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Capital market liquidity in the 2020 coronavirus crisis

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Summary

The coronavirus (Covid-19) crisis is one of the largest shocks to the global economy on record. This paper examines how UK equity markets (exchange traded cash, ETF and derivative) and bond ETFs managed this unprecedented period of stress. It provides descriptive statistics of liquidity measures in these markets during the stress period that began in March 2020. It finds that the dramatic fall in liquidity reached 2008 crisis levels. While this has since mostly recovered, partial deterioration persisted as of February 2021. This paper also examines whether measures of market uncertainty or funding constraints are more associated with the dramatic fall in liquidity during the crisis in equity markets, finding that uncertainty seems to be the most correlated with reductions in liquidity.

1 Overview

Purpose

The Covid-19 pandemic is one of the largest economic shocks to hit the global economy on record. UK GDP fell by 9.9% in 2020 - one of the largest annual declines since records began.[1] It resulted in some of the largest single-day falls in asset prices since the crashes in 1987. On March 12, 2020, for instance, the FTSE 100 fell by more than 10%.[2] The S&P 500 dropped by 9.5% the same day and a further 12% on the 16th March.[3]

These large increases in volatility were accompanied by a significant deterioration in the liquidity of capital markets. Even for the usually deep market for US treasuries, there were reports of 'extreme difficulty in executing even modestly sized transactions' and 'very large increases in transaction costs'.[4]

The purpose of this note is to examine the extent to which the liquidity of UK equity markets (cash, ETF and derivative) and bond ETFs[5] were affected during this period of extraordinary stress. To contextualise our findings, we draw comparisons with the peak of the global financial crisis (GFC) in autumn 2008 and examine key measures which may correlate with reductions in liquidity.

Key findings

We find that for cash equities traded on the LSE measures of liquidity deteriorated to 2008 crisis levels. We find similar results in other markets.

We find that the huge increase in uncertainty arising from the pandemic was reflected in the significant rise in the (implied) volatility index, the VIX. The decrease in liquidity mostly mirrors this rise in uncertainty.

Constraints on funding available to market participants are a concern if they appear to diminish their ability to provide liquidity. At the onset of the crisis we observe sizeable demands for short term funding in money markets, with the spread between 3M LIBOR and OIS rising almost to 2008 levels as well as a significant increase in initial margin requirements on derivatives exchanges. Despite this, our initial analysis[6] finds limited evidence that funding constraints play a major role in cash equities markets with the level of uncertainty or implied volatility, as measured by the VIX, being the most correlated variable. Further research is needed to fully understand drivers of illiquidity.

[1] https://www.ons.gov.uk/economy/grossdomesticproductgdp/bulletins/gdpmonthlyestimateuk/december2020

[2] https://www.bbc.co.uk/news/business-51829852

[3] https://www.ft.com/content/82c5c2ca-670e-11ea-800d-da70cff6e4d3

[4] https://www.brookings.edu/blog/up-front/2020/05/01/how-did-covid-19-disrupt-the-market-for-u-s-treasury-debt/

[5] For an examination of Bond ETF resiliency in times of stress (excluding Covid period due to data limitations) and how ETF Authorised Participants contribute to this, see: "Aquilina et al. 2021, "Research Note: Fixed Income ETFs: secondary market participation and resilience during times of stress", https://www.fca.org.uk/publications/research/research-note-fixed-income-etf

[6] Our analysis is limited in that it does not examine funding constraints outside of equity markets. Further, we do not directly measure funding constraints, such that the proxies we use may not fully capture constraints. Additionally, we only examine aggregate funding constraints and not constraints affecting individual firms.

2 Related literature

In this section, we detail early research examining capital market liquidity during the Covid-19 crisis, noting that this research predominantly focuses on US markets. We also cite numerous studies that examine capital market liquidity in the 2008 crisis, to help inform our understanding of liquidity stress in the Covid-19 crisis. We also consider research on the role of funding constraints in affecting liquidity in times of stress. We use these initial insights to help inform our analysis of drivers of illiquidity in more detail, later in this paper.

Research examining Covid-19 liquidity

Baig et al. (2020) examine the US equity market, finding that the number of confirmed Covid-19 cases, related deaths, lockdowns and measures of public fear are negatively correlated with market liquidity and stability. Ibikunle and Rzayev (2020) examine European markets, finding that after the onset of Covid-19 induced volatility, lit quoted spreads widen by 22 basis points on average and the share of dark trading reduces - with lit market share increasing. They also find that lit quoted spreads widen around 7 basis points less for stocks that allow dark trading (i.e. are not subject to MiFID2 dark trading bans) in a matched sample.

For the US corporate bond market, Kargar et al. (2020) document a significant rise in transaction costs of up to 8 times pre-crisis levels. The US Federal Reserve intervened on 17 March, 2020 to provide loans to dealers in return for investment grade bonds[7], helping them to provide liquidity by reducing inventory costs. It later intervened on 23 March to purchase corporate bonds.[8] They find that after the first intervention, dealer inventories improve and liquidity improves. Liquidity improves for all bonds after the second intervention. Aramonte and Avalos (2020) focus on bond ETFs, showing that ETF prices are more reactive than their Net Asset Values (NAV) – which are often stale in periods of high volatility. This caused ETFs to trade at discounts to NAV.

Fleming and Ruela (2020) show that U.S. bond volatility reached a 15 year high on 19 March, with market makers providing less depth at wider spreads. While volatility was higher than the 2008 crisis, shifts in spreads and market depth were smaller in comparison. Nozawa and Qiu (2020) observe that credit spreads rose to their highest level in mid-March 2020 (5% for BBB-rated corporate bonds and 11% for High-Yield (HY) bonds) in the U.S. bond market. However, these levels of credit spreads are still below 2008 peaks.

Research examining 2008 crisis liquidity

There are many more studies examining the deterioration in liquidity during the 2008 crisis, which can inform our understanding of the more recent crisis. Nagel (2012) uses short-

[7] The US Central Bank, the Federal Reserve, resumed an institution which it created to deal with the 2008 crisis called the "Primary Dealer Credit Facility" (PDCF) which issues overnight loans to the major US bond market dealers in exchange for investment grade bonds as collateral. Source: www.federalreserve.gov/newsevents/pressreleases/monetary20200317b.htm

[8] The US Central Bank, the Federal Reserve, created a special purpose vehicle called the "Primary and Secondary Market Corporate Credit Facility" (PMCCF) which issues loans to investment grade corporations and purchases corporate bonds. This program was extended to include non-investment grade bond on the 9th of April. Source: www.federalreserve.gov/newsevents/pressreleases/files/monetary20200409a5.pdf

term reversal strategy returns to proxy for the returns to liquidity provision, showing that they are significantly correlated with the VIX (the volatility index). The expected return and the risk premium earned by liquidity providers increases during periods of high VIX index. Acharya and Mora (2015) investigate how bank liquidity provision was affected by the US subprime crisis. In contrast to a predicted 'rush to safety' in a crisis in the form of increased bank deposits, they show that banks experienced deposit withdrawals which then hampered their ability to cushion systemic shocks to corporates through increased credit lines.

Research examining funding constraints and impact on liquidity

Trading requires funding. Numerous studies examine whether constraints on dealer (or market maker) funding has an adverse impact on liquidity provision and thus overall market liquidity. Brunnermeier and Pedersen (2009) model the relationship between trader funding constraints and market liquidity. They show that during downturns, when funding constraints are high, traders are less willing to take on positions - particularly those in securities that require more funding. This leads to a reduction in market liquidity which, in times of crisis, creates pro-cyclical illiquidity spirals.

Comerton-Forde et al. (2010) examine equity markets, finding that market maker balance sheet size is correlated with their willingness to provide liquidity, conditional on their lagged inventories and trading revenues. This is consistent with the hypothesis that, as market maker inventories increase, they become reluctant to take on more inventory, leading to widened market effective spreads.

Adrian, Boyarchenko and Shachar (2017) examine bond markets, finding that bonds traded by less funding constrained dealers are more liquid.[9] Hameed et.al. (2010) find that negative market returns are accompanied by greater liquidity reductions when financial intermediaries are expected to face funding constraints.

Regulatory interventions in the wake of the 2008 financial crisis, such as the Volcker rule which placed limits on proprietary trading, are associated with decreases in bond market liquidity (Bao et. al., 2018). Bessembinder et al. (2018) also focus on Basel III requirements, arguing they lead to a reduction in dealer willingness to commit funding, though with no impact on overall transaction costs. Other studies find no significant adverse effect of the Volcker rule on market liquidity (Trebbi and Xiao, 2019; Adrian et al. 2017).

