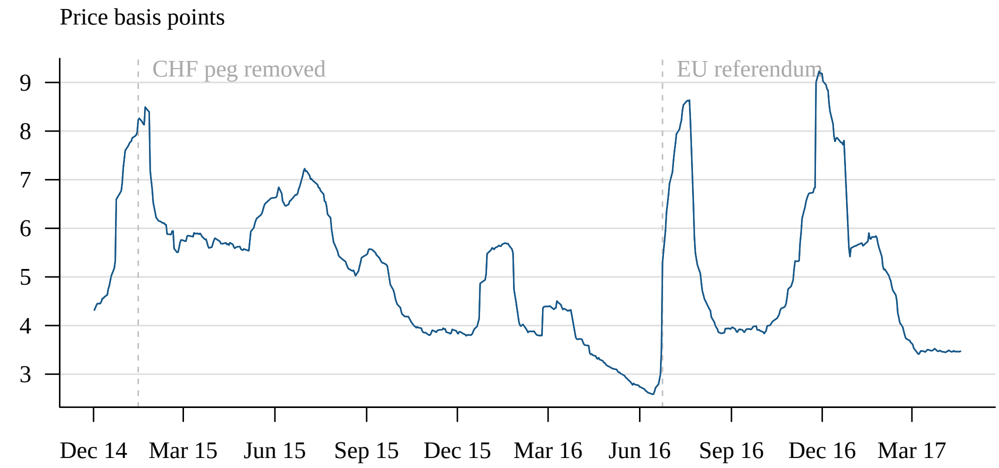
5.1 Liquidity trend

Figure 6 shows the time series of 21-day moving averages of daily average XLM (Adrian et al., 2016). The moving average allows us to separate the trend from the noise in the original series of the liquidity measure. The series for all volumes display a clear downward sloping trend. Because the XLM measures round-trip cost, this implies that market liquidity has not deteriorated over the period considered.

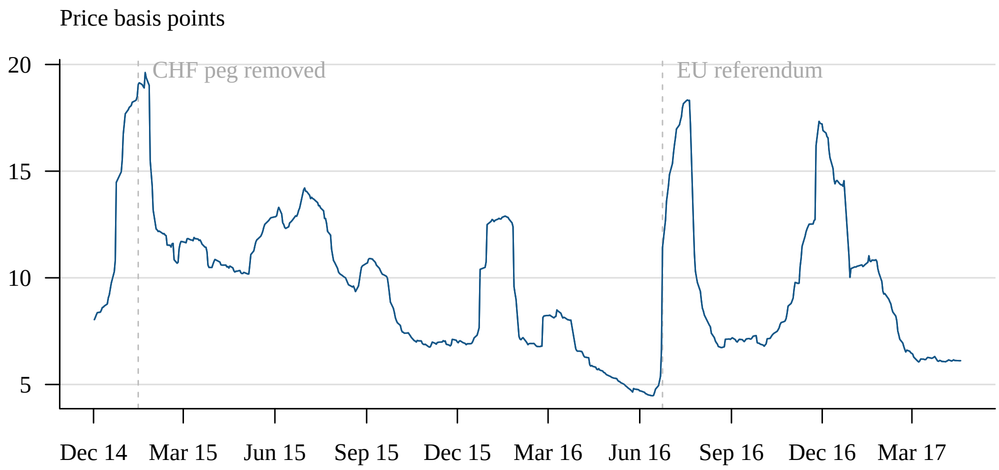
All series show two very clear spikes. In addition the series for GBP50 million and GBP100 million show a third clear spike in November 2016. We will return to discuss this November peak in Section 7 when we discuss the calendar spread order book in more detail.

The first of the clear spikes occurs in January 2015, after the removal of the Swiss franc peg to the euro. The second takes place right after the EU referendum. The moving-average structure of the series may signal the spikes with a delay; it may also fictitiously prolong the actual underlying period of reduced liquidity. In particular, the spike in January 2015 is unrelated to the Swiss franc de-peg and it actually originates during Christmas 2014, as we will discuss in Section 8.3.1. Christmas tends to be a highly illiquid period, as evidenced by the other corresponding spikes in the XLM measure series. We will show in Section 8.3.2 that the second spike is confined to the days immediately following the EU membership referendum. Despite these two noticeable spikes, the level of liquidity in the UK long gilt futures market does not exhibit any evidence of deterioration over the time period under consideration.[8]

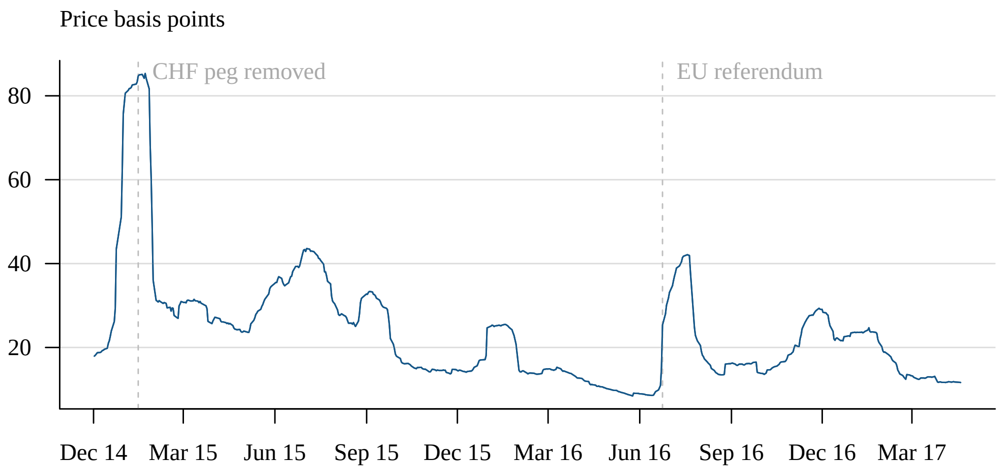
[8]In principle, the trend in liquidity may be driven by the trend in volatility. To ensure that our results are not spuriously driven by market volatility, we produced a version of the XLM measure that was adjusted for a measure of return volatility — we used the standard deviation of all one-minute changes in mid quotes, calculated for each day. The resulting standardised series are qualitatively similar to those displayed in Figure 6. All results are available upon request.



(a) GBP50 million.



(b) GBP100 million.



(c) GBP200 million.

