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The leverage ratio and liquidity in the gilt and repo markets

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Abstract

Market participants have argued that a significant unintended consequence of post-crisis regulatory leverage ratio requirements has been a reduction in the liquidity of fixed income markets. We assess this claim in the context of the gilt (UK government bond) and gilt repo markets. We find that gilt repo liquidity worsened during the period when UK leverage ratio policy was announced, and that gilt liquidity worsened conditional on factors such as funding costs and inventory risk. We also find evidence that gilt repo liquidity has become less resilient. However, evidence from heterogeneity in dealer behaviour is inconclusive regarding a causal link between leverage ratio requirements and the reduction in market liquidity.

Key words: Market liquidity, leverage ratio, bank regulation, repo, gilt market, market-making.

JEL classification: G12, G21, G24, G28.

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1 Introduction

Financial market commentary suggests that the liquidity of fixed income markets has deteriorated in recent years. Market participants argue that one of the key drivers of the apparent reduction in liquidity has been post-crisis regulatory reform, particularly the regulatory leverage ratio proposed as part of Basel III. Unlike the risk-weighted capital framework, the leverage ratio does not differentiate between the riskiness of assets. This means that activities with low credit and market risk, such as repo and trading in high-quality government bonds, are subject to higher capital requirements under the leverage framework than under the risk-weighted framework. To the extent it is binding, introducing a regulatory leverage ratio requirement therefore increases the cost of market-making in these low-risk products. Market participants argue that this increased cost has caused market-makers to reduce their activity, pass on higher costs to their customers, or exit markets completely. These changes in dealer behaviour are reported to have resulted in reduced secondary market liquidity and higher trading costs.

The existing academic literature on the impact of post-crisis regulation on market liquidity has primarily focused on the Volcker Rule and US fixed income markets (Trebbi and Xiao, 2015; Dick-Nielsen and Rossi, 2016; Bao et al., 2016; Bessembinder et al., 2016). To our knowledge, only Adrian et al. (2017) have explicitly estimated the effect of the regulatory leverage ratio on liquidity (their paper considers the US corporate bond market). This is despite the fact that the leverage ratio has frequently been cited as the element of post-crisis regulatory reform with the strongest impact on fixed income businesses (CGFS, 2014; ICMA, 2015; CGFS, 2016).

We contribute to the literature on the costs and benefits of financial regulation by assessing the impact of the leverage ratio on the liquidity of the gilt (UK government bond) and gilt repo markets. These markets have the potential to be good testing grounds for the impact of the leverage ratio on liquidity for two reasons. First, both markets rely heavily on dealers for intermediation, and so their liquidity is likely to be sensitive to the regulatory costs faced by dealers when making markets. Second, the UK authorities have moved to implement the leverage ratio earlier than Basel and EU timelines, meaning that UK-regulated entities may have started to adjust to new regulatory requirements earlier than their international peers.

We base our analysis on three rich proprietary datasets: the Zen dataset maintained by the UK's Financial Conduct Authority (FCA), which contains transaction-level information on secondary market trading in gilts; BrokerTec data on interdealer gilt repo transactions; and regulatory returns on gilt repo trading volumes collected by the Bank of England (Form RSL). We use these datasets to estimate a range of measures of market liquidity, and use principal components analysis to combine these into two liquidity indices, one for the gilt market and one for the gilt repo market. We also estimate network statistics to illustrate how the structure of these markets has evolved in recent years.

Major UK banks have only been formally subject to a minimum leverage ratio requirement from January 2016, and other UK banks will only become formally subject to a minimum requirement in January 2018. But firms are likely to have started adjusting their balance sheets much earlier than this in response to a series of policy announcements, supervisory expectations and reporting requirements. The first of these announcements was in December 2011. We run three sets of regressions to investigate changes in gilt and gilt repo liquidity over the period 2010-2015 and to assess whether the leverage ratio had a causal role in these changes:

- Market-level time series regressions, to assess whether average liquidity deteriorated during the period when leverage ratio policy was announced, conditional on a wide set of control variables.
- Market-level quantile regressions, to assess whether changes in the conditional distribution of liquidity during this period indicate that liquidity has become less resilient.
- Dealer-level panel regressions, to investigate whether heterogeneity in the liquidity provision of individual dealers provides evidence for a causal link between the leverage ratio and any reduction in liquidity.

The market-level regressions suggest that gilt market liquidity did not worsen in an unconditional sense during the period when leverage ratio policy was announced, but that gilt liquidity did worsen conditional on other factors such as funding costs and inventory risk. This suggests that, were funding conditions to become less benign or interest rate volatility to increase, gilt liquidity could fall to lower levels than previously would have been the case. In the case of gilt repo, our measures of liquidity worsened whether or not we control for other factors, with most of the reduction in liquidity occurring during 2014 and 2015. For both markets, the timing of the reduction in liquidity shown by the regressions is consistent with results from structural break tests (Andrews, 1993). Lower turnover in the gilt market, falling repo volumes, and a sharp reduction in the average repo trade size are also indicative of reduced liquidity in these markets in recent years. Particularly sharp reductions in repo liquidity at quarter-ends - when we would expect dealer behaviour to be especially sensitive to regulatory constraints - potentially suggest a causal role for the leverage ratio in the reduction in repo liquidity. We do not, however, observe these quarter-end effects in the gilt market.

The market-level quantile regressions indicate that the (conditional) worsening in liquidity in both the gilt and gilt repo markets was more pronounced in times of poor liquidity after December 2011. This is consistent with a reduction in the resilience of liquidity during the period when leverage ratio policy was announced. Specifically, the conditional 0.9 quantile of illiquidity worsened more than the conditional 0.5 quantile in both markets, although this difference is not always statistically significant. We also find that sudden reductions in liquidity ('liquidity jumps') have become more frequent in the repo market, consistent with concerns that liquidity risk has increased.

While the market-level regressions indicate that liquidity worsened during the period when leverage ratio policy was announced, they do not provide strong evidence of a causal link between the leverage ratio and liquidity because changes in liquidity over this period might have been caused by some other omitted factor. In order to better identify a potential causal impact, we run dealer-level panel regressions that exploit two sources of heterogeneity across dealers: heterogeneity in the balance sheets of individual dealers, and heterogeneity in the timing of regulatory requirements across jurisdictions. These dealer-level regressions provide only weak evidence of a causal role for regulation. Simple difference-in-differences regressions indicate that UK banks with leverage ratios below 3% in December 2011 reduced their liquidity provision by more than banks with leverage ratios above 3%. This is consistent with the leverage ratio having had a causal role in the reduction in liquidity. However, this difference is not statistically significant, and other specifications provide no evidence that the leverage ratio caused the reduction in liquidity.

We do not attempt to quantify the net benefits of the regulatory leverage ratio. Even if the leverage ratio did cause a reduction in liquidity, two considerations suggest that this does not necessarily imply a reduction in social welfare. First, there might be risks associated with excessive liquidity. For example, excessive liquidity might be illusory, disappearing when most needed (Cunliffe, 2015); and excessive repo liquidity might encourage over-reliance on short-term funding (CGFS, 2017). Second, by leading to an increase in the capitalisation of banks, the leverage ratio is likely to have increased their resilience to shocks. An assessment of the overall impact of the leverage ratio on financial stability and social welfare is beyond the scope of this paper.

The rest of the paper is structured as follows. In Section 2 we summarise the debate on the effects of regulation on market liquidity and the related academic literature. In Section 3 we describe the gilt and gilt repo markets from an institutional perspective, and summarise the history of the Basel and UK leverage ratio frameworks. Section 4 describes our datasets and uses these to illustrate some recent trends in the gilt and gilt repo markets. Sections 5 and 6 explain how we estimate network statistics and liquidity measures for the two markets, and describe recent trends in these measures. In Section 7, we set out our empirical strategy for assessing the effects of the leverage ratio on market liquidity, and summarise the results of the market-level regressions. In Section 8 we consider the question of whether liquidity has become less resilient, through quantile regressions and estimates of the frequency of 'jumps' in liquidity. Section 9 uses heterogeneity in dealer behaviour to assess whether the leverage ratio had a causal impact on liquidity. Section 10 concludes.