Another strand of research has focused on the role of trader margin requirements with central clearing counterparties (CCPs). CCPs collect initial margins from traders as collateral to ensure they can meet their obligations in the event of default. This initial margin is, however, a procyclical variable – meaning that it increases in periods of stress – further intensifying market stress (Murphy et al. 2014; Glasserman and Wu, 2018). For example, Dudley and Nimalendran (2011) find that initial margins of future contracts jumped from 5% to around 15% during the last quarter of 2008. They discuss that margins are known to be 'sticky', meaning when they increase, they tend to be persistent. They find that only part of the variation in margins is accounted for by variation in the volatility index.[10] This suggests that margin requirements relate to

[9] See also Adrian and Shin (2010).

[10] The VIX is a measure of the implied volatility embedded in S&P500 equity options, weighted at a 30-day horizon. It therefore measures the market's expectations of future volatility via expectations of future movements in equity prices (in either direction).

funding risks unrelated to the VIX. They also observe a negative correlation between margins and the Amihud (2002) measure of illiquidity.

3 Descriptive statistics for market liquidity

Market liquidity is the degree to which a security can be traded at a price close to its consensus value, (Foucault, Pagano and Röell, 2013). Because we focus our attention on exchange traded markets, measuring liquidity is more straightforward. This is because these markets contain 'centralised limit order books' which are collections of buy and sell orders by participants – at specified prices and quantities - that rest on the market until a buyer matches a resting sell order, or vice versa. The difference between best (or highest) buy order and the best (or lowest) sell order is the quoted spread.

There are 2 key measures of liquidity which we focus on: the quoted spread, which is measured as the difference between the best buy (or highest) price and the best sell (or lowest) price – the 'cost of liquidity', and market depth which is measured as the total volume at each buy and sell price – the 'amount of liquidity'.[11] We describe the data and calculation specifics in more detail in the Annex 2.[12]

Key measures in cash equities (LSE)

We focus our attention on cash equities, but we note that the results across exchange traded bond and equity ETFs and exchange traded equity futures are highly similar, which we discuss in detail in the Annex 1. On the LSE, quoted spreads in the pre-crisis period for the most liquid stocks (FTSE 100 stocks) average 4 basis points[13]. Figure 1 shows that at the peak of the crisis, spreads increase 5 times to 20 basis points on the 19 March, 2020 – levels not seen since 2008 – before settling to an average of 5.5 basis points in November. Given the UK's 'second wave' lockdown began on the 5 November, it does not appear to have impacted liquidity in the same way as the first. This could be because second wave lockdowns were less strict[14], consumers postponed rather than cancelled spending[15], and second wave expectations were already priced into financial markets. Spreads have continued to improve, averaging 4.85 basis points in February 2021 for the FTSE100 but this still appears elevated in comparison to pre-crisis levels.[16]

The average of the sum of market depth at the best 10 prices in FTSE 100 stocks decreases from £628k[17] to £167k on the 19 March - a 4-fold decrease - shown in Figure 2. Depth has recovered to an average of £474k in November, which is 75% of pre-crisis

[11] The EU's Markets in Financial Instruments and amending Regulation (MIFIR) introduced a concept of "Non-addressable liquidity" in Article 23(3). Non-addressable liquidity consists of trades that "do not contribute to the price discovery process". Examples given in ESMA technical standards include "give up" trades and "allocation trades" that do not occur on lit market exchanges. In this paper, we consider only lit-market liquidity, which forms part of the price discovery process and is thus addressable liquidity.

[12] We calculate these measures first as time-weighted averages for a given stock-date and then value-weighted averages across each of the securities in the market on a given date. This approach follows standard practice in market microstructure research. Further details on methodology are provided in the Annex.

[13] Mean quoted spreads for 7-day period of the 13th of February to the 20th of February, 2020 are 4.05 basis points.

[14] https://www.reuters.com/article/us-europe-economy-lockdown-factbox-idCAKBN27I1KG

[15] https://www.ft.com/content/446124cb-17ea-4913-a0ad-fc2230dc64ec

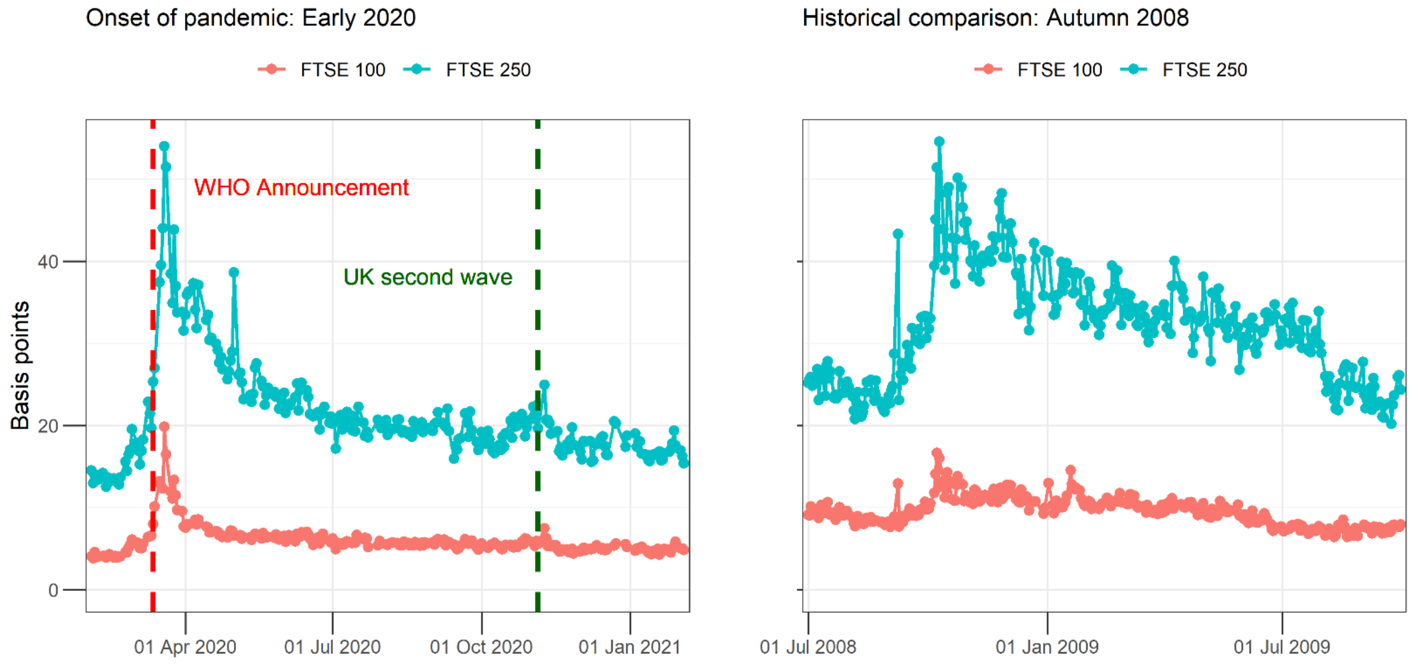
[16] As at publication date spreads and depths have now almost entirely recovered to pre-crisis levels.

[17] Mean depth on both sides of the orderbook for the 7-day period of the 13th of February to the 20th of February.

levels, and £522k in February 2021, which is 83% of pre-crisis levels. Therefore, liquidity has mostly recovered, but remained partially deteriorated as of February, 2021.