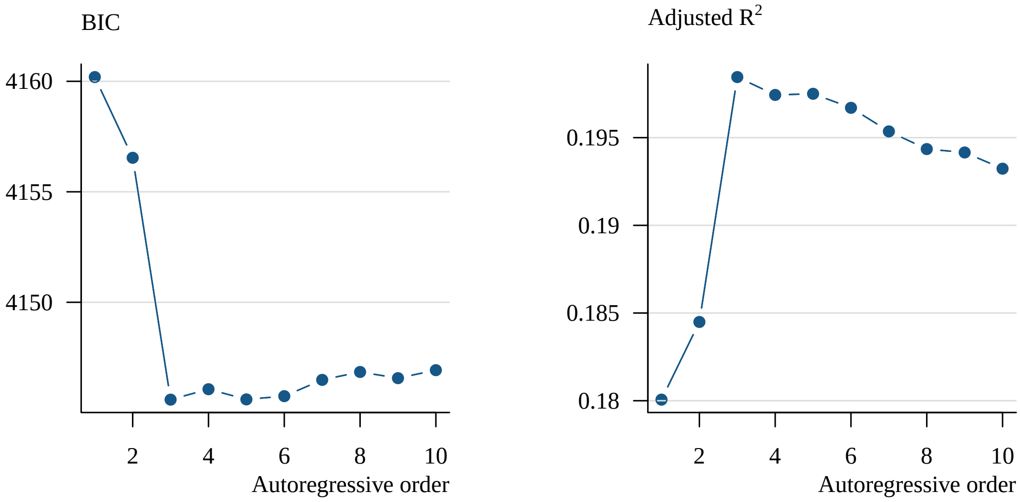
Figure 6: Xetra liquidity measure 21-day rolling averages.

In order to quantitatively describe the trend in liquidity over the period, we fitted a model to daily average values of the XLM round-trip cost for GBP100 million trades. We performed a series of linear regressions for an autoregressive model that can be written as

$$y_t = \sum_{j=1}^{p} \phi_j y_{t-j} + t\beta_{trend} + \epsilon_t,$$

where t is time, ϕ_j is the coefficient for the j^{th} autoregressive term, β_{trend} is a coefficient representing the trend and ϵ_t is an error term.

Up to 10 autoregressive lags were considered with the Bayesian information criterion (BIC) used to identify the preferred model. Figure 7 shows that three autoreggressive terms were preferred.



(a) Bayesian information criterion. (b) Adjusted R^2.

Figure 7: Model selection using the Bayesian information criterion. Maximising adjusted R^2 for the models produces a consistent outcome.

The results of the regression are shown in Table 7. We note that the trend term is slightly negative and consistent with being non-zero at the 5 percent level. The magnitude of the trend coefficient is consistent with a fall in round-trip cost of around 0.8 basis points per year. Results were consistent across order sizes; the annual trend reductions in round-trip cost for deals of GBP50 million and GBP200 million were 0.3bp and 3.0bp, respectively. Formal statistical analysis thus confirms what comes out of the visual inspection of Figure 6.

5.2 Liquidity risk

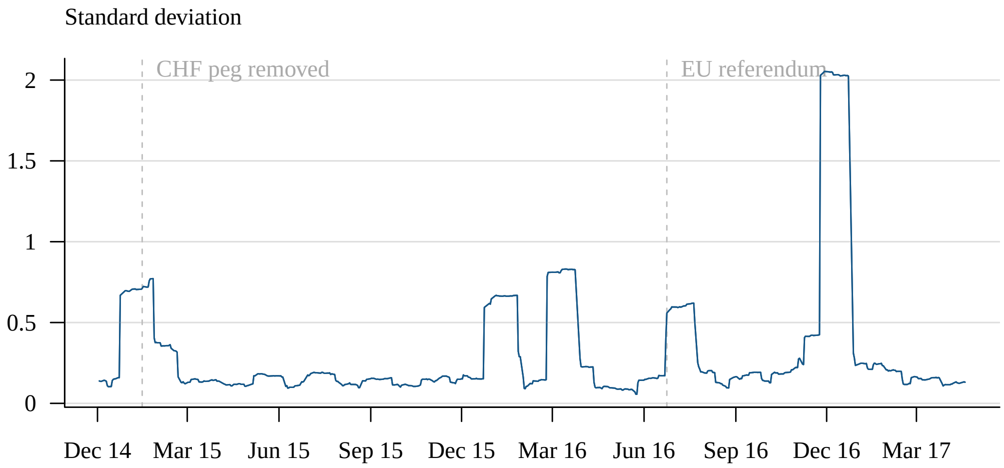
As suggested in Adrian et al. (2016), we also study liquidity *risk* in addition to liquidity *level*. We characterise liquidity risk through the conditional volatility. To be consistent with Section 5.1,

	Estimate	Standard error	t-statistic	p-value
Intercept	5.603	0.792	7.070	0.000
β_{tend}	-0.003	0.002	-2.105	0.036
ϕ_1	0.356	0.040	8.907	0.000
ϕ_2	0.033	0.042	0.779	0.436
ϕ_3	0.137	0.040	3.418	0.001

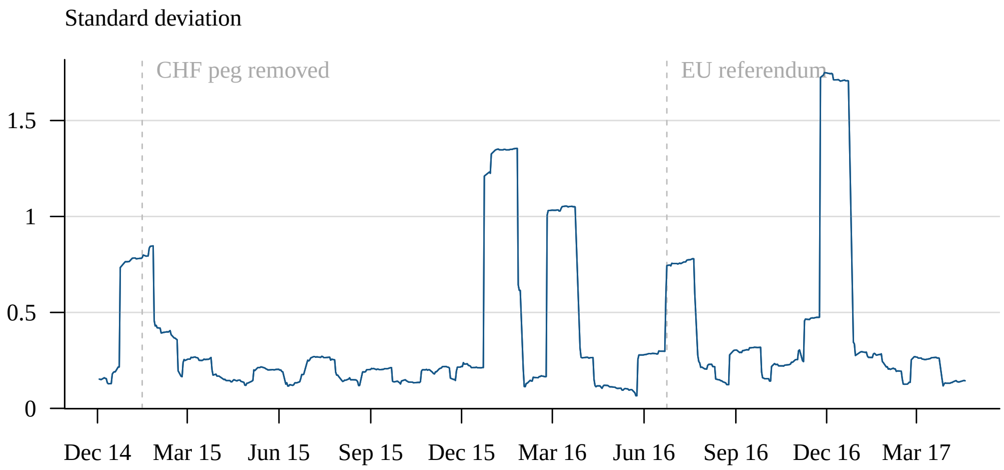
Table 7: Summary statistics for an AR(3) plus trend model of the XLM (GBP100mn) liquidity measure.

we estimate the conditional volatility using the 21-day rolling standard deviation of one-day changes in the liquidity measure.