2 Related literature

This paper contributes to the debate on the effects of post-crisis regulatory reform on market liquidity. Market participants have argued that new regulations - particularly the leverage ratio and Net Stable Funding Ratio (NSFR) proposed as part of Basel III, and the Volcker Rule introduced as part of the US Dodd-Frank Act - have led to a deterioration in liquidity across a range of markets. See, for example, ICMA (2015), PwC (2015) and Morgan Stanley and Oliver Wyman (2015, 2016). These reports argue that new prudential standards have increased costs for market-makers across a range of markets, leading to a reduction in the balance sheet capacity allocated to market-making and therefore to a reduction in the liquidity of dealer-intermediated markets. Participants argue that the effect is not uniform across jurisdictions, which can be partly explained by differences in implementation timelines, calibration and frequency of reporting requirements (CGFS, 2017).

Academic studies paint a more mixed picture when assessing recent trends in the liquidity of fixed income markets. Most studies have focussed on US markets. Adrian et al. (2015b,d) find evidence of ample liquidity in the US corporate bond market and mixed evidence for US Treasuries. Price impact measures imply some deterioration in the liquidity of US Treasuries, while other metrics such as bid-ask spreads indicate benign conditions. Trebbi and Xiao (2015) test for structural breaks in the liquidity of US corporate and government bonds and find no evidence that liquidity has deteriorated in recent years. Instead, the breaks appear to indicate a move towards improved liquidity. Studying the US corporate bond market, Bessembinder et al. (2016) find that trade execution costs have fallen since the crisis, but that other measures - such as dealer capital commitment, dealer participation as principal, frequency of block trades, and interdealer trading - indicate a worsening of liquidity. By focussing on dates when bonds are excluded from an investment grade index, Dick-Nielsen and Rossi (2016) find that the cost of immediacy in the US corporate bond market has increased since the crisis. Bao et al. (2016) find that US corporate bonds have suffered a larger deterioration in liquidity upon being downgraded since the introduction of the Volcker Rule. They also find that dealers subject to the Volcker Rule have reduced their provision of liquidity in this market relative to non-Volcker dealers, and conclude that the Volcker Rule has had a causal, negative impact on US corporate bond liquidity. The evidence also appears to be mixed outside of US markets. Aquilina and Suntheim (2017) analyse the UK corporate bond market and conclude that it has become more liquid in recent years. IMF (2015) investigates the liquidity of fixed income markets in the US, Europe, emerging markets and Japan, and finds that trends in liquidity differ according to the market considered and the measure used.

Few academic studies have attempted to empirically link changes in market liquidity to the planned introduction of the regulatory leverage ratio. This is despite the fact that the leverage ratio has frequently been cited as the element of post-crisis regulatory reform with the strongest impact on fixed income businesses (CGFS, 2014; ICMA, 2015; CGFS, 2016). To our knowledge, only one paper has sought to identify the impact of leverage ratio policy on market liquidity. Analysing the US corporate bond market, Adrian et al. (2017) find that prior to the crisis, bonds traded by more levered institutions were more liquid, but that this relationship reversed after new regulations were introduced, such that bonds traded by institutions with lower leverage were more liquid. They argue that this is consistent with leverage regulation causing a reduction in liquidity. Three other papers assess the impact of the leverage ratio on the behaviour of individual banks. Acosta Smith et al. (2017) find that leverage-constrained European banks shifted towards higher risk-weighted activity following the Basel III leverage ratio announcement. Allahrakha et al. (2016) find that the introduction of the supplementary leverage ratio (SLR) in the US led affected broker-dealers to decrease their total repo borrowing but to increase their use of repo backed by more price-volatile collateral. Conversely, Bucalossi and Scalia (2016) find that leverage-constrained European banks did not reduce their repo volumes between 2013 and 2014. However, none of these papers assesses the potential impact of this behaviour on market liquidity. On the theoretical side, Cimon and Garriott (2017) show that the leverage ratio and other post-crisis regulations lead market makers to intermediate fewer client trades.

Our paper is also related to the literature on the determinants of market liquidity more broadly, including the impact of balance sheet constraints and funding costs on liquidity. From a theoretical perspective, Gromb and Vayanos (2002) and Brunnermeier and Pedersen (2009) show that limited market-maker capital can impact liquidity. Brunnermeier and Pedersen (2009) show that funding liquidity is also an important determinant of market liquidity. Dick-Nielsen et al. (2014) test this hypothesis in the Danish bond market, and find that the market becomes less liquid when dealer funding costs increase. The study closest to our research is Benos and Zikes (2016), who also consider the determinants of liquidity in the gilt market. In line with theoretical results, they show that dealer balance sheet constraints (proxied by aggregate net trading volume) and funding costs are important determinants of liquidity. However, their paper focusses on the crisis period, before new regulatory requirements were introduced.

The paper is also related to a small recent empirical literature on the resilience of liquidity, spurred by market commentary claiming that the risk of 'flash crashes' and sudden reductions in liquidity has risen. IMF (2015) examines the effects of structural drivers and cyclical factors on the level and resilience of market liquidity. The authors conclude that changes in market structure - such as larger and more concentrated holdings of corporate bonds by mutual funds - may have increased the fragility of liquidity. They argue that accommodative monetary policy and benign cyclical conditions in recent years may be masking growing liquidity risks. Adrian et al. (2015a,c) use the frequency of sudden large increases in a composite illiquidity metric as a measure of liquidity risk. They find that 'jumps' in illiquidity have become more frequent in the US equity and Treasury markets in recent years. In contrast, there appears to be no increase in the liquidity risk of US corporate bonds, a heavily dealer-intermediated market which might have been expected to be more sensitive to changes in regulation. The authors interpret this as evidence against the claim that regulation is the main driver behind recent episodes of volatility in US equity and Treasury markets. Following a similar approach, CGFS (2016) finds an increase in the frequency of 'jumps' in the bid-ask spreads of US, Japanese and Italian government bonds in recent years.

Our paper is, to our knowledge, the first academic study of liquidity in the gilt repo market. Most empirical papers on repo markets have focussed on US markets (for example, Gorton and Metrick, 2012; Krishnamurthy et al., 2014; Copeland et al., 2014) and euro markets (Mancini et al., 2016).

3 Institutional and regulatory background

This section describes the gilt and gilt repo markets from an institutional perspective. It then discusses the regulatory leverage ratio.

3.1 The gilt market

Gilts are UK government bonds, issued by the UK Debt Management Office (DMO). The DMO issues gilts, typically via auctions and syndications, to financial institutions designated as primary dealers for the gilt market, known as Gilt-Edged Market Makers (GEMMs). There are currently nineteen GEMMs, although there has been entry and exit among the GEMMs, such that twenty-five firms have been GEMMs at some point since 2008.[1]

The vast majority of secondary-market trading in gilts takes place over the counter. End-investors typically transact with GEMMs, either negotiating trades bilaterally over the phone or through electronic trading platforms. The GEMMs are required to provide secondary market liquidity by quoting continuous bid and ask prices to their customers. In return, the GEMMs are entitled to certain privileges. For example, they are the only institutions eligible to bid directly in the DMO's gilt auctions, so that other market participants wishing to bid must route their order through a GEMM.[2] GEMMs frequently trade with each other, in order to rebalance their gilt portfolios and to hedge trades with

[1] The current GEMMs are Barclays, BNP Paribas, Citigroup, Deutsche Bank, Goldman Sachs, HSBC, Jefferies, JP Morgan, Lloyds, Merrill Lynch, Morgan Stanley, Nomura, Royal Bank of Canada, Royal Bank of Scotland, Santander, Scotiabank, Toronoto-Dominion Bank, UBS and Winterflood Securities. The other firms that have been GEMMs since 2008 are ABN Amro, Lehman Brothers, Commerzbank, Société Générale, State Street and Credit Suisse.

[2] See DMO (2016a) for more details on the role of GEMMs.

their clients. Often this takes place through interdealer brokers (IDBs), which act as intermediaries for anonymous trading between the market-makers.

The main investors in gilts are UK-based insurance companies and pension funds, and overseas investors such as governments, central banks, sovereign wealth funds and asset managers. Currently, the largest single holder of gilts is the Bank of England, which since 2009 has purchased gilts through its Asset Purchase Facility (APF) in its programme of quantitative easing.