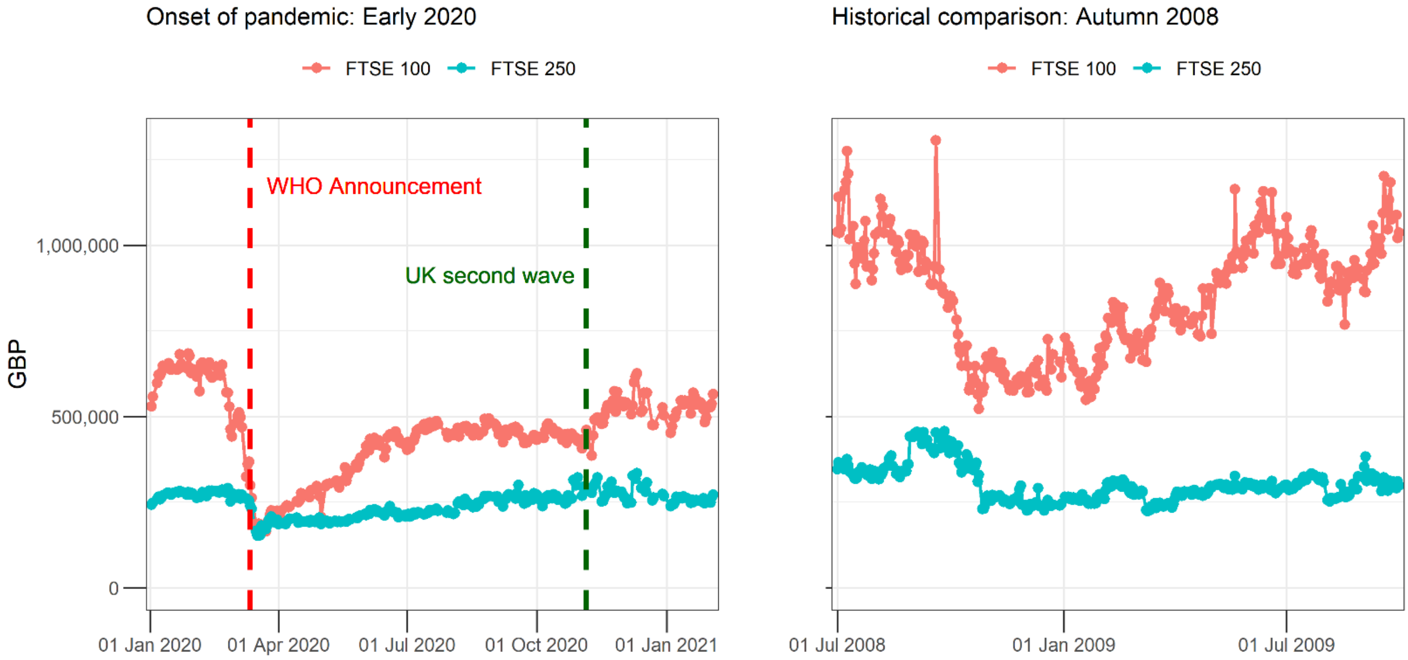
To contextualise this deterioration in liquidity, we calculate the same metrics for the duration of the 2008 crisis, the period 1 July 2008 to 1 October 2009. We see that similarly to this crisis, spreads remain elevated for a prolonged period, taking several months to fully revert to previous levels. Spreads peak at 17 basis points in October 2008. 10-level FTSE100 depth similarly declines from an average of £1,029 in July 2008 to £605 in the last 2 weeks of October 2008, 59% of pre-crisis levels. It takes until September 2009 for depth to fully recover, a period of 11 months since the beginning of the crisis.

Figure 1: Quoted spreads in cash equities on LSE – 2020 vs 2008



Source: Analysis of Thomson Reuters Tick History data

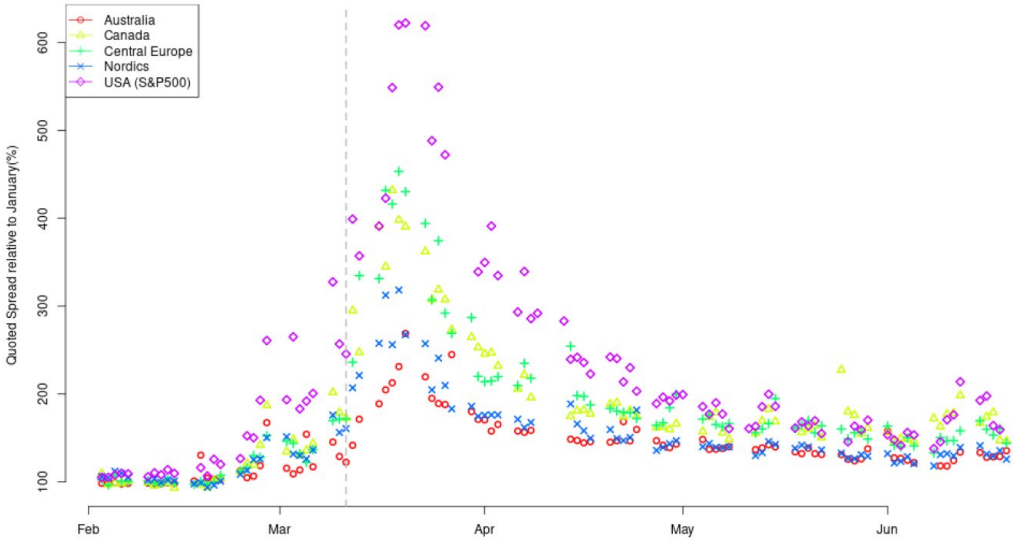
Figure 2: Depth in cash equities on LSE – 2020 vs 2008



Source: Analysis of Thomson Reuters Tick History data

When liquidity is calculated on other major equity market indices, a similar picture emerges in Figure 3, taken from Foley et al. (2020). This demonstrates that the reduction in liquidity on UK financial markets was experienced in other countries. There is likely commonality in the drivers of illiquidity at a global level.

Figure 3: Quoted spreads on global exchanges – 2020



Source: Foley et al. (2020)

Low liquidity – associated with uncertainty?

Both 2020 and 2008 crises represent periods of significant uncertainty about the value of assets. Liquidity providers in markets bear risks from uncertainty as prices may move against their resting orders. They demand greater remuneration for increased risks in the form of higher spreads. So as expected volatility increases, liquidity decreases. A proxy for levels of uncertainty is the Volatility Index (the VIX) which measures the implied volatility in S&P500 options, weighted at a 30-day horizon.[18] We chart quoted spreads and depth against the VIX in Figure 4.

Figure 4 shows that changes in quoted spreads and volatility are highly correlated.[19] As short-term volatility declines, so does the spread. Changes in depth and volatility are also correlated, as predicted by theory (eg Foucault, Pagano and Roell, 2012).

[18] While the VIX focuses on relatively short-term volatility, at a 30-day horizon, futures on the VIX that expire at longer time-frames provide evidence of expectations of medium and long-term volatility. See Annex for VIX June vs October and November expiries.

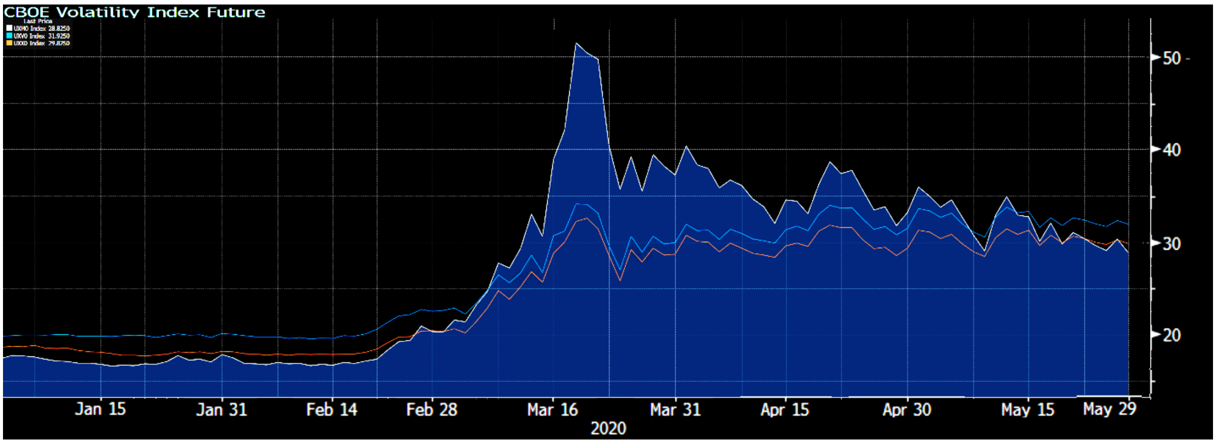
[19] We also compare the Volatility index of the FTSE 100 index, with qualitatively similar results.

Figure 4: Liquidity and volatility

Source: Refinitiv Datascope Select

We also examine longer term expectations of volatility in Figure 5. The VIX Index measures expectations of volatility over the next 30 days, which may be different to expectations of volatility in 90 days or even longer time periods. This means that while the shorter term (30-day horizon) VIX may have declined, longer-term expectations may not have declined. Figure 5 charts CBOE Futures on the VIX for longer-term expiries, as observed at May 29th 2020. The VIX contract expiring in June (charted in white) has declined but longer-term expiries have not (October and November expiries in blue and orange), demonstrating that expectations of long-term volatility remain high.

Figure 5: CBOE VIX Futures traded on June, October, and November 2020 Expiries



June expiry charted in White, October in Blue, November in Orange.

Source: Bloomberg

Low liquidity – associated with funding constraints?

Traders, including liquidity providers, draw on funds to hold inventory but also to fund separate positions which may net to zero. This is because they are required to post collateral with clearers. As funding is finite, constraints on funding may become more severe in stress periods. Understanding the presence of these factors is important for preparing for the next crisis.

In examining funding constraints, we are concerned specifically with situations where liquidity providing firms do not have enough funding available to them to provide liquidity, and/or the price of additional funding impacts their liquidity provision. For example, Virtu, a large global trading firm, announced on 20 March, 2020 that they would be raising almost half a billion USD in additional funding, almost half of their existing FY2019 equity,[20] to 'augment our liquidity provisioning services globally'[21].

We propose various measures below that attempt to proxy for the overall level of funding constraints in a market. A limitation of these measures is that funding constraints are specific to each trading firm, so that overall measures may not accurately reflect the constraints an individual firm faces.