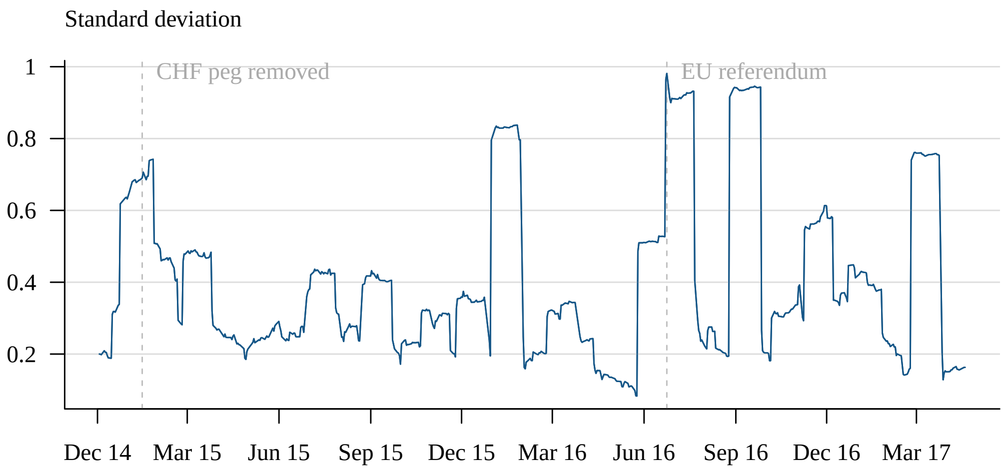
For all volumes, the volatility for XLM displays four distinctive periods of high volatility, namely early 2015, 2016, 2017 and the EU referendum (see Figure 8). The first three are induced by very high illiquidity during the Christmas period as discussed in Section 5.1. In the case of the EU referendum, the results in Section 8.3.2 suggest that the spike in volatility is related only to the days right after voting took place — the slightly prolonged volatility spike is due to the rolling window estimator.



(a) GBP50 million.



(b) GBP100 million.



(c) GBP200 million.

Figure 8: Xetra liquidity measure, 21-day standard deviation of changes in daily averages.

Table 8 displays the correlation between liquidity level and liquidity risk for different order sizes. The values are all positive; liquidity risk increases when round-trip costs increase (as liquidity dries up). Notice that we do not attempt to uncover any causal relationship between liquidity level and liquidity risk; this interesting research question is left for future work.

	Correlation
XLM_{50}	0.26
XLM_{100}	0.23
XLM_{200}	0.21

Table 8: Correlations between liquidity level and liquidity risk.

5.3 Discussion

We have studied the time series dynamics of liquidity level and liquidity risk in the UK long gilt futures market as measured by the XLM metric described in Section 4.1.5. Our analysis provides two main results: liquidity level has not deteriorated during the sample period we are considering; and liquidity risk and liquidity level are negatively correlated. Given the available sample period, our results support the view that regulatory reforms such as leverage ratio requirements did not have a sizeable effect on market liquidity (see Adrian et al. (2016) and Bicu et al. (2016)).

6 Market liquidity and funding liquidity

In this section we study the linkages between market liquidity and funding liquidity. According to Dudley (2016), funding liquidity is the "ability of a financial entity to raise cash by borrowing on either an unsecured or a secured basis". It differs from market liquidity, which is "the cost of buying or selling an asset for cash". Although market and funding liquidity are conceptually different, in practice they are very closely related. The connection between market liquidity and funding liquidity is stressed by Dudley (2016) and finds its theoretical justification in Brunnermeier and Pedersen (2008). Bank of England (2014) views market liquidity and funding liquidity from a macro-financial perspective as potential causes of systemic risk.

We follow Bicu et al. (2016) and measure funding liquidity through the gilt repo market. A repo contract is a formal repurchase agreement. Under the agreement, one party sells a security to another party at a given price under the commitment to buy back the security at a future date and a pre-specified price. The repurchase price is generally higher than the original selling price. A repo contract thus is a form of secured lending, in which the seller of the security acts as the borrower and the buyer is the lender. The security acts as collateral and the price difference gives rise to a "repo" rate.

As in Bicu et al. (2016), we look at the inter-dealer repo market where almost all trading is for overnight maturity. Liquidity in this market may capture also market liquidity due to the overnight maturity of the underlying contract. Nonetheless, it still is informative about funding liquidity. We consider contracts with either "specific" or "general" collateral. In the former, trade and security are agreed at the same time. In the latter, any security within a general class can be exchanged after the trade is agreed.

We look at the three liquidity measures put forward in Amihud (2002), Roll (1984) and Hong and Warga (2000), as applied to specific and general repo contracts. We also consider two other metrics, constructed as the first principal component of the three measures for each type of repo contract. Finally, we study the aggregate measure obtained as the first principal component of all six measures.[9] All metrics are measures of *illiquidity* and may be interpreted in a similar manner to the XLM.

	Volume	XLM_{50}	XLM_{100}	XLM_{200}
General Amihud	-0.15	0.24	0.32	0.39
General Roll	-0.07	0.08	0.13	0.27
General Effective Spread	-0.09	0.09	0.20	0.15
Specific Amihud	-0.15	0.10	0.20	0.22
Specific Roll	-0.11	-0.01	0.07	0.17
Specific Effective Spread	0.01	0.06	0.10	0.01
General Score	-0.13	0.19	0.28	0.36
Specific Score	-0.12	0.08	0.16	0.18
Combined Score	-0.15	0.17	0.27	0.34

Table 9: Correlations for daily averages (21-day rolling window) with funding liquidity measures.

The correlation matrix displayed in Table 9 shows that the trading volumes in the long gilt futures market displayed in Figure 4 tend to be lower when funding liquidity conditions have deteriorated.[10] At the same time, funding and market liquidity tend to be positively correlated, and the degree of co-movement between the two generally increases with the volume of the underlying round trip.

Our results confirm that market and funding liquidity are reasonably closely related. It is important to stress that we are not making any statement about the direction of causality; our findings imply that the market is likely to be more liquid in periods of abundant funding liquidity. A rigorous analysis of the direction of causality goes beyond the purpose of our paper and will be the topic of future research.

[9] We are very grateful to Bicu et al. (2016) for providing us with all the gilt repo market liquidity measures.
[10] Due to data availability issues, we use data from 4 November, 2014 to 31 December, 2016.

7 Market liquidity and calendar spread trading

Section 2.4 describes how calendar spread trading is important for the rolling of open futures positions. In this section we discuss the effect of this phenomenon on our liquidity measure.