3.2 The gilt repo market

A market closely related to the gilt market is the gilt repo market. Formally, a repo is a 'repurchase agreement': one counterparty sells a security to another counterparty for a given price, and commits to repurchase the same (or similar) security at a specified future date and for a specified price. The trade is economically equivalent to a secured loan from the second counterparty to the first: the underlying security acts as collateral, and the difference between the prices at which the security is sold and repurchased implies an annualised interest rate known as the 'repo rate.' From the point of view of the cash borrower, the transaction is referred to as a 'repo', while from the point of view of the cash lender, it is referred to as a 'reverse repo'. If the precise security to be exchanged is agreed when the trade is struck, the trade is referred to as a 'specific collateral' repo. Alternatively, the counterparties may agree that any of a certain group of securities may be exchanged. In this case, the trade is referred to as a 'general collateral' repo.

The vast majority of sterling-denominated repo involves the sale and repurchase of gilts. A wide range of market participants use the gilt repo market. Money market funds, corporates and local authorities use the market to deposit cash securely. Meanwhile, hedge funds, asset managers, pension funds and insurance companies borrow cash via repo to finance leveraged investment strategies. GEMMs frequently use the gilt repo market to cover short gilt positions. Banks use reverse repo to borrow gilts for their liquid asset buffers. And if a bank needed to liquidate gilts at short notice, it would most likely access the repo market, rather than sell the gilts outright in the secondary market. The gilt repo market also plays an important role in the Bank of England's monetary policy transmission and liquidity insurance operations (see Bank of England, 2015a).

Like the secondary gilt market, the gilt repo market is intermediated by a group of dealer banks, and there is significant overlap between the communities of GEMMs and repo dealers. The interdealer repo market is also intermediated by interdealer brokers, mostly using electronic broking platforms, the largest of which is BrokerTec. Almost all interdealer gilt repo trading is at overnight term, and the vast majority of interdealer gilt repo trades are centrally cleared through LCH.Clearnet Ltd. In contrast to the dollar repo market, only a small proportion of the gilt repo market is intermediated by tri-party agents.

3.3 The leverage ratio

Following the global financial crisis, the Basel Committee on Banking Supervision (BCBS) undertook a significant programme of reform to banking regulation known as 'Basel III.' This proposed new international regulatory standards for capitalisation and liquidity risk management. The revised capital standards include reforms to the risk-based capital framework that existed under previous Basel accords, and a new regulatory leverage ratio to supplement the risk-based framework.

The leverage ratio is an indicator of a firm's solvency, and is defined as Tier 1 capital divided by the 'exposure measure.' The exposure measure includes on-balance sheet exposures, derivative exposures, securities financing transaction exposures (including repo), and certain off-balance sheet exposures. Requiring banks to maintain a minimum leverage ratio is intended to 'restrict the build-up of leverage in the banking sector to avoid destabilising deleveraging processes that can damage the broader financial system and the economy' and to 'reinforce the risk-based requirements with a simple, non-risk based "backstop" measure' (BCBS, 2014).

The BCBS first indicated that it planned to introduce a regulatory leverage ratio in a consultation document in 2009 (BCBS, 2009). In 2010, the BCBS proposed a 3% minimum leverage ratio (BCBS, 2010). At this time, the BCBS also proposed a transition path to implementation, whereby banks would be required to publically disclose their leverage ratios from January 2015 and meet a 3% minimum as part of their 'Pillar 1' capital requirements by January 2018. In 2014, the BCBS finalised the definition of the leverage ratio that banks would be required to disclose from 2015 and reiterated that the leverage ratio would become a Pillar 1 requirement from 2018 (BCBS, 2014).

The way in which domestic legislators and regulators have decided to implement the leverage ratio varies across jurisdictions: see Bank of England (2014a) for a summary. Since most GEMMs and gilt repo dealers are UK banks or UK subsidiaries of foreign banks, the leverage ratio frameworks most relevant to the functioning of the gilt and gilt repo markets have been those of the UK and EU.

UK authorities have moved to implement the leverage ratio earlier than the Basel and EU timelines. In December 2011, the Bank of England's Financial Policy Committee (FPC) recommended that the FSA (the UK regulator at the time) encourage banks 'to disclose their leverage ratios... not later than the beginning of 2013' (Bank of England, 2011), two years ahead of the Basel timeline for disclosure. The FSA implemented this recommendation by asking large UK banks to publish their leverage ratios in their 2012 annual reports and on a bi-annual basis thereafter. In June 2013, the Prudential Regulation Authority (PRA), which now regulates UK banks, required the two large UK banks that at that time did not meet a 3% leverage ratio to submit plans for how they would reach that standard (Bank of England, 2013b). Major UK banks have been expected to meet a 3% leverage ratio since January 2014, four years ahead of the Basel and EU implementation date of January 2018 (Bank of England, 2013a). Following a review by the FPC (Bank of England, 2014b,a), the PRA finalised the UK leverage ratio framework in 2015 (Bank of England, 2015b,c), stipulating a 3% minimum requirement for large UK banks starting January 2016. Other UK banks will be subject to a 3% minimum requirement from January 2018 under CRD IV. See Table 1 for a summary of this timeline.

Several large dealers in the gilt and gilt repo markets are UK subsidiaries of US banks. This means that the US leverage ratio framework might also have an impact on the functioning of these markets. A domestic leverage ratio has applied to US banks since 1981, but the framework has been substantially revised and toughened in recent years (including changes to the definition of the exposure measure). The 'supplementary leverage ratio' (SLR), proposed in June 2012 and finalised in July 2013, implements the Basel III leverage ratio in the US. In addition, the 'enhanced supplementary leverage ratio' (eSLR) requires G-SIBs and insured depository institutions of G-SIBs to meet a 5% and 6%

minimum leverage ratio, respectively. The SLR and eSLR will both become fully effective in 2018. See Allahrakha et al. (2016) for more detail on the US leverage ratio framework.

The leverage ratio exposure measure does not seek to differentiate between the riskiness of different assets. Taken in isolation, activities that receive low risk-weights under the risk-based framework, such as market-making in the gilt and gilt repo markets, are therefore more capital intensive under the leverage framework than under the risk-based framework. If binding, the introduction of a regulatory leverage ratio therefore increases the capital requirements associated with these business lines. On the basis that equity is more expensive than debt for banks,[3] participants in these and related markets have argued that a higher marginal cost of market-making is causing market-makers to reduce their activity, charge higher margins, or exit certain markets completely (ICMA, 2015; CGFS, 2014; SLRC, 2014; DMO, 2016b). Indeed, two recent GEMM resignations - by Credit Suisse in 2015 and Société Générale in 2016 - have been attributed to the increased capital cost of market-making in gilts (Reuters, 2016). In aggregate, these changes in dealer behaviour are reported to have resulted in reduced secondary market liquidity in both the gilt and gilt repo markets.

4 Data and summary statistics

Our paper utilises three proprietary datasets: the 'Zen' dataset maintained by the UK Financial Conduct Authority (FCA), which contains transaction-level information on secondary-market trading in gilts; transaction-level data from the BrokerTec platform for interdealer gilt repo; and regulatory returns on gilt repo activity collected by the Bank of England (Form RSL). This section discusses the three key proprietary datasets before setting out some descriptive summary statistics for the gilt and gilt repo markets.

4.1 Zen dataset

Our analysis of the secondary market for gilts is based on the 'Zen' dataset maintained by the FCA.[4] This dataset has also been used by Benos and Zikes (2016) and by Aquilina and Suntheim (2017).

Zen should include transaction reports for all secondary-market trades in gilts where at least one counterparty is an EEA firm. Since GEMMs are EEA entities, the dataset covers the entire gilt market-making business of dealers. Each transaction report includes the date, time, quantity, price, International Securities Identification Number (ISIN), a buyer/seller flag, trading capacity information, the identity of the reporting firm, and in most cases, the identity of their counterparty. The counterparty identifier field allows us to match reports in cases where both counterparties report the trade. We clean the data by dropping trades that are implausibly large or small, or that have prices very far from the end-of-day prices recorded by Bloomberg. The dataset covers the period between January 2008 and December 2015, with a total of 2020 business days. After cleaning and matching trade reports, we have around seven million unique trades.

[3] This claim is questioned by, for example, Miles et al. (2013).
[4] Trades prior to August 2011 are recorded in a similar database called 'Sabre II'.

4.2 BrokerTec

We obtain transaction-level data on the interdealer gilt repo market from BrokerTec, NEX Markets, which is the largest electronic platform for interdealer gilt repo. For each transaction, we observe the date, time, quantity, repo rate, and collateral. The dataset is anonymised. However, we do observe counterparty identifiers, which allow us to estimate the network statistics discussed in Section 5.