Short-term funding rates

As discussed in Brunnermeier and Perdersen (2009), funding liquidity is a key determinant of market liquidity. As was the case in 2008, the 2020 crisis has seen similar stress in short-term funding markets. In its Interim Financial Stability Report (FSR), the UK's Financial Policy Committee (FPC) notes that a significant 'dash for cash' ensued in the crisis with non-banks raising cash to meet margin calls and 'dealers stepping back from repo markets'.[22]

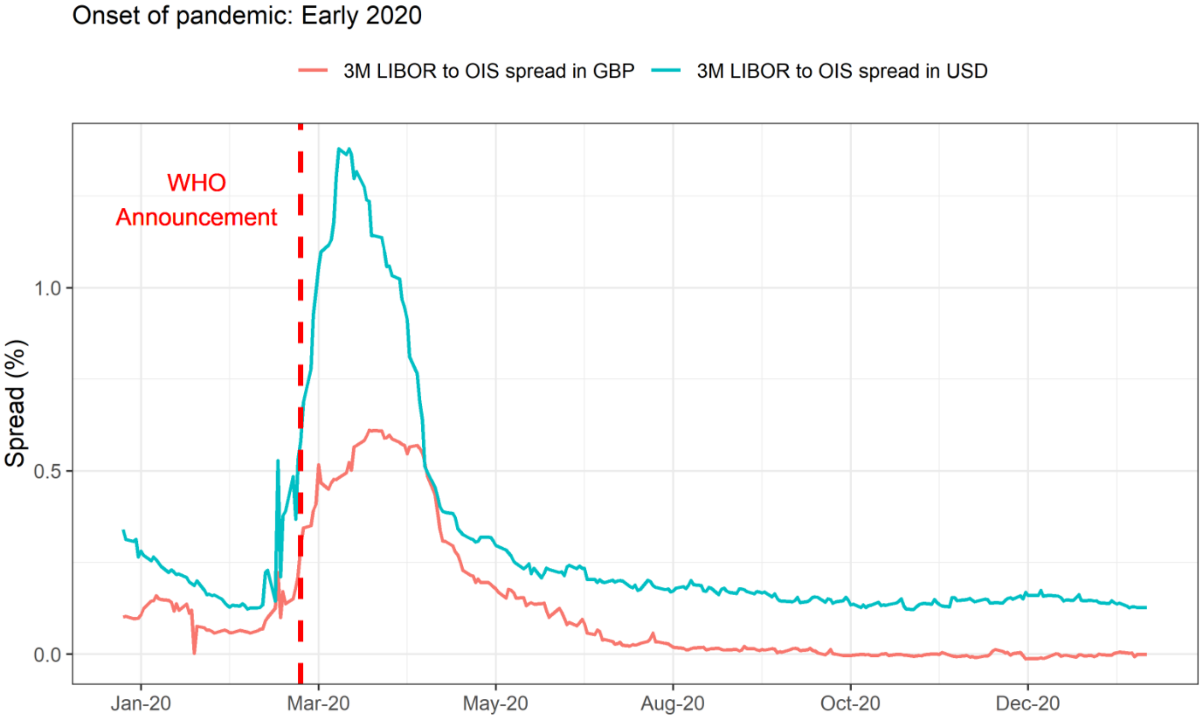
[20] s2.q4cdn.com/591992113/files/doc_downloads/Virtu_10K.pdf

[21] ir.virtu.com/press-releases/press-release-details/2020/Virtu-Announces-450-Million-of-Additional-Broker-Dealer-Borrowing-Capacity-and-Preliminary-Quarter-to-Date-Results/default.aspx

[22] www.bankofengland.co.uk/-/media/boe/files/financial-stability-report/2020/may-2020.pdf

These stresses are perhaps visible in LIBOR to Overnight Index Swap (OIS) spreads during March and April. The USD and GBP Libor-OIS spread peaked at the end of March and mid-April respectively, but have mostly recovered to pre-crisis levels since then (see Figure 6). Stress is also visible in the spread of the US Treasuries to overnight-index swap (OIS) rates, as documented in He et al. (2020).

Figure 6: Short -term funding rates



Source: Refinitiv Datascope Select

<u>Exchange margin requirements</u>

As noted in Brunnermeier and Perdersen (2009), increases in margin requirements may lead to market participants facing funding constraints as they make large margin payments, which then impact funding available to provide liquidity. The Bank of England's August 2020 Financial Stability Report (FSR) details that the non-bank sector made significant variation margin payments and experienced an increase in margin calls, as well as increases in initial margins. The Bank of International Settlements calculates that initial margins on US equity index futures indexes roughly doubled (Huang and Takáts, 2020). Eurex, the largest derivatives exchange in Europe, had its EURO STOXX 50 index initial margin jump from 7 to 17% in March 2020 compared to March 2019[23], and said they were experiencing an average of 51 margin calls a day.

We find that on the UK's primary derivatives exchange, ICE Futures Europe, LIFFE initial margins more than doubled from 5% pre-crisis to around 12%, where they remain as of December 2020.[24] Futures exchanges are highly interlinked with their underlying cash markets, such that studies show that most price discovery occurs on futures markets

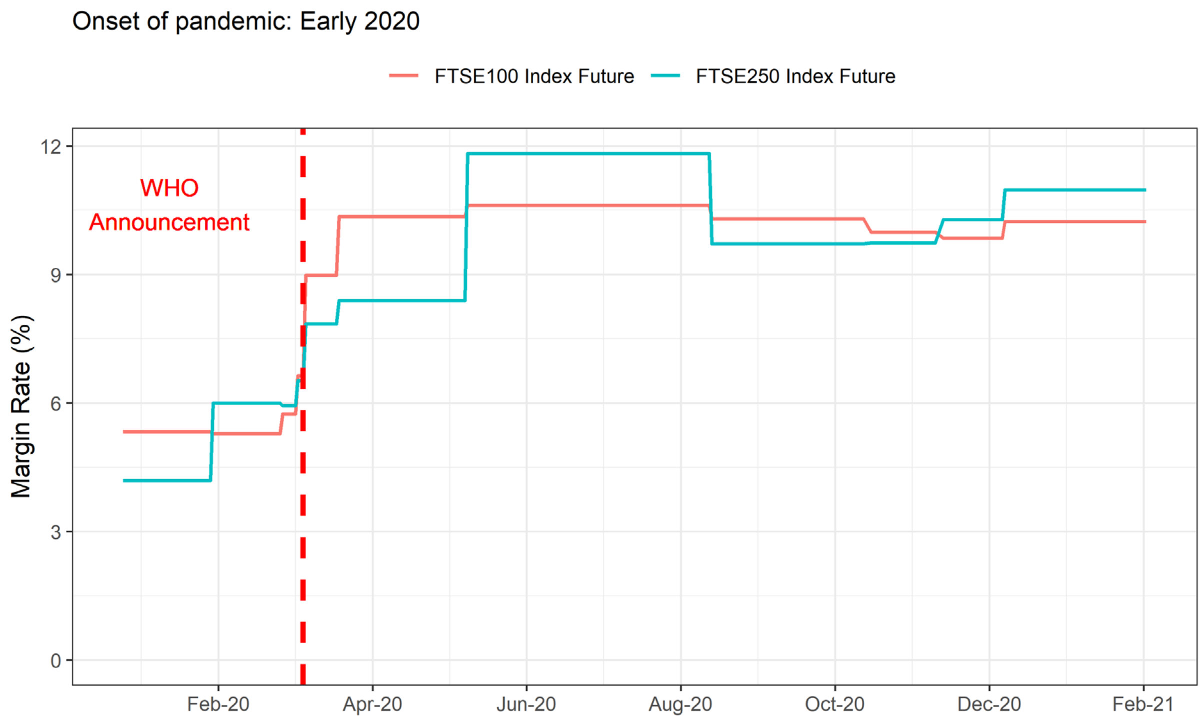
[23] Eurex Exchange, (2020)

[24] Note: the minor change in the margin rate (%) over time is caused by the "initial margin" being expressed in index points such that as the underlying index price changes, the margin rate as a % of the index fluctuates.