We have already seen in Figure 6 that trading patterns during the rolling over of open positions can decrease liquidity in single future contracts. Figure 9 provides further evidence of this by adding lines marking first notice days to a chart of daily average round-trip cost. It is clear that the XLM round-trip cost is higher during Christmas periods and during times of market stress such as the period around the EU referendum. It is also evident that increases in trading cost typically appear around first notice date. Some of the first notice peaks are small and some far larger; the spike in late November 2016 was particularly large, explaining why its impact was evident in the liquidity trend charts in Section 5.1.

How do we interpret this? While it is clear that the order books for long gilt futures are far shallower around most first notice days, what about the order book for calendar spreads? Based on our XLM measure of liquidity, it turns out that the spread market around first notice days is very liquid. The XLM measure for a size of GBP100 million for example is often at its theoretical minimum value (determined by the minimum tick size). That is, there is frequently sufficient volume at the best price in order to fill even large trades.

In summary, we suggest that the observed features around first notice days merely reflect traders' preferences. Around first roll days, the bulk of trading activity will be focused on rolling over open positions. Because the most efficient way to roll a position into the next contract is a calendar spread trade, the spread market temporarily becomes the most liquid.

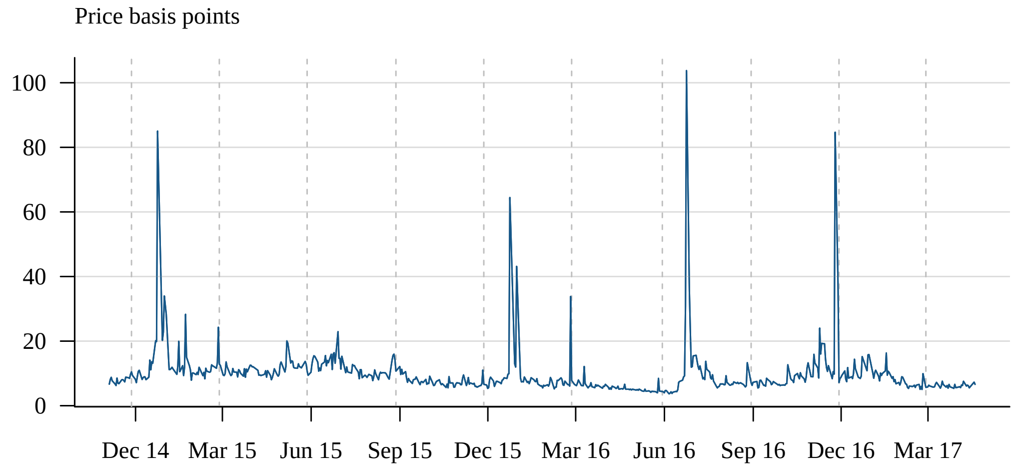


Figure 9: First notice day and XLM_{100} round trip cost. Spread trading ahead of first notice appears to reduce liquidity in single contract markets. First notice days are displayed as dashed lines.

8 Case studies of market liquidity events

We have already alluded to the fact that liquidity trends, while interesting, only offer a partial picture. For example, it could be the case that liquidity in general has increased, but at the cost of reduced resilience. That is, efforts to improve the depth of markets in ordinary trading may make the drying up of liquidity in times of uncertainty more likely. A potential trade-off between average liquidity and the resilience of liquidity in times of stress is something that policymakers worry about. Dudley (2016), for example, highlights the role of regulation, changes in market structure, and high-frequency trading activity.

Through a number of case studies we identify the impact of both expected and unexpected events on gilt future liquidity. We start with an overview of the intraday pattern of market liquidity in Section 8.1. We then consider Bank of England quantitative easing operations in the form of Asset Purchase Facility auctions in Section 8.2. These events are scheduled in advance and take place regularly. Two unexpected events are considered in Section 8.3: the removal of the EURCHF exchange rate floor by the Swiss National Bank; and the somewhat unexpected outcome of the EU referendum.[11] Section 8.4 provides some further discussion.

8.1 Intraday market liquidity

Thus far we have concerned ourselves with daily measures of liquidity. Often these daily averages have been smoothed further by taking rolling averages. Now that we wish to examine short periods of market stress in detail, however, these aggregate data are not helpful.

Intraday data make more sense. Our dataset contains order books sampled at one minute frequency, allowing changes in liquidity to be tracked in detail throughout the day. Before we proceed to look at the case studies though, we should bear one important fact in mind: intraday liquidity shows strong patterns even in the absence of market moving events.

Figure 10 shows how liquidity on average varies throughout the day. The chart is constructed by taking averages over our whole dataset for hourly grid-points. Liquidity in general increases throughout the day, with the most liquid time of the day (when round-trip costs are lowest) being 14:00. There are some features of note though. After improving through the morning, liquidity appears to decline around lunchtime. It is also notable that there is a sharp increase in trading cost in the mid afternoon as trading activity begins to wind down for the day.[12]

[11] Opinion polls by Populus, YouGov and Ipsos MORI in the days before the referendum all gave the lead to the Leave campaign (see http://www.independent.co.uk/news/uk/politics/eu-referendum-poll-brexit-remain-vote-leave-live-latest-who-will-win-results-populus-a7097261.html).

[12] We also note that 15:00 in London coincides with the release of US economic data at 10:00 Eastern Time. The other grid points in Figure 10 do not align with regular US data releases.

(a) GBP50 million.

(b) GBP100 million.

(c) GBP200 million.

Figure 10: Full sample mean values for XLM liquidity measure throughout the day.

8.2 Market liquidity around APF gilt auctions

We now consider liquidity in the UK gilt futures market around Asset Purchase Facility (APF) gilt purchases.[13] The APF scheme is implemented by the Bank of England to ease monetary conditions through large-scale asset purchases. The aim is to bring nominal demand to a level that is consistent with the 2 percent inflation target in the medium run.

The APF scheme comprises gilt and corporate bond purchases and a Term Funding Scheme. The Bank of England carries out gilt purchases through competitive and non-competitive auctions. The competitive element is available to all participants in the Bank's gilt purchase Open Market Operations (now suspended), and to firms that are registered as Gilt-Edged

[13]See Bank of England (2016b) for an introduction to the APF operating procedures. We note that the purchase of corporate bonds under the scheme was not annouced until August 2016.