We estimate that the BrokerTec data cover the majority of the interdealer gilt repo market. And comparisons with the Form RSL data (discussed below) suggest that the BrokerTec data cover around 40% of the total gilt repo market (by value). We have data for the period January 2006 to December 2015, consisting of 2526 business days. The dataset consists of around two million trades.

4.3 Form RSL

Participants in the gilt repo market report summary statistics of their activity to the Bank of England through the regulatory return Form RSL. Reporting is voluntary, but currently around thirty-five institutions choose to report, including most of the major dealer banks. Firms report their turnover and number of transactions, summing over the quarter and aggregating across counterparties, as well as the cash value of their outstanding positions. In this paper, we focus on total repo turnover (value of cash borrowed, summed across all maturities), because repo borrowing increases the leverage exposure measure. The dataset runs from 1996 to the present and is at quarterly frequency.

4.4 Summary statistics

Figure 1 shows the nominal value of gilts outstanding. The stock of gilts in issue has grown substantially since the financial crisis, from around £400 billion in 2008 to £1.4 trillion by the start of 2016. Between 2009 and 2013, the Bank of England purchased a stock of £375 billion of gilts through its Asset Purchases Facility (APF) by market value (around £325 billion by nominal value). Since the pace of gilt issuance by the DMO was generally faster than the pace of asset purchases by the Bank of England, the nominal 'free float' - total outstanding gilts minus government holdings, APF holdings, and other Bank of England holdings - more than doubled between 2008 and 2016.

Gilt trading volumes did not keep pace with the growth of gilts in issue over this period. Figure 2 shows annual gilt trading volumes and turnover ratios, which measure trading volume relative to gilts outstanding and free float. Trading volumes increased between 2008 and 2013, before remaining relatively steady over the rest of the sample period. But given the large increases in the stock of gilts outstanding and free float, turnover ratios fell over this period. The free float turned over 9.3 times in 2013 but only 7.6 times in 2015. Falling turnover ratios might be indicative of reduced gilt market liquidity - for example, if investors are choosing to rebalance their portfolios more slowly in order to avoid increased transaction costs. But they are not definitive evidence of reduced liquidity, since they might reflect other trends such as structural changes in the investor base. Figure 3 shows the number of trades per year and the average trade size. Both increased after the financial crisis but have remained relatively stable since 2012.

Figure 4 shows aggregate annual repo borrowing in the gilt repo market since 1997, broken down by maturity. The market tripled in size between 1997 and the financial crisis. It continued to grow after the financial crisis, which Jackson and Sim (2013) argue reflected a substitution from unsecured borrowing to secured borrowing, driven by heightened sensitivity to credit risk and new liquidity regulations. But repo volumes have fallen sharply since 2012, a trend that market participants primarily attribute to the regulatory leverage ratio (ICMA, 2015; SLRC, 2014). The average size of a gilt repo trade has also fallen substantially in recent years (Figure 5). The average gilt repo trade was £73 million in 2008 but only £42 million in 2015. This fall in the average trade size might indicate reduced liquidity, to the extent that it reflects market participants choosing to break up trades in order to reduce transaction costs.

Figures 4 and 5, which are based on the Form RSL data, refer to the gilt repo market as a whole. But similar trends are also evident in the interdealer market, as recorded by BrokerTec. Figure 6 shows a significant fall in quarterly interdealer gilt repo volumes since 2012. Relative to pre-crisis averages, the reduction in repo trades of longer maturity is particularly notable. By 2012, more than 99% of interdealer gilt repo trading by value was at overnight maturity. The average trade size in the interdealer gilt repo market also fell sharply during the post-crisis period, from around £50mn in 2009 to less than half of this amount by the end of 2015 (Figure 7).

5 Network structure of the gilt and gilt repo markets

Our three proprietary datasets also allow us to view recent developments in the gilt and gilt repo markets through the lens of network analysis. We construct three network statistics for the gilt market using the Zen dataset, at daily frequency:

1. *Connectivity of the interdealer market:* Following Soramaki et al. (2007), we define connectivity as the unconditional probability that two nodes in a network are linked. In this case, each node represents a GEMM, and a link is formed when one GEMM purchases a gilt from another. We estimate connectivity by dividing the number of actual links by the number of potential links. A higher value for connectivity suggests that it would be easier for GEMMs to find counterparties in the interdealer market when rebalancing their gilt portfolios. As a result, a dealer might be more willing to accommodate its clients' demands to buy or sell gilts. Define N_t to be the number of GEMMs active on day t (where a GEMM is active if it engages in at least one interdealer gilt trade on day t), and define $I_{i,j}(t)$ to be the indicator function that takes the value 1 if GEMM i purchases a gilt from GEMM j on day t and 0 otherwise. Then interdealer connectivity on day t is given by:

$$Connectivity_t = \frac{1}{N_t(N_t - 1)} \sum_{i=1}^{N_t} \sum_{j \neq i} I_{i,j}(t)$$

2. *Ratio of interdealer trading to total trading:* As an alternative measure of the ease of finding counterparties in the interdealer market, and following Benos and Zikes (2016), we calculate the ratio of interdealer trading volume to total trading volume each day. Higher values might indicate a more active interdealer market, and therefore better opportunities for dealers to rebalance their portfolios.

3. *Herfindahl index for the dealer-to-client market:* We measure the concentration of market-making

in the gilt market using the Herfindahl index. Higher numbers indicate more concentration in the dealer-to-client segment of the market, and therefore potentially less competition between market-makers. Define $V_{i,t}$ to be the volume of trading that GEMM i does with clients (in either direction) on day t,[5] and let N_t be the number of GEMMs active on day t. The Herfindahl index is then calculated as the sum of squared market shares:

$$Herfindahl_t = \sum_{i=1}^{N_t} \left(\frac{V_{i,t}}{\sum_{j=1}^{N_t} V_{j,t}} \right)^2$$

We also construct two network statistics for the gilt repo market:

1. *Connectivity of the interdealer market:* This is calculated exactly as for the gilt market, and at daily frequency, using the BrokerTec data.

2. *Herfindahl index for the repo market:* We are unable to measure the concentration of market-making in the gilt repo market directly: the BrokerTec data only cover the interdealer market, and the RSL reporters aggregate across all their counterparties, meaning that we cannot isolate dealer-to-client volumes. We instead calculate the Herfindahl index for total repo borrowing by dealers, using the RSL data to construct this statistic at quarterly frequency.

Our estimated network statistics for the gilt market are shown in Figure 8 and those for the gilt repo market are shown in Figure 9.

Figure 8 indicates that the connectivity of the interdealer gilt market, and the ratio of interdealer gilt trading to total gilt trading, both increased steadily between 2008 and 2015. For example, the average probability that any two GEMMs would trade on a given day increased from 17% in 2008 to 32% in 2015. These trends suggest that the interdealer market became better connected over the sample period, potentially making it easier for GEMMs to recycle and hedge their positions.

The Herfindahl concentration index for the dealer-to-client market fell between 2008 and 2012, reflecting the entry of several new GEMMs over this period,[6] and possibly indicating an increase in the competitiveness of gilt market-making. The Herfindahl index increased marginally between 2012 and 2015.

The connectivity of the interdealer gilt repo market increased between 2006 and 2013 before falling sharply (Figure 9). The timing of the fall in connectivity corresponds approximately to the fall in interdealer repo trading volume shown in Figure 6 and the decline in the number of interdealer repo trades shown in Figure 7. Together, these trends suggest a marked reduction in interdealer gilt repo activity, across several dimensions, since 2013.

The Herfindahl index suggests that the concentration of the repo market increased between 2006 and 2009 before falling. The Herfindahl index remained relatively flat between 2010 and 2015.

[5] Clients are simply defined as all counterparties that we are unable to identify as a GEMM, an IDB, the DMO or the Bank of England.

[6] Nomura in 2009; Jefferies, Toronto Dominion, Santander, Société Générale and Scotiabank in 2010; Lloyds and (briefly) State Street in 2011.

6 Measures of market liquidity

The literature has typically distinguished between three concepts of liquidity: monetary liquidity, which relates to the ease of converting monetary assets into goods and services; funding liquidity, which relates to the ability of market participants to obtain funding; and market liquidity, which relates to the ease with which an asset can be traded (ECB, 2012; IMF, 2015). This paper is principally concerned with market liquidity. But market liquidity itself has multiple facets, and no one metric is likely to be able to measure it perfectly. We therefore construct several measures of market liquidity that have frequently been used in the literature.