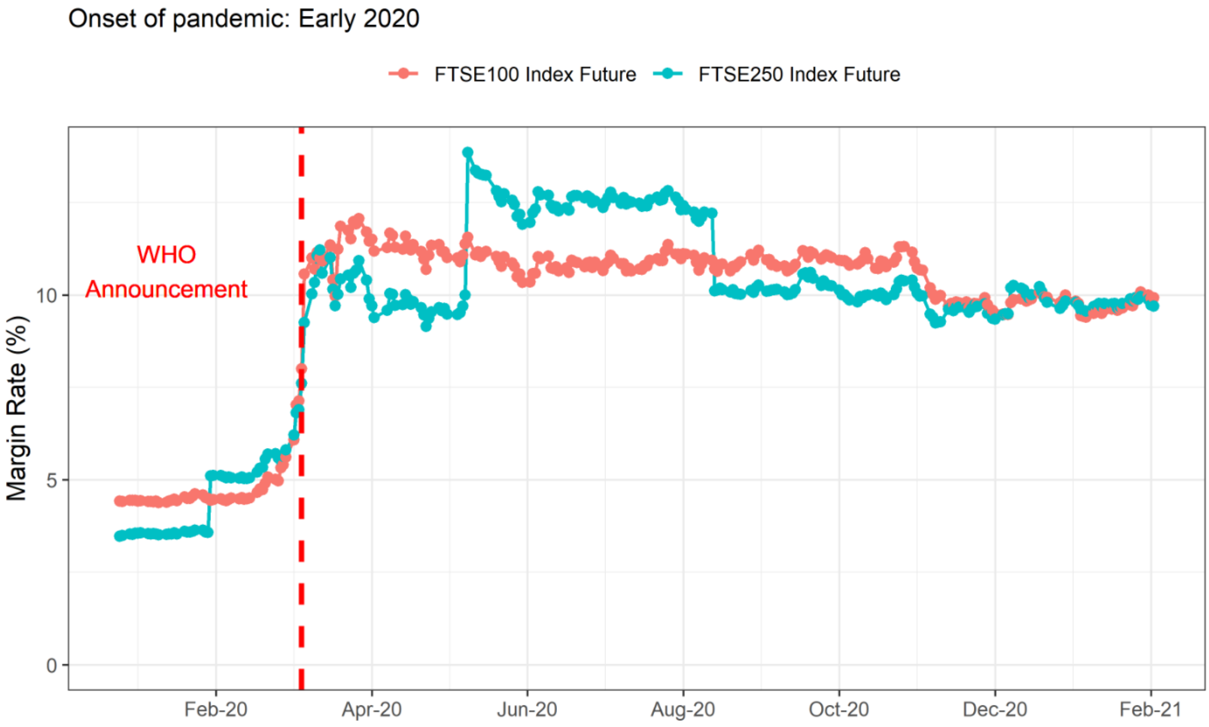
(Kawaller, Koch, and Joch, 1987; Chan, 1992). Figure 7 details ICE LIFFE margin requirements expressed as a percentage of notional trade value. This is expressed as a proportion of the average index price over the same period in Panel A (to remove the effects of daily price changes) and as a proportion of the daily price in Panel B. Dudley and Nimalendran (2011) demonstrate that margins are 'sticky' in response to volatility, which we find evidence for. Foley et al. (2020) provide evidence that exchange margins relate to liquidity measures.

Figure 7: ICE LIFFE FUTURES EUROPE initial margin requirements

Panel A: Margin rate as a % of average index price over sample period



Panel B: Margin rate as a % of daily index price over sample period



Source: ICE Europe Initial Margin Schedules

Competition for funding across asset classes

The significant selling of US Treasuries, as well as redemptions in Money Market Funds, created a significant volume of treasuries needing to be intermediated by dealer liquidity providers, requiring significant funding, as detailed in Duffie (2020) and the US Federal Reserve (Fed) Financial Stability Report (FSR).[25] The UK's Financial Policy Committee (FPC) FSR also states that this 'intermediation of markets was in part constrained' by capital requirements such as the leverage ratio (BoE Interim FSR 2020, and Bicu, Chen and Elliot, 2017).

These dealers may ration their funding internally amongst competing demands for it, so demands from the Treasuries market-making desk would affect funding available to the equities desk.

Conclusion

In this section, we detail levels of liquidity in the 2020 Covid-19 crisis, comparing them with levels in the 2008 crisis and showing that they deteriorated to similar levels during the peak. We also demonstrate that levels have recovered substantially, but remain impaired as of February 2021. In the next section, Section 4, we examine potential drivers of the deterioration in liquidity.

[25] US Federal Reserve 2020 Financial Stability Report, "As investors sold less-liquid Treasury securities to obtain cash, dealers absorbed large amounts of these Treasury securities onto their balance sheets. It is possible that some dealers reached their capacity to absorb these sales, leading to a deterioration in Treasury market functioning."

4 Drivers of market liquidity

In this section, we aim to determine whether there is a statistical relationship between changes in liquidity and our measures of volatility and funding constraints. We also want to assess the strength of this relationship in order to infer which measures are the most important drivers of illiquidity.

Numerous studies have empirically examined the relationship between illiquidity and the VIX in the US, (Chung and Chuwonganant, 2014; Nagel, 2012), funding constraints in individual market-makers (Comerton-Forde et al. 2014) and exchange margins (Foley et al. 2020). We examine the same drivers of illiquidity in this section for the UK.

Descriptive statistics: Volatility, funding constraints, margins and liquidity

	Statistics					
Variable	Mean	St.Dev	Min	Pctl(25)	Pctl(75)	Max
VIX	29.04	12.15	12.1	22.52	32.61	82.69
VIX_{100}	26.57	10.68	10.08	21.71	29.12	69.73
LIBOROIS_US	0.3	0.3	0.12	0.15	0.27	1.38
FTSE 100						
Spread	5.83	1.87	3.19	4.91	6.25	19.86
HF_vol	20.86	11.47	8.7	14.61	22.71	75.56
Margin	9.42	1.95	5.33	9.92	10.43	10.7
Depth	455,815.02	120,200.39	164,266.13	416,535.67	534,687.21	683,747.30
FTSE 250						
Spread	20.45	6.76	8.09	16.58	22.24	54
HF_vol	30.86	16.28	12.48	20.51	34.21	108.66
Margin	9.47	2.4	4.27	8.55	11.17	12.04
Depth	245,906.36	35,996.89	152,506.84	217,040.54	271,323.69	334,588.15

We run separate regression models of our different measures of liquidity (spreads and depth) against our explanatory variables of illiquidity in the following model specification:

$$\Delta LiquidityVariable_t = \alpha_t + \Delta ExplanatoryVariable_t + \Delta ExplanatoryVariable_{t-1} + \varepsilon_t$$

Our liquidity variables are time-weighted quoted spreads in basis points and 10-level time-weighted depth in £1000s which are taken as the value-weighted mean across all stocks in the FTSE100 or FTSE250. Our explanatory variables are lagged intraday volatility[26] ('HF_Vol'), the closing VIX ('VIX'), the closing 30-day implied volatility of the FTSE100 Index Options ('VIX_100'), the USD Overnight Index Swap to LIBOR spread ('LIBOROIS_US') and the ICE FTSE100 Futures margin ('Margin') in percentage terms, which are all sourced from Bloomberg except for the ICE margins which are sourced from ICE. Margins are calculated as a proportion of the average index price over the sample period to remove the effects of daily price changes. All measures are calculated daily and differenced for each date. Our sample period is 6 January 2020 to 3rd February 2021.

Our results are presented in Tables 1 for FTSE100 spreads and Table 2 for depth. Tables 3 and 4 report the same for the FTSE250. Across all models, previous day intraday volatility has almost no explanatory power in comparison to the implied volatility

[26] Measured as weighted average of the sum of squared 5-minute returns in each stock-date. Each date is lagged such that IntradayVol_t represents IntradayVol_t-1. We do this due to avoid endogeneity concerns.
The Akaike Information Criterion (AIC) determines that 1 lag is appropriate for our model.

measures: VIX and FTSE100 implied volatility. This implies that expected changes in asset prices are associated with illiquidity much more than recent changes in asset prices.

In Tables 1 and 2, FTSE100 implied volatility is the most effective explanatory variable, with the amount of variance in liquidity the model predicts (the adjusted R^2) being 7% for spreads and 16% for depth. This is likely because it aligns more closely with the risk of FTSE100 stocks. In contrast, in Tables 3 and 4 the VIX is more effective, which implies that the risk of FTSE250 stocks more closely aligns with global factors than the FTSE100.

Table 1 shows that an increase in the FTSE100 implied volatility of 1 results in a widening of the spread of .06 basis points and a reduction in depth of £4k (Table 2). As the standard deviation of the FTSE100 implied volatility is 13.97 this relationship is economically significant. These magnitudes are similar with the VIX, which implies that they likely share a common global factor.[27]

We first examine our first proxy for funding constraints, LIBOR_OIS, which aims to proxy for the cost of short-term funding. There is no statistically significant relationship with spreads and a low adjusted R^2 of 1%, but a statistically significant relationship with depth for the FTSE100. The relationship with depth is small however, with an adjusted R^2 of 2% for FTSE100 and 1% for FTSE250.

ICE Futures margin requirements have only a very weak statistically significant relationship for FTSE100 spreads and depth. Explanatory power is also low, with an adjusted R^2 of 0.3% and 0.1% for depth for FTSE100 and FTSE250 respectively, and 1% for spreads for FTSE100.