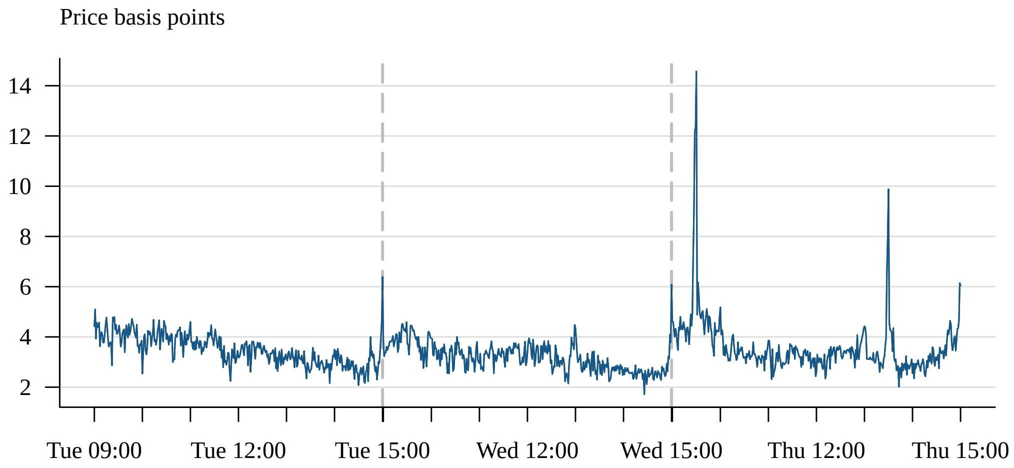
Market Makers (GEMMs).[14] The non-competitive element is only open to GEMMs. Only allocations determined through competitive auctions were available during our sample period.

Three auctions per week normally take place, on Mondays, Tuesdays and Wednesdays. Competitive auctions are held between 14:15 and 14:45. Gilt purchases are based on the residual maturity of the underlying asset. Short maturity operations, which involve assets with residual maturity between three and seven years, occur on Mondays. Long maturity operations, for asset with residual maturity greater than fifteen years, are held on Tuesdays. Medium maturity operations, for gilts with residual maturity between seven and fifteen years, take place on Wednesdays. We are interested in medium maturity auctions, so that the residual maturity is comparable to the maturity for the long gilt future underlying.

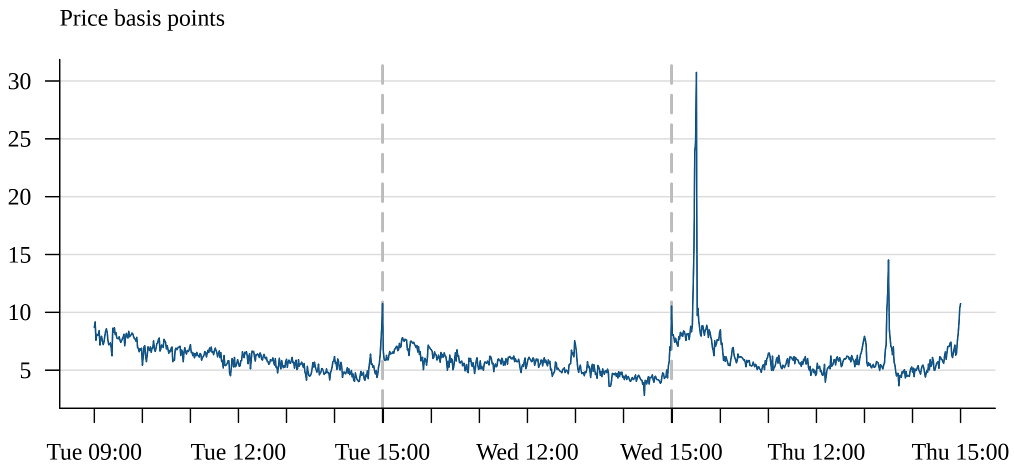
We report results for APF auctions with the lowest and the highest cover ratios in the sample.[15] These took place on January 27th, 2016 and August 10th, 2016, respectively. Figures 11 and 12 show the XLM series for January 27th and August 10th, respectively, as well as for the previous and the following days (i.e., the Tuesdays and Thursdays). Both auction days are tranquil; the value of the XLM is aligned to the unconditional average shown in Table 3. Inspection of Figures 11 and 12 shows that no discernible effect on liquidity dynamics occurred at the time of the auctions.

[14] A list of GEMMs can be found on the UK Debt Management Office website.

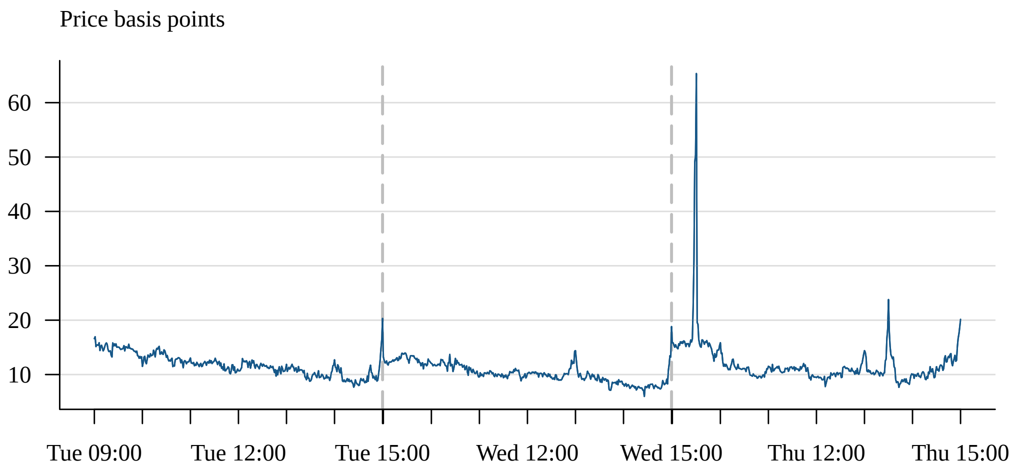
[15] The cover ratio is defined as the ratio between the total offers received and the total allocation



(a) GBP50 million.

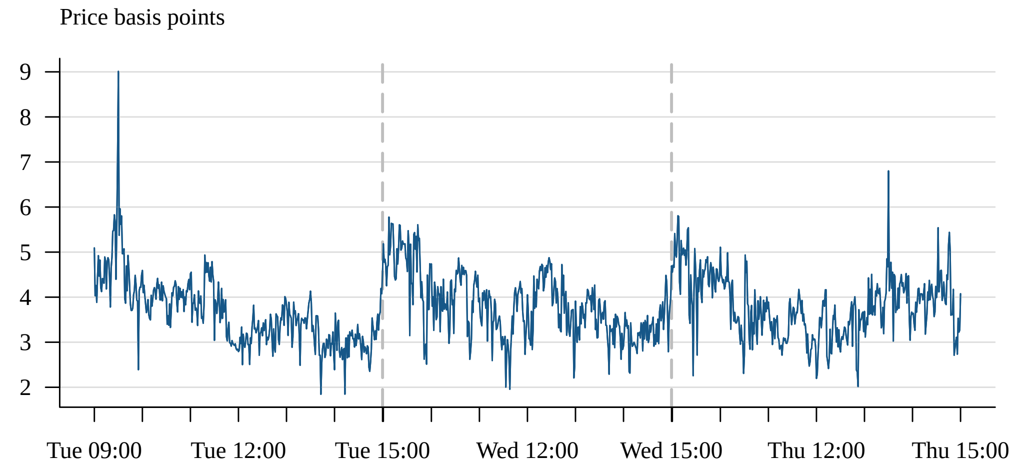


(b) GBP100 million.