6.1 Gilt liquidity measures

For the gilt market, we compute the following four measures of market liquidity. The first three are constructed using transaction-level information from the Zen dataset, at the level of individual bonds. The fourth (yield curve noise) is estimated using end-of-day yields from Bloomberg, and is calculated at the level of the market rather than individual bonds. All the metrics are computed at daily frequency, with higher values indicating lower liquidity.

1. *Amihud measure*: Amihud (2002) measures liquidity as the ratio of absolute return to trading volume. This measure is intended to indicate the price impact of trades. Following Dick-Nielsen et al. (2012), we estimate the price impact at the level of individual trades, and average over the trade-level values each day to obtain a measure at daily frequency. More precisely, for a given gilt and a given day t, define $r_{i,t}$ to be the return and $Q_{i,t}$ to be the trade size (in £ million) of the ith trade, and define N_t to be the number of trades. The Amihud measure at gilt level is the daily average of the absolute returns divided by the corresponding trade sizes:[7]

$$Amihud_t = \frac{1}{N_t - 1} \sum_{i=2}^{N_t} \frac{|r_{i,t}|}{Q_{i,t}}.$$

2. *Roll measure:* Roll (1984) shows that under certain assumptions, the percentage bid-ask spread is equal to two times the square root of the negative first-order serial covariance of returns. The intuition is that the transaction price will tend to bounce between the bid price and ask price, so that returns on consecutive trades are negatively correlated, and that this negative correlation will be larger if the bid-ask spread is wider. For a given gilt and a given day t, define $r_{i,t}$ to be the return on the i-th trade. We define the Roll measure at gilt level as:

$$Roll_t = 2\sqrt{\max\{0, -cov\left(r_{i,t}, r_{i-1,t}\right)\}}.$$

3. *Round-trip cost (RTC):* As an additional measure of the bid-ask spread, we estimate the round-trip cost of trading a bond, following Goldstein et al. (2007). We search for instances in which a given dealer buys a gilt from a client, and then the same dealer subsequently sells the gilt to

[7] In line with Bessembinder et al. (2009), we exclude trades smaller than £100,000 because these can have a disproportionate effect on the Amihud measure.

another client on the same day; or alternatively, instances in which a given dealer sells a gilt to a client, and then subsequently buys the same gilt from another client on the same day; and we find the dealer's return on this chain of transactions. For a given gilt and a given day, we then take the average of these returns.

4. *Yield curve noise:* Following Hu et al. (2013), our final measure of liquidity for the gilt market is based on the differences between observed bond yields and the fitted yields from a smoothed yield curve. The intuition is that these differences indicate deviations from fundamental values. The noise measure is computed as the root-mean-squared difference between end-of-day actual and fitted yields on bonds with maturity between one and ten years. For fitted yields, we use the Bank of England's fitted nominal gilt curve, which is based on the Anderson and Sleath (2001) 'variable roughness penalty' (VRP) approach. On day t, suppose that there are N_t conventional gilts with residual maturity between one and ten years, define y_t^i to be the actual end-of-day yield of gilt i, and define $y^i(\mathbf{b}_t)$ to be the fitted yield of gilt i based on the model parameters $\mathbf{b}_t$ estimated for day t. Then the noise measure is defined as:

$$Noise_t = \sqrt{\frac{1}{N_t}\sum_{i=1}^{N_t}\left[y_t^i - y^i(\mathbf{b}_t)\right]^2}.$$

Our estimated liquidity metrics for the gilt market are shown in Figure 10, with higher values indicating worse liquidity (for Amihud, Roll and round-trip cost, we show the median value across gilts). We combine the information from these measures by extracting the first principal component, which is shown in Figures 15 and 16.[8] Annual averages of the four measures are shown in Table 2, along with the factor loadings of the first principal component. The four measures are strongly correlated, with the first principal component explaining 71% of the sample variance. All four measures increased sharply during the financial crisis of 2008-09, before drifting back down over late 2009 and 2010. Most of the measures were again elevated over 2011-12, during the European sovereign debt crisis. All measures increased again during 2014 and 2015.

The Zen dataset does not cover the pre-crisis period, meaning that we cannot compare the latest levels of Amihud, Roll and round-trip cost to pre-crisis averages. However the yield curve noise measure is available pre-crisis. Table 2 shows that yield curve noise was on average higher (indicating worse liquidity) over 2015 than the pre-crisis period 2000-06, although the difference is small.

6.2 Repo liquidity measures

We construct three liquidity measures for the interdealer gilt repo market, in each case using the transaction-level BrokerTec data. We construct these separately for general collateral trades and specific collateral trades, at daily frequency.

1. *Amihud:* As for gilts, we construct an Amihud measure of repo liquidity, which is intended to measure the impact on the repo rate of a £1 million trade. For a given type of repo (general

[8] Before computing the first principal component, we standardise the measures to have mean zero and standard deviation equal to one.

collateral or specific collateral) and a given day t, define $R_{i,t}$ to be the repo rate and $Q_{i,t,}$ to be the trade size (in £ million) of the ith trade, and define N_t to be the number of trades. The Amihud measure for repo is then the daily average of absolute changes in repo rates divided by the corresponding trades sizes:

$$Amihud_t = \frac{1}{N_t - 1} \sum_{i=2}^{N_t} \frac{|R_{i,t} - R_{i-1,t}|}{Q_{i,t}}.$$

2. *Roll:* Using the same notation, the Roll measure that we calculate for gilt repo is defined as:

$$Roll_t = 2\sqrt{\max\left\{0, -cov\left(R_{i,t} - R_{i-1,t}, R_{i-1,t} - R_{i-2,t}\right)\right\}}$$

3. *Effective spread:* As an alternative measure of the bid-ask spread, and following Hong and Warga (2000), we calculate the 'effective' bid-ask spread, defined as the difference between the volume-weighted average repo rates on cash-borrower-initiated and cash-lender-initiated trades.

Our estimated liquidity measures for the gilt repo market are shown in Figures 11 and 12 and in Table 3, again with higher values indicating worse liquidity. The first principal component is shown in Figures 15 and 16. As for gilts, the repo liquidity measures are quite strongly correlated. The first principal component explains 61% of the variance of the three measures for general collateral, 73% of the variance of the three measures for specific collateral, and 47% of the variance when we pool the six measures. The measures indicate that repo liquidity worsened during the early stages of the financial crisis in 2007, before deteriorating dramatically with the collapse of Lehman Brothers in September 2008. This is in line with the findings of Gorton and Metrick (2012) for the US repo market.

All of the measures indicate a worsening in gilt repo liquidity over the post-crisis period, a point more clearly seen in Figures 13 and 14. The trend towards worse liquidity appears to begin in 2010 for general collateral repo and in 2014 for specific collateral repo. We can use Table 3 to compare recent levels of liquidity to pre-crisis levels. All but one of the six measures indicate that liquidity was worse on average in 2015 than in 2006, although in most cases the difference is modest. However, it is important to emphasise that these measures only use data from the interdealer market, which is almost entirely overnight and centrally cleared. These characteristics mean that the interdealer market is likely to be the part where most netting can occur under leverage ratio rules, making this segment the least affected by leverage ratio requirements. As such, to the extent that this reduction in liquidity was caused by the leverage ratio, it is likely to represent a lower bound for any deterioration in gilt repo liquidity more broadly.

7 Market-level analysis

We seek to test the hypothesis that the introduction of leverage ratio policy in the UK caused a reduction in the liquidity of the gilt and gilt repo markets. Our empirical analysis proceeds in three steps:

- First, we estimate market-level time series regressions, to assess how the liquidity of the gilt and gilt repo markets changed during the period when UK leverage ratio policy was announced, conditional on other factors. By identifying changes in liquidity on key reporting dates, when dealers' behaviour is likely to be most sensitive to regulatory requirements, these regressions also provide preliminary evidence on whether there was a causal link between the leverage ratio and liquidity.

- Second, we estimate market-level time series quantile regressions. While the first set of regressions provides information about the conditional mean of liquidity, the quantile regressions indicate how other parts of the conditional distribution changed during this period, providing insights into the resilience of liquidity.
- Third, we estimate dealer-level panel regressions, which use heterogeneity in dealer behaviour to identify any causal relationship between the leverage ratio and changes in liquidity.