It is possible that the relationship between liquidity and funding constraints only exist because changes in LIBOR_OIS and Margin are highly correlated with changes in the VIX. To test this, we include these measures alongside the VIX in the same model (column 8 of each table). We find that the relationship with Margin and LIBOR_OIS disappears for spreads and depth across all regressions. Therefore, we can conclude that there is no evidence that our measures of funding constraints affect liquidity.[28]

We also examine the role of non-financial measures of the severity of the pandemic. We do this to assess any omitted correlated variable bias in our model. In other words, perhaps it is key events, such as the announcement of an emergency or lockdowns that are most important in driving illiquidity. We utilise dummy variables for the announcement of a nationwide lockdown in Italy and China, the declaration of a national emergency in the USA, the announcement of congress being close to passing a stimulus bill, and the announcement of a global pandemic by the WHO. We find that only the announcement of an emergency in the USA is strongly associated with an increase in spreads of 2.1 basis points for the FTSE100, but no impact on smaller FTSE250 stocks. We find that the announcement of the lockdown in Italy has a negative impact on FTSE100 depth with the announcement associated with an £82k reduction. We also obtain daily changes in the number of confirmed cases, and deaths, as reported by the

[27] When charted against one another the FTSE100 implied volatility (as well as the European Euro Stoxx, Australian ASX and even CBOE's China ETF volatility index) is highly similar to the VIX. This implies that the onset of volatility in financial markets was global and symmetric.

[28] Additionally, in unreported results we regress VIX against LIBOR_OIS and Margin which result in statistically significant relationships, again implying that that they are highly correlated with the VIX.

Johns Hopkins University COVID-19 data repository.[29] We find that both variables are not statistically significantly related to changes in spreads or depth.

Overall, we find evidence that changes in liquidity are highly correlated with changes in expected levels of volatility (such as the VIX). This is true for both of our measures of liquidity, quoted depth and quoted spreads. We find no evidence that funding constraints play a role. We speculate that this could be because funding constraints are less important in cash equities than in other asset classes.[30]

[29] "COVID-19 Data Repository by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University", https://github.com/CSSEGISandData/COVID-19

[30] For example, FCA Occasional Paper 50 finds that adverse selection comprises almost all of the spread in equities markets whilst Friewald and Nagler (2019) find inventory costs and other frictions are found to be significant in corporate bond markets.
We also estimate regressions by quartile subgroups based on pre-crisis liquidity, with results qualitatively unchanged.

Table 1: FTSE 100

	Dependent variable: $\Delta Spread_t$						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ΔHF_vol_{t-1}	−0.017** (0.008)						
ΔHF_vol_{t-2}	−0.012 (0.008)						
ΔVIX_t		0.050*** (0.014)					
ΔVIX_{t-1}		0.041*** (0.014)					
ΔVIX_100_t			0.061*** (0.018)				0.055*** (0.018)
ΔVIX_100_{t-1}			0.048*** (0.018)				0.049** (0.019)
$\Delta LIBOROIS\_US_t$				1.710 (1.143)			0.648 (1.193)
$\Delta LIBOROIS\_US_{t-1}$				1.144 (1.143)			−0.051 (1.178)
$\Delta Margin_t$					0.258 (0.262)		0.015 (0.281)
$\Delta Margin_{t-1}$					0.569** (0.262)		0.399 (0.272)
$Italylockdown$						0.519 (0.778)	
$USemergency$						2.119*** (0.778)	
$USstimulusbill$						−0.841 (0.778)	
$WHOpandemic$						0.124 (0.778)	
$Chinalockdown$						0.077 (0.778)	
Constant	0.004 (0.048)	0.005 (0.050)	−0.0004 (0.047)	0.005 (0.048)	−0.012 (0.048)	−0.005 (0.048)	−0.008 (0.048)
Observations	265	248	263	266	266	267	263
R^2	0.019	0.061	0.073	0.010	0.021	0.034	0.085
Adjusted R^2	0.012	0.054	0.066	0.002	0.014	0.015	0.063

Note: *p<0.1; **p<0.05; ***p<0.01

The variables $Chinalockdown$, $Italylockdown$, $USemergency$, $USstimulusbills$ and $WHOannouncement$ are dummy variables equal to 1 for the following events correspondingly; the lockdown of Wuhan, China on Jan 23, the announcement of the quarantine in Italy on Feb 22, the declaration of national emergency in the US on Mar 13, and the news that congress is close to passing a stimulus bill on Mar 24 and the WHO announcement of the pandemic on Mar 11.

Table 2: FTSE 100

	Dependent variable: $\Delta Depth_t$						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ΔHF_vol_{t-1}	0.155						
	(0.287)						
ΔHF_vol_{t-2}	0.222						
	(0.287)						
ΔVIX_t		-2.809^{***}					
		(0.483)					
ΔVIX_{t-1}		-1.602^{***}					
		(0.483)					
ΔVIX_100_t			-3.995^{***}				-3.824^{***}
			(0.623)				(0.643)
ΔVIX_100_{t-1}			-1.380^{**}				-1.579^{**}
			(0.623)				(0.664)
$\Delta LIBOROIS\_US_t$				-89.832^{**}			-49.625
				(41.928)			(41.785)
$\Delta LIBOROIS\_US_{t-1}$				-49.664			-4.537
				(41.899)			(41.263)
$\Delta Margin_t$					-1.643		7.230
					(9.706)		(9.848)
$\Delta Margin_{t-1}$					-15.974		-3.739
					(9.706)		(9.516)
$Italylockdown$						-82.179^{***}	
						(28.581)	
$USemergency$						-36.840	
						(28.581)	
$USstimulusbill$						26.437	
						(28.581)	
$WHOpandemic$						7.552	
						(28.581)	
$Chinalockdown$						-27.421	
						(28.581)	
Constant	-0.133	-0.088	0.073	-0.075	0.355	0.555	-0.027
	(1.776)	(1.714)	(1.644)	(1.762)	(1.787)	(1.762)	(1.673)
Observations	265	248	263	266	266	267	263
R^2	0.003	0.128	0.157	0.019	0.010	0.043	0.165
Adjusted R^2	-0.005	0.120	0.151	0.011	0.003	0.025	0.145

Note: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

The variables $Chinalockdown$, $Italylockdown$, $USemergency$, $USstimulusbills$ and $WHOannouncement$ are dummy variables equal to 1 for the following events correspondingly; the lockdown of Wuhan, China on Jan 23, the announcement of the quarantine in Italy on Feb 22, the declaration of national emergency in the US on Mar 13, and the news that congress is close to passing a stimulus bill on Mar 24 and the WHO announcement of the pandemic on Mar 11.
$\Delta Depth_t$ is in £1000s.

Table 3: FTSE 250

	Dependent variable:						
	$\Delta Spread_t$						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ΔHF_vol_{t-1}	−0.010						
	(0.019)						
ΔHF_vol_{t-2}	0.004						
	(0.019)						
ΔVIX_t		0.222***					0.219***
		(0.042)					(0.044)
ΔVIX_{t-1}		0.119***					0.114**
		(0.042)					(0.044)
ΔVIX_100_t			0.255***				
			(0.055)				
ΔVIX_100_{t-1}			0.063				
			(0.055)				
$\Delta LIBOROIS\_US_t$				6.312*			1.405
				(3.538)			(3.615)
$\Delta LIBOROIS\_US_{t-1}$				4.169			0.902
				(3.535)			(3.617)
$\Delta Margin_t$					0.142		0.300
					(0.505)		(0.498)
$\Delta Margin_{t-1}$					0.157		0.020
					(0.505)		(0.499)
$Italylockdown$						1.907	
						(2.437)	
$USemergency$						1.666	
						(2.437)	
$USstimulusbill$						−3.544	
						(2.437)	
$WHOpandemic$						−1.792	
						(2.437)	
$Chinalockdown$						0.434	
						(2.437)	
Constant	0.002	−0.009	−0.014	0.007	−0.009	0.004	−0.016
	(0.150)	(0.150)	(0.145)	(0.149)	(0.151)	(0.150)	(0.152)
Observations	265	248	263	266	266	267	248
R^2	0.002	0.105	0.084	0.014	0.001	0.014	0.107
Adjusted R^2	−0.006	0.098	0.077	0.007	−0.007	−0.005	0.085

Note: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

The variables $Chinalockdown$, $Italylockdown$, $USemergency$, $USstimulusbills$ and $WHOannouncement$ are dummy variables equal to 1 for the following events correspondingly; the lockdown of Wuhan, China on Jan 23, the announcement of the quarantine in Italy on Feb 22, the declaration of national emergency in the US on Mar 13, and the news that congress is close to passing a stimulus bill on Mar 24 and the WHO announcement of the pandemic on Mar 11.