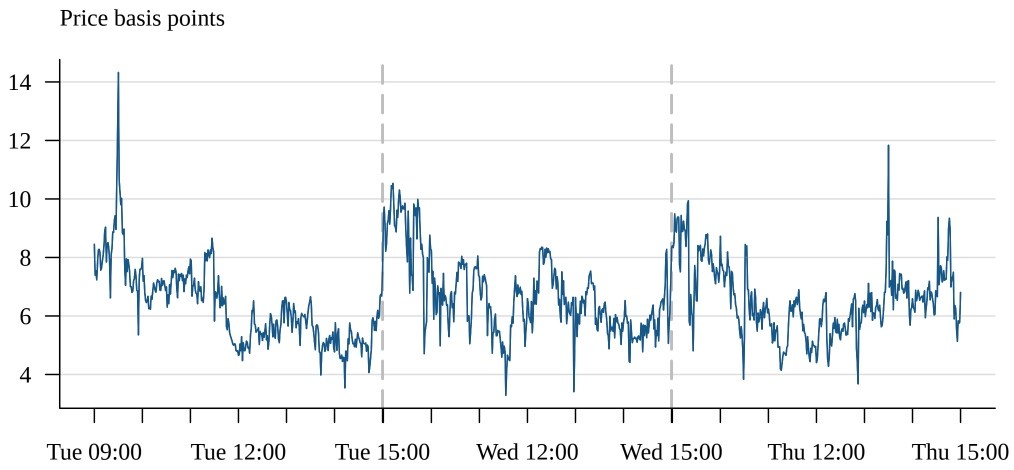


(c) GBP200 million.

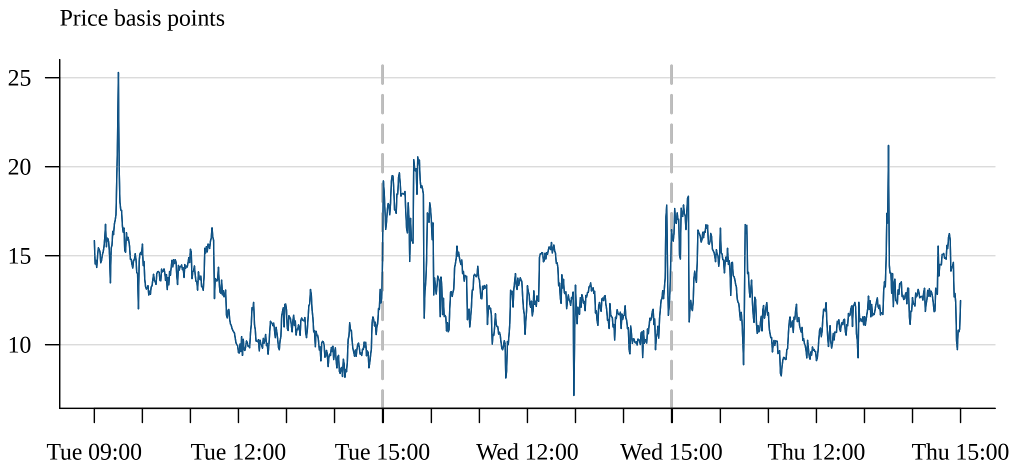
Figure 11: Xetra liquidity measures for January 26th, 27th and 28th, 2016.



(a) GBP50 million.



(b) GBP100 million.



(c) GBP200 million.

Figure 12: Xetra liquidity measures for August 9th, 10th and 11th, 2016.

8.3 Market liquidity during episodes of distress

We assess liquidity resilience in the gilt futures market during two episodes of potential distress: the Swiss franc de-peg from the euro on January 15th, 2015; and the EU Referendum on June 23rd, 2016. These are described in Sections 8.3.1 and 8.3.2, respectively.

8.3.1 The Swiss franc de-peg

Amid turbulent financial markets, in 2011 the Swiss National Bank (SNB) imposed a floor under the EURCHF exchange rate. The Swiss franc's "safe haven" status had seen the currency strengthen sufficiently to hurt Switzerland's export market which accounted for 70 percent of the country's gross domestic product. A level of 1.20 was defended by the central bank, which saw a strongly expanding balance sheet as a result of the necessary interventions in the foreign exchange market.

At 09:30 on January 15th, 2015 the SNB unexpectedly announced that it would no longer prevent appreciation of the franc against the euro.[16]

Three main reasons have been put forward for the abandonment of the policy.[17] First, foreign exchange intervention was funded by printing Swiss francs, and it was feared that this would eventually lead to uncontrolled inflation. Second, the European Central Bank was about to introduce "quantitative easing", which would push down the value of the euro and make it more difficult to maintain the floor. Third, in 2014 the euro depreciated against other major currencies such as the dollar and so did the Swiss franc. This implied that the franc was no longer overvalued and the argument for intervention was weakened.

The repercussions of the removal of the floor by the SNB were felt most strongly in the EURCHF currency market (see Bank for International Settlements (2015) and Cielinska et al. (2017)). We consider the potential effect of the change in policy on liquidity in the long gilt futures market.

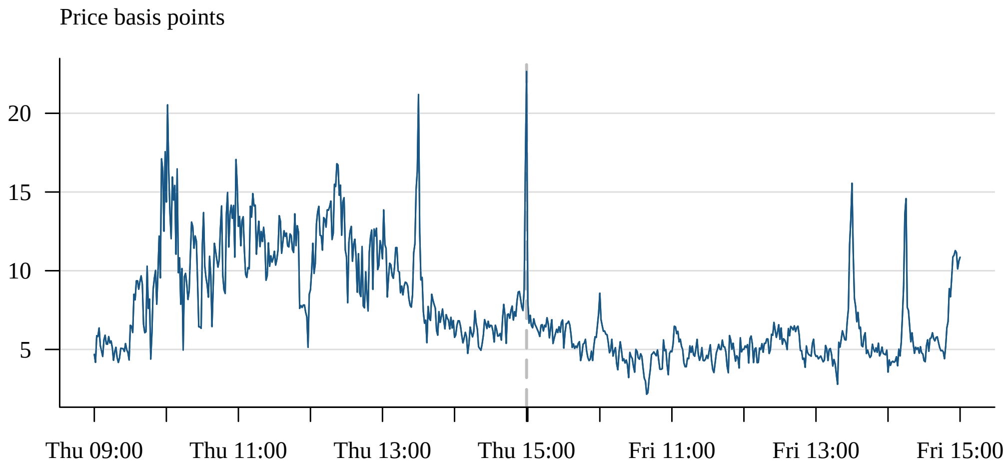
Figure 13 shows the intraday series of XLM on Thursday, January 15th, 2015 and on the following day. At 09:00 on Thursday morning, liquidity does not suggest any sign of market turmoil, which is consistent with the fact that the de-peg was unanticipated. Prior to the floor in EURCHF being removed, the XLM values for 50, 100 and 200 million GBP (see Figures 13a, 13b and 13c, respectively) are similar to their unconditional means shown in Table 3. The XLM displays a clear spike across all volumes at 09:30, when the exchange rate floor was abandoned. Liquidity, however, in each case returned almost to pre-event levels by the end of the trading