This section discusses the market-level time series regressions. The quantile regressions and panel regressions are discussed in Sections 8 and 9, respectively.

7.1 Market-level regression specifications

The primary role of our market-level regressions is to investigate how the liquidity of the gilt and gilt repo markets changed during the period when UK leverage ratio policy was announced. Major UK banks have only been formally subject to a minimum leverage ratio requirement from January 2016, and other UK banks will only become formally subject to a minimum requirement in January 2018. But firms are likely to have started to adjust their balance sheets much earlier than this in response to a series of policy announcements, supervisory expectations and reporting requirements (see Section 3.3 and Table 1 for more detail). The first of these announcements was in December 2011, and so we assume that the adjustment process began in 2012 or later. We therefore include indicator variables for the years 2012, 2013, 2014 and 2015 in order to estimate whether the conditional mean of liquidity shifted during this period. We also employ structural break tests as a complement to this regression analysis.

While the indicator variables provide information on whether there was a change in the liquidity of these markets during the period that banks were adjusting to meet leverage ratio requirements, they cannot establish causality, because any change in liquidity might have been caused by variables omitted from the regressions. To provide preliminary evidence on causality, we additionally include indicator variables for quarter-ends from 2012 and month-ends from 2014. Large UK banks have disclosed quarter-end leverage ratios beginning with their 2012 annual reports (following the FPC's December 2011 recommendation), and all PRA-regulated firms have reported leverage ratios based on month-end balance sheets since 2014 (when EU-level reporting requirements, COREP, came into force). Dealers' behaviour is therefore likely to be particularly sensitive to leverage ratio policy on these dates. If the leverage ratio did cause a change in liquidity, we therefore expect this to be particularly pronounced at month-ends and quarter-ends. We consider the question of causality more formally in Section 9.

By providing information on the determinants of liquidity more broadly, these regressions also allow us to test several other hypothesis concerning, for example: the impact of market structure on liquidity; the impact of predictable events, such as Bank of England QE purchases and DMO gilt auctions, on liquidity; and the relationship between funding liquidity and market liquidity.

We run separate regressions for gilts and gilt repo. The regressions are at daily frequency, for the period January 2010 to December 2015 (to exclude the impact of the financial crisis), and take the following form:

$$\begin{aligned} Liquidity_t \quad = \quad & \beta_0 + \beta_1 YearIndicators_t + \beta_2 PeriodEndIndicators_t \\ & + \beta_3 LiquidityOtherMarket_{t-1} \\ & + \beta_4 FundingCosts_{t-1} + \beta_5 Sentiment_{t-1} + \beta_6 InventoryRisk_{t-1} \\ & + \beta_7 EuroCrisis_{t-1} + \beta_8 MarketStructure_{t-1} + \beta_9 GiltMarketEvents_t \\ & + \beta_{10} OtherControls_t + \varepsilon_t, \end{aligned} \tag{1}$$

where:

- $Liquidity_t$ is the first principal component of the liquidity measures discussed in Section 6. These are shown in Figures 15 and 16. Higher values of this variable indicate worse liquidity. $Liquidity_t$ is normalised such that its standard deviation over the regression sample period is equal to one.
- $YearIndicators_t$ consists of four indicator variables, indicating each of the four years (2012, 2013, 2014, 2015) following the first major UK policy announcement on leverage ratio regulation (December 2011).
- $PeriodEndIndicators_t$ consists of four indicator variables for month-ends and quarter-ends: a variable equal to one on the last day of the month and zero otherwise; a variable equal to one on the last day of the month if the date is after 1 January 2014 and zero otherwise; a variable equal to one on the last day of the quarter and zero otherwise; and a variable equal to one on the last day of the quarter if the date is after 1 January 2012 and zero otherwise. The coefficients on these variables can be interpreted additively: for example, on quarter-ends during 2014 and 2015, all four of the variables are equal to one.
- $LiquidityOtherMarket_t$ is the liquidity measure from the other market. That is, in the gilt regressions, this variable is the first principal component of the repo liquidity measures; while in the repo regressions, it is the first principal component of the gilt liquidity measures.
- $FundingCosts_t$ consists of variables related to dealer funding costs, specifically the 3-month Libor-OIS spread (unsecured funding) and the spread between the 3-month general collateral repo rate and the OIS rate (secured funding).
- $Sentiment_t$ is a set of variables indicating general financial market sentiment: the VIX (the implied volatility of the S&P 500), the percentage change in the FTSE 100, and the change in the 10-year gilt yield.
- $InventoryRisk_t$ consists of variables that affect the riskiness of a gilt portfolio: the implied volatility of the 10-year sterling interest rate, and the change in the UK sovereign CDS premium.

- $EuroCrisis_t$ consists of two variables to control for the potential impact of the European sovereign debt crisis on liquidity: the Euro Libor-OIS spread, and the change in the spread of the 10-year Italian sovereign bond yield over the 10-year German bund yield.
- $MarketStructure_t$ is a set of variables related to the structure of the market: the share of gilts held by insurance companies and pension funds (ICPFs), the change in the market value of the free float (total outstanding gilts minus government holdings, APF holdings, and other Bank of England holdings), and the network structure variables discussed in Section 5.
- $GiltMarketEvents_t$ consists of indicator variables for the dates of Bank of England APF (quantitative easing) purchases and the dates of DMO gilt auctions.
- $OtherControls_t$ consists of additional control variables, specifically several lags of the dependent variable (the number of lags is chosen using the Bayesian information criterion), and fixed effects for each quarter-end.[9]

All potentially endogenous explanatory variables are lagged by one day. For each of gilt and gilt repo, we run three regressions: the first includes only $YearIndicators_t$, $PeriodEndIndicators_t$ and $OtherControls_t$; the second includes the full set of control variables; and the third is a more parsimonious specification which includes only those control variables that are statistically significant in the full specification. We report HAC standard errors for all regressions (Newey and West, 1987, 1994).

7.2 Market-level regression results

The results are presented in Tables 5 and 6 for gilts and gilt repo, respectively. In the last row of each table, we show the results of a Wald test for the hypothesis that the year indicator variables are jointly equal to zero.

We consider first the results for gilt liquidity. Column (1) of Table 5 shows that when we do not control for factors such as funding costs and inventory risk, there is no evidence that gilt market liquidity became systematically worse during the period when UK leverge ratio policy was announced. The 2012 and 2015 indicators are positive and significant, indicating that liquidity in these years was worse than in the 'control' years (2010 and 2011). However, the 2014 indicator is negative and significant, indicating that liquidity was on average better during this year relative to 2010 and 2011. This is consistent with a visual inspection of Figure 10, which shows no clear trend in gilt liquidity over the post-crisis period. However, as shown by column (2), once we control for a wider range of influences on liquidity, we find that the conditional liquidity of the gilt market was significantly worse over 2012-2015 relative to 2010 and 2011. Each of the year indicators is positive, statistically significant and economically significant (recall that the units of the dependent variable are standard deviations). We find the same result in column (3), where we include a smaller range of control variables.

Surprisingly, the month-end indicator variable for the period 2014-2015 and the quarter-end indicator variable for the period 2012-2015 have negative coefficients. This indicates that liquidity on

[9]The quarter-end fixed effects are constrained to sum to zero. This means that the quarter-end indicator variables in $PeriodEndIndicators_t$ measure the average impact of quarter-ends on liquidity, while the quarter-end fixed effects pick up the individual deviations around this average. The purpose of the quarter-end fixed effects is to prevent the very large spikes in the liquidity measures that occur on some quarter-ends from impacting the coefficients on the year indicator variables.

month-ends and quarter-ends *improved* relative to average liquidity during the adjustment period. This casts doubt on a causal connection between the leverage ratio and the conditional deterioration in gilt liquidity. These coefficients are, however, not statistically significant in most specifications.

Turning to the other variables, we observe a strong association between the Libor-OIS spread and gilt liquidity, indicating that funding liquidity supports market liquidity, in line with the prediction of Brunnermeier and Pedersen (2009). Meanwhile, increases in inventory risk - measured through interest rate implied volatility and the UK sovereign CDS premium - are associated with reductions in liquidity. Consistent with Benos and Zikes (2016), we find that a larger interdealer market is associated with an improvement in liquidity. This is consistent with the hypothesis that a larger interdealer market improves dealers' ability to manage their inventories and share risk, and therefore makes dealers more willing to provide liquidity to their clients.[10] Finally, we find that gilt market liquidity improves on days when the DMO issues gilts.