Table 4: FTSE 250

	Dependent variable: $\Delta Depth_t$						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ΔHF_vol_t	−0.069 (0.108)						
ΔHF_vol_{t-2}	−0.071 (0.108)						
ΔVIX_t		−0.721*** (0.257)					−0.711*** (0.270)
ΔVIX_{t-1}		−0.147 (0.257)					−0.154 (0.270)
ΔVIX_100_t			−0.545* (0.330)				
ΔVIX_100_{t-1}			−0.686** (0.330)				
$\Delta LIBOROIS\_US_t$				−27.422 (20.724)			−10.957 (21.957)
$\Delta LIBOROIS\_US_{t-1}$				−3.096 (20.710)			5.850 (21.971)
$\Delta Margin_t$					−2.352 (2.943)		−3.129 (3.023)
$\Delta Margin_{t-1}$					−2.164 (2.943)		−1.424 (3.029)
$Italylockdown$						−10.024 (14.289)	
$USemergency$						−8.749 (14.289)	
$USstimulusbill$						11.130 (14.289)	
$WHOpandemic$						−3.287 (14.289)	
$Chinalockdown$						−2.174 (14.289)	
Constant	0.052 (0.875)	0.143 (0.912)	0.133 (0.870)	0.070 (0.871)	0.209 (0.878)	0.158 (0.881)	0.268 (0.925)
Observations	265	248	263	266	266	267	248
R^2	0.002	0.032	0.028	0.007	0.004	0.006	0.039
Adjusted R^2	−0.005	0.024	0.021	−0.001	−0.003	−0.013	0.015

Note: *p<0.1; **p<0.05; ***p<0.01

The variables $Chinalockdown$, $Italylockdown$, $USemergency$, $USstimulusbills$ and $WHOannouncement$ are dummy variables equal to 1 for the following events correspondingly; the lockdown of Wuhan, China on Jan 23, the announcement of the quarantine in Italy on Feb 22, the declaration of national emergency in the US on Mar 13, and the news that congress is close to passing a stimulus bill on Mar 24 and the WHO announcement of the pandemic on Mar 11.
$\Delta Depth_t$ is in £1000s.

5 Conclusion

At the peak of the Covid-19 crisis (19 March 2020) our measures of market liquidity show a deterioration to levels not seen since 2008. Since March 2020, liquidity has mostly recovered, but remains partially deteriorated at around three quarters of pre-crisis levels as of February 2021.[31]

Understanding the drivers of this deterioration in liquidity and its persistent impairment is important for identifying any structural issues that might drive illiquidity.

We empirically examine variables which are associated with this deterioration, examining implied volatility indexes, a measure of funding constraints and margin requirements that might constrain available funding. We find that the deterioration in liquidity is mainly correlated with increases in the implied volatility index.[32] Further work is needed to understand drivers of illiquidity, perhaps by examining constraints on liquidity provision at the participant level.

[31] As at publication date spreads and depths have now almost entirely recovered to pre-crisis levels.

[32] See footnote 6. Our analysis is limited in that it does not examine funding constraints outside of equity markets. Further, we do not directly measure funding constraints, such that the proxies we use may not fully capture constraints. Additionally, we only examine aggregate funding constraints and not constraints affecting individual firms.

Annex 1: Liquidity on other markets

The main paper examined the liquidity of UK cash equities markets. We provide measures of liquidity of other key UK capital markets in this annex. We consider the following markets:

- Cash Exchange Traded Funds (ETFs) on the LSE
- Cash Exchange Traded Commodities (ETCs) on the LSE
- Equity Index Futures – FTSE100 on ICE Europe

Cash ETFs (LSE)

We select the most traded ETFs in the UK and construct volume-weighted averages for our liquidity measures. We select 9 equity ETFs and 12 for bond ETFs which are presented in Table 5 below.

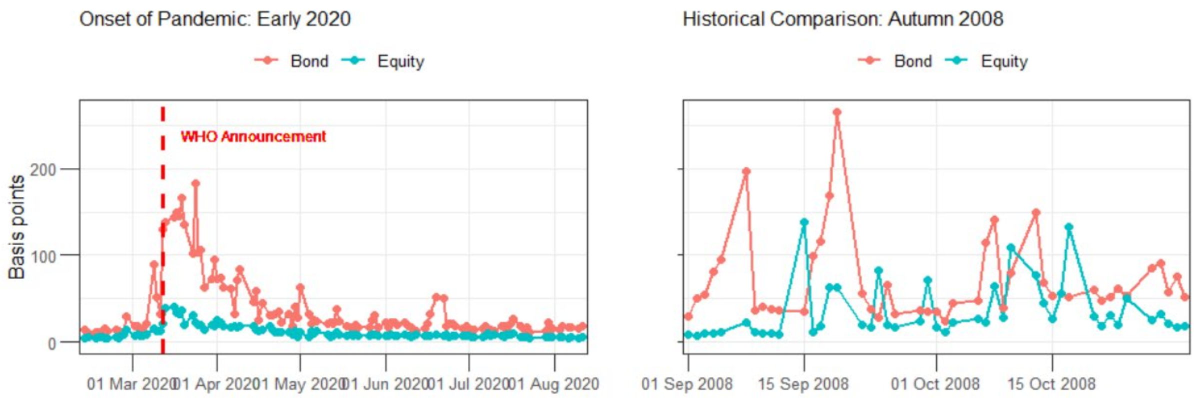
Table 5: Cash ETFs Included in Sample

ETFs	*Instrument*	*TR.RIC*
Bond	iShares £ Ultrashort Bond UCITS ETF GBP (Dist)	ERNS.L
	Lyxor Core FTSE Acturs UK Gilts(DR)UCITS ETF-Dist	GILS.L
	SPDR Bloomberg Barclays 1-5 Year Gilt UCITS ETF	GLTS.L
	SPDR Bloomberg Barclays UK Gilt UCITS ETF	GLTY.L
	iShares UK Gilts 0-5yr UCITS ETF GBP (Dist)	IGLS.L
	iShares Core UK Gilts UCITS ETF GBP (Dist)	IGLT.L
	iShares £ Index-Linked Gilts UCITS ETF GBP Dist	INXG.L
	iShares£CorpBondex-Financials UCITS ETF GBP(Dist)	ISXF.L
	PIMCO Sterling Short Mat UCITS ETF GBP Inc	QUID.L
	iShares Core Corp Bond UCITS ETF GBP (Dist)	SLXX.L
	SPDR Bloomberg Barclays Stg Corp Bond UCITS ETF	UKCO.L
	Vanguard U.K. Gilt UCITS ETF	VGOV.L
Equity	SPDR FTSE UK All Share ETF UCITS Acc	FTAL.L
	HSBC FTSE 100 UCITS ETF	HUKX.L
	iShares Core FTSE 100 UCITS ETF GBP (Dist)	ISF.L
	iShares FTSE 250 UCITS ETF GBP (Dist)	ISMIDD.L
	iShares UK Dividend UCITS ETF GBP (Dist)	IUKD.L
	Lyxor FTSE 100 UCITS ETF - Acc	L100.L
	UBS (Irl) ETF plc - MSCI UK IMI SR U ETF (GBP) Ad	UKSR.L
	Vanguard FTSE 250 UCITS ETF GBP Dist	VMID.L
	Vanguard FTSE 100 UCITS ETF GBP	VUKE.L

Results

Overall, in Figure 8 we see spreads rise dramatically for all ETFs, especially for bond ETFs, which increase to nearly 200 basis points in mid-March. Equity ETFs are less affected and approach pre-crisis levels by the end of April. Comparisons to 2008 should be careful, as ETFs were only recently developed at the time. Nonetheless, in the 2008 panel we see that ETFs experienced similar illiquidity.

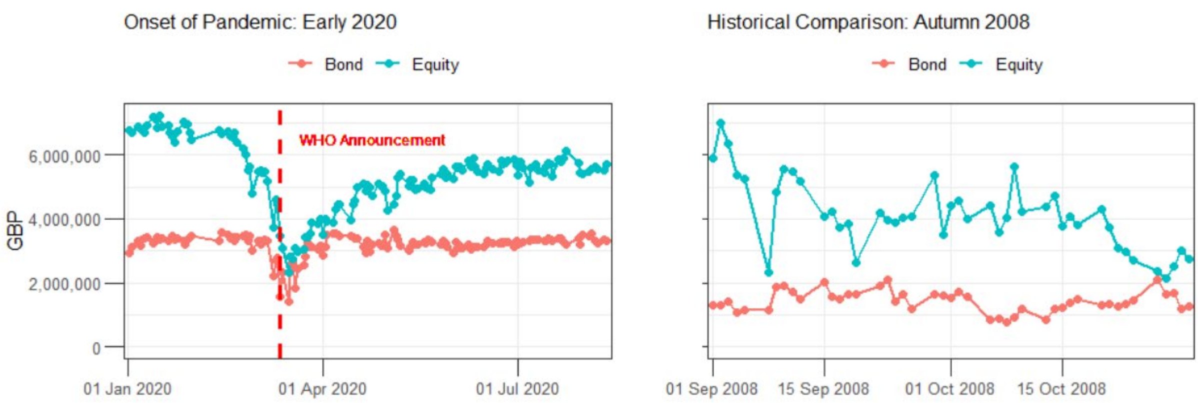
Figure 8: Average Quoted Spreads of Cash ETFs



Source: Refinitiv Datascope Select

Examining market depth at the top 10 price levels in Figure 9, both equity and bond ETFs drops by more than 50%. However, while bond ETF depth recovered to its pre-crisis level by the end of March, equity ETF depth has recovered only partially.