[16]See Cielinska et al. (2017) for a recent analysis of the Swiss franc de-pegging.

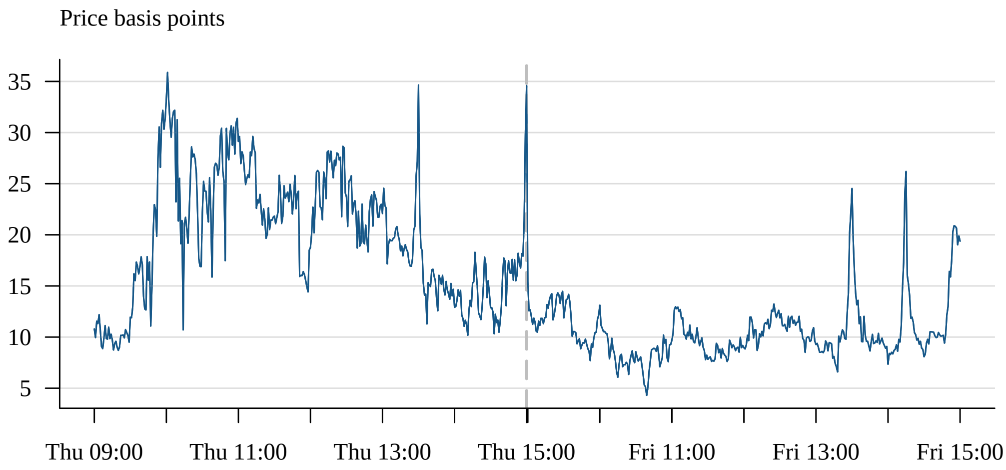
[17]See Economist (2015) for a discussion of the reasons that led to the de-peg.

day. By the following morning, liquidity has returned to normal levels. The few visible spikes during the following day are most likely due to normal trading activity.

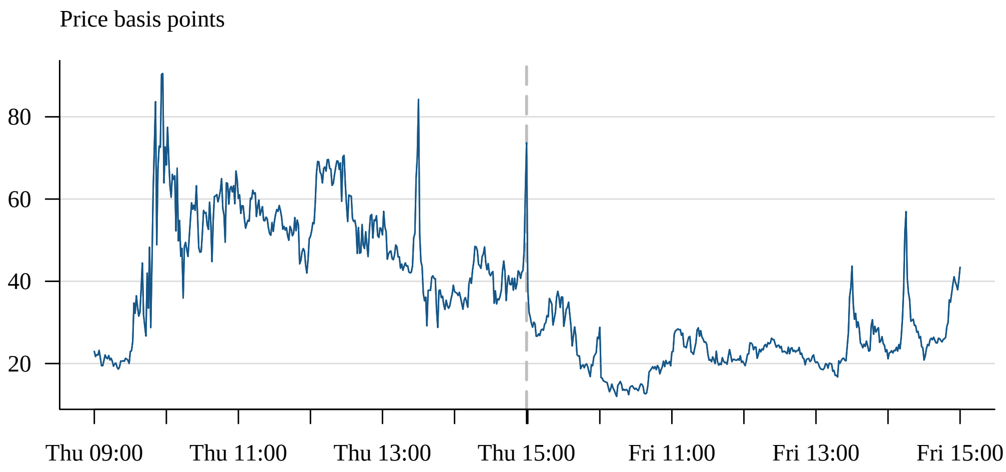
The Swiss Franc de-peg thus did not produce any major effect on the UK long gilt futures market.



(a) GBP50 million.



(b) GBP100 million.



(c) GBP200 million.

Figure 13: Xetra liquidity measures for January 15th and 16th, 2015.

8.3.2 The EU referendum

The United Kingdom European Union membership referendum, also known as the EU referendum, took place in the United Kingdom and in Gibraltar on Thursday, June 23rd, 2016.[18] According to the non-binding outcome, 51.9 percent of voters expressed their wish to leave the European Union.[19]

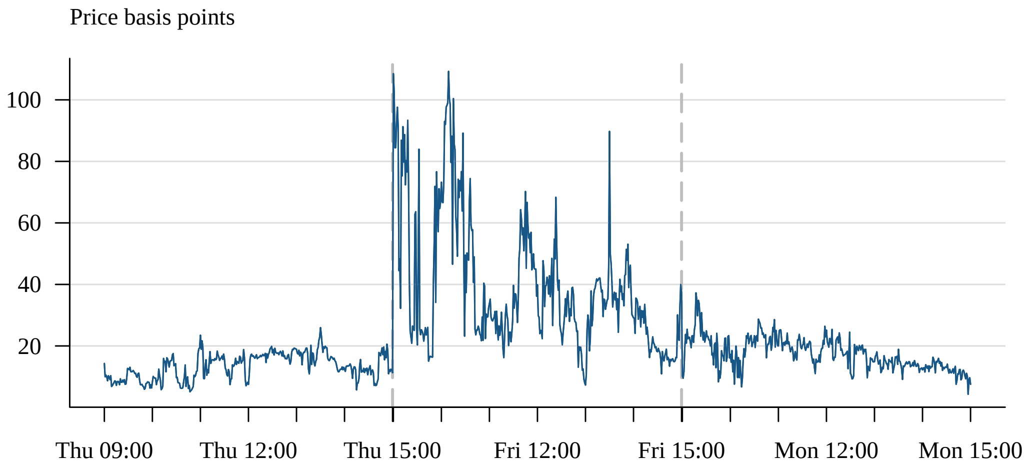
As the public voted, the UK long gilt futures market was already relatively illiquid. The XLM for volumes equal to 50, 100 and 200 million GBP were all above their unconditional means shown in Table 3 (see Figures 14a, 14b and 14c, respectively). This is consistent with the view that market participants were still pricing in some uncertainty about the outcome of the referendum.