We consider now the results for repo liquidity. All three columns of Table 6 indicate that repo liquidity was little changed over 2012 and 2013 but worsened significantly in 2014 and 2015. This result holds whether or not we control for other potential determinants of liquidity, and is consistent with Figures 13 and 14.

The estimated coefficient on the indicator variable for quarter-ends over 2012-2015 is large, positive and highly statistically significant. This indicates that the deterioration in repo liquidity over this period was particularly pronounced at quarter-ends. This provides indicative evidence of a causal connection between the leverage ratio and the reduction in repo liquidity (and reflects the results in Munyan, 2015 for the US tri-party repo market). Very few of the other coefficients in the repo regressions are statistically significant, suggesting that repo liquidity is less sensitive to changes in funding costs, inventory risk and market structure than gilt liquidity.

For both markets, the timing of the reduction in liquidity shown by the regressions is consistent with results from structural break tests. We re-estimate the regressions with the full set of controls but without the year indicators, and test for a single unknown breakpoint in the intercept using the supremum Wald test of Andrews (1993). For gilts we detect a structural break in December 2011, while for repo we detect a structural break in July 2013.

In summary, the market-level regressions suggest that liquidity did worsen in both markets during the period when UK leverage ratio policy was announced. For gilts this result only holds when we control for other factors, while for gilt repo the result also holds unconditionally. Changes in liquidity on quarter-ends also provide preliminary evidence of a causal connection between the leverage ratio and the deterioration in repo liquidity, although not for gilt liquidity. We find that gilt liquidity is sensitive to several other variables - particularly funding costs and inventory risk. On the other hand, repo liquidity appears to be relatively insensitive to changes in market conditions.

8 Liquidity resilience

Policymakers and market participants have expressed concern that the risk of sudden reductions in liquidity has increased in recent years, with several well-publicised bouts of volatility cited as evidence

[10]See Ho and Stoll (1983) for a related theoretical model.

(see, for example, Shafik, 2015 and CGFS, 2016). We therefore consider the question of whether liquidity became less resilient as banks adjusted to the leverage ratio. We address this question in two ways. First, we estimate quantile regressions, which allow us to compare changes in liquidity at different parts of the conditional distribution. Second, we plot the frequency of sudden 'jumps' in liquidity.

Tables 7 and 8 show the results from quantile regressions of liquidity in the gilt and repo markets, respectively. The specifications of these regressions are very similar to the specifications used in the second columns of Tables 5 and 6.[11] In each case, column (1) shows results from the median regression and column (2) shows the 0.9 quantile regression. The results for the 0.9 quantile indicate the impact of the regressors on liquidity in times of poor conditional liquidity. Column (3) shows the differences between the estimated coefficients from the two regressions. We report bootstrapped standard errors in parentheses.

For both gilts and gilt repo, the results for the conditional median regressions (first column) are broadly similar to the conditional mean regressions shown in Tables 5 and 6. And in both cases, the third column shows that the estimated coefficients on the year indicator variables are larger at the 0.9 quantile than at the median. This indicates that the (conditional) worsening in liquidity over this period was more pronounced at times of poor liquidity than at times of normal liquidity, consistent with a reduction in the resilience of liquidity. However, these differences are not statistically significant for all years. For gilts the difference is significant only for the 2015 indicator, while for repo the difference is significant only for the 2012 and 2014 indicators. In addition, Wald tests indicate that the differences are jointly insignificant (third column, last row). We also note that, in the repo market, the 2012-15 quarter-end effects are substantially larger at the 0.9 quantile than at the median.

Further evidence that repo liquidity became less resilient is provided by considering the frequency of 'jumps' in liquidity. Following an approach similar to Adrian et al. (2015a,c), we define a 'jump' to be a one-day increase in the first principal component of liquidity of at least one standard deviation.[12] Figure 17 shows quarterly sums of the number of 'jumps' in liquidity in the two markets. In both markets, jumps were most frequent during the financial crisis. There is no clear trend in the frequency of jumps in gilt liquidity during the post-crisis period. But jumps became more frequent in the repo market over the period 2012-15, indicating an increase in the risk that liquidity suddenly evaporates.

9 Dealer-level analysis

The market-level regressions indicate that liquidity in both the gilt and gilt repo markets worsened during the period when UK leverage ratio policy was announced, once we control for factors such as changes in funding costs and inventory risk. And the quantile regressions indicate that this worsening in liquidity was more pronounced in times of poor liquidity, consistent with a reduction in the resilience of liquidity. However, these regressions do not provide strong evidence of a causal link between the leverage ratio and liquidity because the changes in liquidity over this period might have been caused

[11] The only difference is that in the quantile regressions we do not include quarter-end fixed effects, because quantile regressions are robust to outliers.

[12] We use the standard deviation of the level of the first principal component across the period 2008-2015 for gilts and 2006-2015 for gilt repo.

by some other omitted factor. In order to better identify a potential causal impact, we run dealer-level panel regressions that exploit two sources of heterogeneity across dealers: heterogeneity in the balance sheets of individual dealers, and heterogeneity in the timing of regulatory requirements across jurisdictions.

A significant challenge to this analysis is that we lack a clear treatment date. Policies were developed gradually, and banks were given lengthy periods of time (typically years) to adjust ahead of full implementation, making it difficult to establish when a given bank would have started its adjustment process. Therefore, as discussed in more detail below, we consider several different specifications and treatment dates. In some specifications all banks are assumed to start the adjustment process at the same time. In others the treatment date differs across banks. For this second set of regressions, we partition the sample of dealers into three groups: large UK banks ($LargeUK$), UK subsidiaries of US banks ($SubsidiaryUS$), and other UK entities ($OtherUK$). The $OtherUK$ group includes both smaller UK banks and UK subsidiaries of foreign (non-US) banks. The sizes and market shares of these three groups are shown in Table 9. We exclude a small number of dealers that are UK branches of foreign banks because we do not have consistent balance sheet data for these entities. We also exclude any banks that are inactive over either the full pre-treatment period or the full post-treatment period. For example, we exclude GEMMs that exited the market before the treatment date. This ensures that all banks in the sample are active both before and after the treatment date.

The treatment dates that we focus on are the following (see Section 3.3 and Table 1 for further detail):

- **December 2011:** The FPC recommended that the FSA encourage UK banks to disclose their leverage ratios. The FSA implemented this by asking banks in the $LargeUK$ group to publish their leverage ratios in their 2012 annual reports and on a bi-annual basis thereafter.
- **June 2012:** US regulators proposed a supplementary leverage ratio for large US banks, including the parent companies of the banks in the $SubsidiaryUS$ group. Allahrakha et al. (2016) find that this announcement caused affected broker-dealers to decrease their total repo borrowing.
- **January 2014:** PRA-regulated firms started to report regulatory leverage ratios through COREP on the basis of month-end balance sheets. This was the first time that banks in the $OtherUK$ group were required to report regulatory leverage ratios.

9.1 Dealer-level regression specifications

We consider several different specifications for the dealer-level regressions. Each takes the following general form:

$$\begin{aligned} LiquidityProvision_{i,t} &= \alpha_i + \lambda_t + Treatment_{i,t} \\ &\quad + \beta_1 CountryControls_{i,t} + \beta_2 DealerControls_{i,t} + \varepsilon_{i,t}, \end{aligned} \tag{2}$$

where:

- $LiquidityProvision_{i,t}$ is a measure of the liquidity provided by dealer i at date t. We measure liquidity provision in the gilt market in two ways: first, round-trip cost (RTC) at the dealer level, measured in basis points, which is a measure of the average bid-ask spread that the dealer charges its clients on gilt trades;[13] and second, the log of the dealer's trading volume with clients. For the gilt repo market, we measure liquidity provision as the log of the dealer's total repo borrowing (we do not observe transaction-level repo data for individual dealers).

- $Treatment_{i,t}$ is a function which differs across specifications, as defined below.

- $CountryControls_{i,t}$ is a vector of control variables for the country where dealer i has its main headquarters, specifically the GDP growth rate and the equity index growth rate.

- $DealerControls_{i,t}$ is a vector of control variables at the dealer-level: the first lag of liquidity provision; the log of total assets; return on assets; the share of the bank's assets that are recorded as being in the trading book; the share of the bank's assets that are cash or government bonds; and the bank's risk-weighted capital ratio.