Figure 9: Average Depth (Top 10 Price Levels) of Cash ETFs



Source: Refinitiv Datascope Select

Equity Index Futures (ICE Europe)

We also examine liquidity in the UK's largest derivatives exchange, focusing on the FTSE100 index futures. We examine the most liquid contract for each date, which is almost always the closest contract to expiry. Each day the most liquid contract by level-10 depth is used (this is virtually always the front month contract).

Figure 10 presents quoted spreads over the crisis, showing that just after the WHO announcement quoted spreads increased to four times their pre-crisis level and still remains slightly elevated.

Figure 10: Average Quoted Spreads of FTSE100 Futures

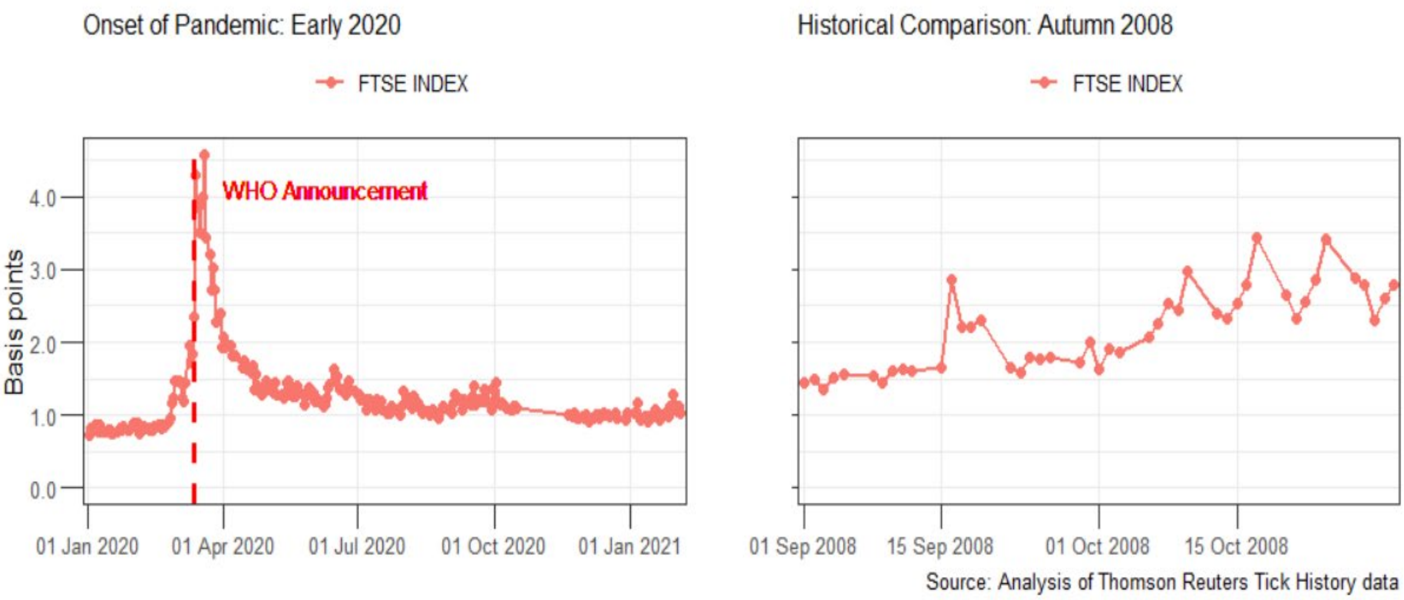
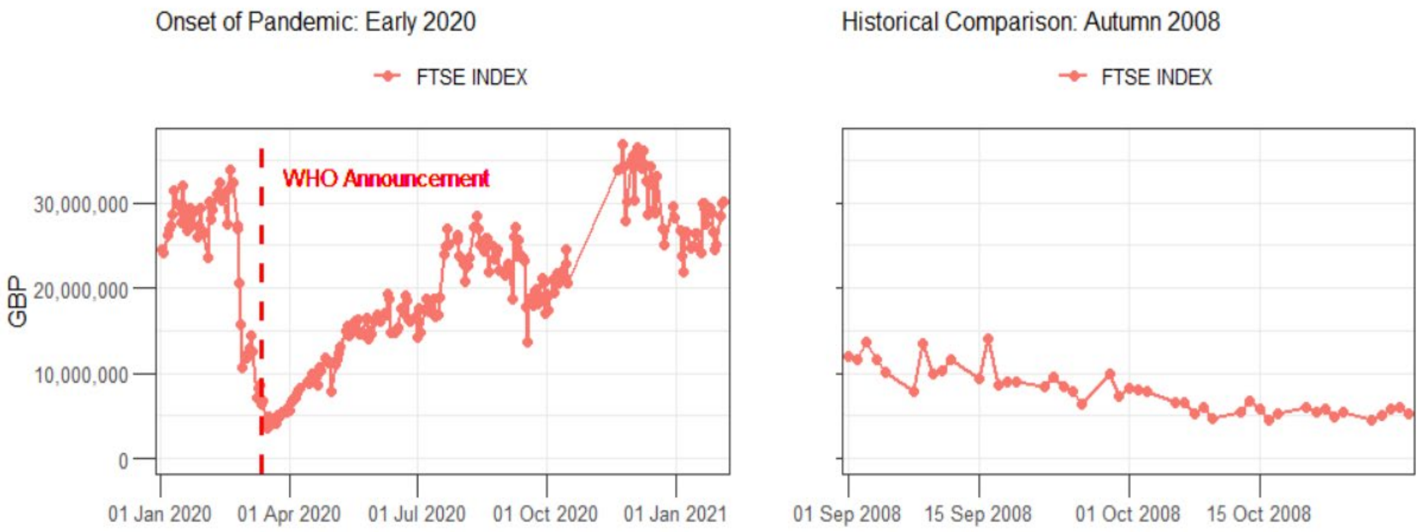


Figure 11 presents 10-level depth, which his calculated by multiplying the sum of contracts on the top 10 levels of the bid and ask by the futures price. Figure 11 shows that depth drops markedly before the WHO announcement on the 11th of March. This is likely a result of large falls in the index price which commence on the 5th of March which engender a mechanical effect in reducing depth. However, it takes a long time for this depth to be replenished, and it is still slightly impaired in early August.

Figure 11: Average Depth (Top 10 Price Levels) of FTSE100 Futures



Source: Analysis of Thomson Reuters Tick History data

Annex 2: Data and methodology

The raw data is extracted from Refinitiv's "Datascope Select" database which includes millisecond timestamped BBO updates as well as 10-level depth updates. For each stock in the FTSE100 and FTSE250 index (or for each ETF in the ETF sample) we extract millisecond timestamped trades and quotes for each day starting from 1st of Jan 2020 to 11th August 2020 and calculate the following measures;

- time weighted average Quoted Spread ($\boldsymbol{Spread}$)
- time weighted average 10-Level Depth ($\boldsymbol{Depth}$)

The average quoted spread, $\boldsymbol{Spread}$**,** is calculated as the difference between best bid and ask, relative to the current midpoint, expressed in basis points. $\boldsymbol{Depth}$ is the sum of trading interests at 10 best bid-ask quotes, translated into GBP. $\boldsymbol{Spread}$ and $\boldsymbol{Depth}$ are then constructed as time-weighted averages for each stock-date. In our charts in Section 3 we then construct weighted means across the relevant indexes (eg. FTSE 100 or 250) that are weighted by the volume traded for each stock.

Table 6 provides descriptive statistics for our liquidity measures for the period of 1st of Jan to 11th August 2020.

Table 6: Descriptive Statistics of Liquidity Measures

Stock	$Spread$	$Depth$(1000GBP)
FTSE 100	6.2689382	428.718286
FTSE 250	22.5659105	227.946534
Bond	37.311364	3201.179161
Equity	11.2574614	5361.982515
FTSE INDEX	1.390702	1775.473472

Margin requirements that we use in our analysis are calculated using *new scanning ranges* reported in ICE Margin Scanning reports[33]. Using scanning ranges, for a given future contract the *Margin* requirement series are generated by the following;

$$Margin_t = \frac{new\_scanning\_range_t}{close\_price_t \times multiplier}$$

where the *multiplier* is contract multiplier for the corresponding contract.

[33] Please see https://www.theice.com/clear-europe/risk-management for further details regarding margin computation.

We also use *“LIBOROIS_US”, “VIX” and “VIX 100”.* These are daily timeseries taken directly from Bloomberg with the following codes, “LOIS USD”, “VIX Index”, and “IVIUK Index”.

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