The result of the referendum was already known by the time trading began on Friday, 24th June. In the first few hours of trading, liquidity dried up to the point at which an order of GBP200 million was not executable (see Figure 14c). After the initial step higher, the XLM exhibits a declining trend which is more obvious for lower trade sizes. The existence of such a trend is confirmed by including Monday 27th June. Following the weekend, liquidity had clearly improved. By the end of the Monday the long gilt futures market was more liquid than on the day of the poll. By 15:00 on the 27th, the XLM for trades of 50, 100 and 200 million GBP were equal to 7.5, 16.4 and 32.6bp respectively — not too far from the unconditional mean values reported in Table 3. In light of the link between market liquidity and funding liquidity uncovered in Section 6, this result suggests that an adequate level of funding liquidity was present.[20]

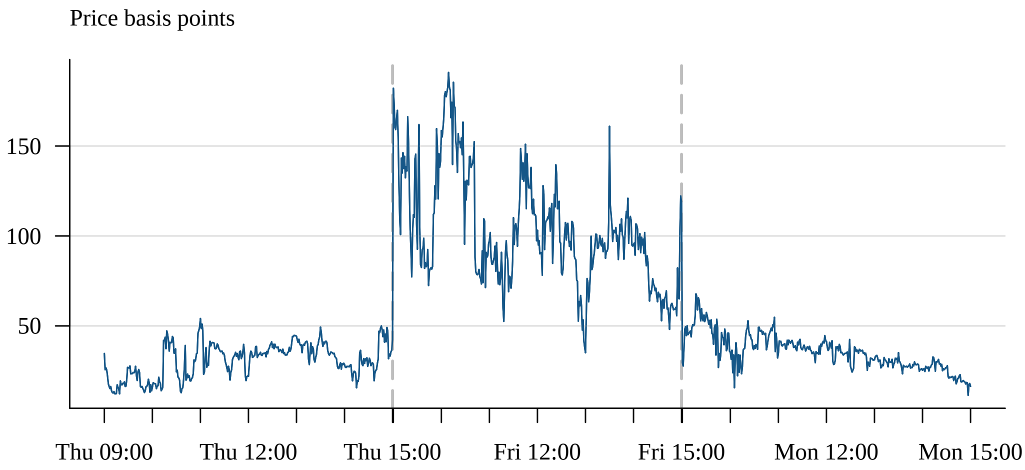
[18] See the European Union Referendum Act 2015 available at http://www.legislation.gov.uk/ukpga/2015/36/contents/enacted.

[19] The official results of the EU referendum may be found at http://www.electoralcommission.org.uk/find-information-by-subject/elections-and-referendums/past-elections-and-referendums/eu-referendum/electorate-and-count-information.

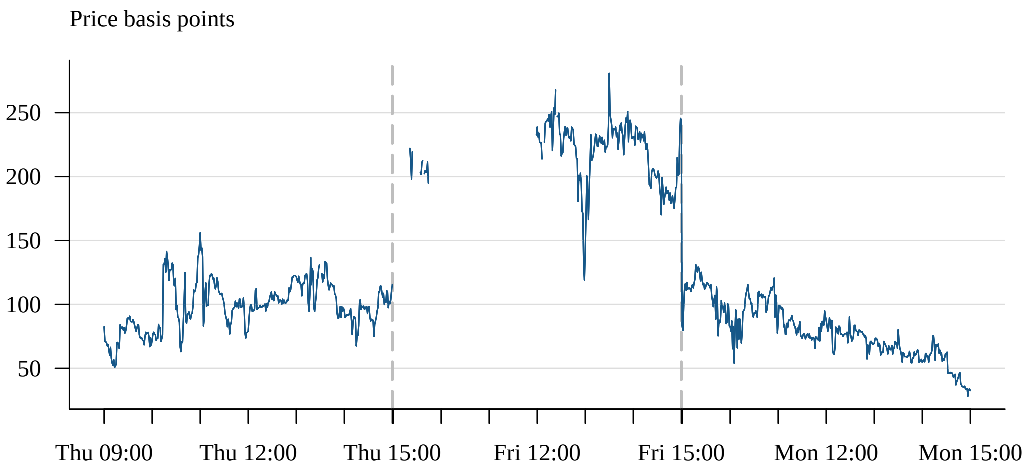
[20] Because we have data only to 19th April, 2017, we are not able to say anything about long term effects of the leave vote. However, the mean values for the period between 27th June, 2016, and 19th April, 2017, are equal to 5.00, 8.80 and 18.38bp, respectively. Again close to the long term averages in Table 3.



(a) GBP50 million.



(b) GBP100 million.



(c) GBP200 million.

Figure 14: Xetra liquidity measure on June 23rd, 24th and 27th, 2016.

8.4 Discussion

We have studied the effects of expected and unexpected events on liquidity in the UK long gilt futures market. Our analysis suggests that these effects are either absent or short-lived, which implies that liquidity is resilient to shocks. In light of the discussion in Section 6, one possible explanation is that funding liquidity is adequate to ensure that market liquidity does not deteriorate during periods of potential turmoil.

9 Conclusion

This paper studies liquidity dynamics in the UK long gilt futures market between the end of 2014 and mid-April 2017. Compared to the related existing literature, the novelty of our work is in that we use high frequency intraday order book data. We can thus build a precise liquidity measure using the information stemming from the entire order book. In particular, we are able to express liquidity in terms of a round-trip cost as a function of the underlying transaction volume. We use our chosen liquidity measure to assess liquidity resilience in response to a shock.

Our results show that liquidity is resilient to external sources of pressure, be they generated by recurrent policy operations such as the APF auctions, or by less predictable events such as the Swiss franc de-peg or the outcome of the EU referendum. Such resilience does not come at the expense of deterioration in liquidity during normal times, for example as a result of some form of regulatory intervention. During the sample period of interest, liquidity displays statistically significant evidence of improvement. Although we cannot draw any conclusion regarding the underlying trend due to the limited time series coverage of the data, this result implies that liquidity does not deteriorate. This finding may be motivated by an adequate provision of funding liquidity and it has important implications for policy makers such as regulators: in line with Adrian et al. (2016), our results suggest that there is no trade-off between liquidity resilience and a positive liquidity trend as an effect of a regulatory intervention.

Our work could be extended in several directions. In particular, it is our priority to understand the joint dynamics of liquidity in the UK cash gilt and gilt futures market. This would complement the analysis carried out in this paper, which only looks at the latter. This research question is highly relevant to policy makers; we will attempt to provide an adequate answer in future work.

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