- α_i and λ_t are bank and time fixed effects, respectively. The bank fixed effects control for all time-invariant heterogeneity at the bank level. The time fixed effects control for factors that might have impacted the liquidity provision of all banks in a similar way, such as the implementation of quantitative easing.

The samples consist of sixteen GEMMs and nineteen repo dealers. The regressions are at quarterly frequency, because the dealer-level control variables and the RSL data are available only at quarterly frequency. The sample period is 2008Q1 to 2015Q4. Standard errors are double-clustered at the bank and time level using the implementation in Correia (2017).

We estimate three versions of regression (2) which differ according to the definition of $Treatment_{i,t}$. Each of these exploits variation in banks' leverage ratios at the time of key policy announcements. The third version also exploits variation in the timing of leverage ratio implementation across jurisdictions.

The **first version** of regression (2) defines $Treatment_{i,t}$ as

$$Treatment_{i,t} = \delta Dec11\_Constrained_{i,t} \tag{3}$$

where

$$Dec11\_Constrained_{i,t} = \begin{cases} 1 & \text{if } LR_{i,s} < 3\% \text{ and } t > s, \\ 0 & \text{otherwise,} \end{cases}$$

for $s =$ December 2011. This results in a simple difference-in-differences specification, where the treatment group is the set of dealers whose leverage ratios were below 3% in December 2011 and the control group is the set of dealers whose leverage ratios were above 3% in December 2011. December 2011 was the first major UK policy announcement regarding the leverage ratio, when the FPC recommended that UK banks be encouraged to disclose their leverage ratios from 2013. While this recommendation was only applied to large UK banks, it might have also affected the behaviour of other banks by

[13] We do not consider the other two transaction-based liquidity measures (Amihud and Roll) to be meaningful at the level of individual dealers.

signalling that UK authorities would be front-running the Basel and EU timelines. More generally, using a treatment date early in the policy-making process reduces the possibility that the date falls after banks had started adjusting their balance sheets. This choice of date is also supported by our market-level analysis, which indicates that there was a structural break in conditional gilt liquidity in December 2011. The rationale for this definition of $Treatment_{i,t}$ is that banks whose leverage ratios were below 3% (the regulatory minimum proposed by the BCBS) at the start of the adjustment process would, over the following years, have needed to adjust their balance sheets by more than banks with leverage ratios above 3%. If the leverage ratio had a causal impact on liquidity, we would therefore expect this to have occurred mainly through the liquidity provision of banks in the treatment group ('constrained' banks). This regression specification is similar to those used in Acosta Smith et al. (2017) and ESRB (2016).

The **second version** of the regression defines $Treatment_{i,t}$ as

$$Treatment_{i,t} = -\delta Dec11\_PTLR_{i,t}, \tag{4}$$

where

$$Dec11\_PTLR_{i,t} = \begin{cases} LR_{i,s} & \text{if } t > s, \\ 0 & \text{otherwise,} \end{cases}$$

for $s =$ December 2011. The variable $Dec11\_PTLR$ is equal to the bank's December 2011 leverage ratio if the date is after December 2011 and zero otherwise (PTLR stands for 'pre-treatment leverage ratio'). Again this results in a difference-in-differences specification, but in this case the treatment variable is continuous rather than binary. We include this version because a bank's adjustment to the regulatory leverage ratio may have depended on how far it was from the proposed minimum. In addition, banks typically maintain buffers over regulatory minima, meaning that even banks with leverage ratios above 3% in December 2011 may have attempted to increase their leverage ratios further. This regression specification is broadly similar to those used in Allahrakha et al. (2016).

The **third version** allows the treatment date to differ across banks. It defines $Treatment_{i,t}$ as

$$Treatment_{i,t} = \delta_1 Treated_{i,t} - \delta_2 PTLR_{i,t}, \tag{5}$$

where

$$Treated_{i,t} = \begin{cases} 1 & \text{if } t > s_i, \\ 0 & \text{otherwise,} \end{cases}$$

and

$$PTLR_{i,t} = \begin{cases} LR_{i,s_i} - \overline{LR_{i,s_i}} & \text{if } t > s_i, \\ 0 & \text{otherwise,} \end{cases}$$

where

$$s_i = \begin{cases} \text{December 2011} & \text{if } i \in LargeUK, \\ \text{June 2012} & \text{if } i \in SubsidiaryUS, \\ \text{January 2014} & \text{if } i \in OtherUK, \end{cases}$$

and $\overline{LR_{i,s_i}}$ is the average leverage ratio across banks in the same group as i ($LargeUK$, $SubsidiaryUS$ or $OtherUK$) at date s_i. In words, $Treated$ is an indicator variable equal to one for a given bank after its 'treatment date' (s_i) and zero otherwise. δ_1 therefore measures the average post-treatment change in the liquidity provision of treated banks, relative to banks not yet treated. And $PTLR$ is the bank's leverage ratio at the time of treatment, minus the mean leverage ratio across all banks in its group. δ_2 therefore identifies how changes in the liquidity provision of treated banks are associated with deviations from the within-group average leverage ratio at the time of treatment.

Each of the variables used in $Treatment_{i,t}$ is defined such that, for the regressions with gilt volumes or repo volumes as the dependent variable, a *negative* coefficient suggests that the leverage ratio led to reduced liquidity provision (because treated banks, or those with lower leverage ratios, reduced volumes relative to other banks); while for the regressions with round-trip cost as the dependent variable, a *positive* coefficient suggests that the leverage ratio led to reduced liquidity provision (because treated banks, or those with lower leverage ratios, increased their bid-ask spreads relative to other banks).

The definition of banks' leverage ratios differs across specifications due to data availability. For most banks in the sample, Basel-consistent leverage ratios are unavailable in December 2011. So for the first and second regression specifications we use the simple leverage ratio (Tier 1 capital divided by total assets), calculated from regulatory returns at the individual entity level. Acosta Smith et al. (2017) show that the simple leverage is highly correlated with the Basel regulatory definition. For the third specification we are able to use regulatory leverage ratios. For $LargeUK$ banks, we use Basel-consistent leverage ratios at the group level, as reported in their Quantitative Impact Study (QIS) submissions for 2011Q4. For banks in the $OtherUK$ group, we use regulatory leverage ratios at the UK-group level reported through COREP for 2014Q1. For the $SubsidiaryUS$ group, we use the Basel-consistent leverage ratio estimates computed by Allahrakha et al. (2016). These are based on Form Y-9C filings for 2012Q2 and are calculated at BHC level.

9.2 Dealer-level regression results

The regression results are shown in Table 10 for gilts and Table 11 for repo.

We first consider the results for the **first version** of $Treatment_{i,t}$. Columns (1) and (5) of Table 10 and column (1) of Table 11 show estimated coefficients when we include bank and time fixed effects but no other control variables. The results for this simple difference-in-differences specification are also represented graphically in Figures 18, 19 and 20. The charts show the evolution of dealer-level liquidity provision between 2009-2015, distinguishing between banks with leverage ratios above and below 3% as of December 2011. For all measures of liquidity provision, the sign of the estimated effect is consistent with a causal role for the leverage ratio in the reduction in liquidity: relative to the control group, banks with leverage ratios below 3% increased their average bid-ask spreads on gilt transactions by 1.2 basis points, reduced their gilt trading volumes with clients by around 18%, and reduced their repo borrowing by around 69%. However, in each case the estimated coefficient is statistically insignificant.

Columns (2) and (6) of Table 10 and column (2) of Table 11 again show results for the first definition of $Treatment_{i,t}$, but include additional country-level and dealer-level controls. In each case the added control variables lead to a reduction in the estimated effect, and in the case of dealer-to-client gilt volumes the effect changes sign. The results remain statistically insignificant.

The results for the **second version** of $Treatment_{i,t}$ are shown in columns (3) and (7) of Table 10 and column (3) of Table 11. The results for the **third version** of $Treatment_{i,t}$ are shown in columns (4) and (8) of Table 10 and column (4) of Table 11. If the leverage ratio caused the reduction in liquidity, we would expect to see positive coefficients in the regressions with gilt round-trip cost as the dependent variable, and negative coefficients in the regressions with gilt volumes or repo volumes as the dependent variable. But these patterns are not observed: the signs of the estimated coefficients vary across specifications (some are consistent with a causal role for the leverage ratio, while others are not), and few of the estimated coefficients are statistically significant.

In summary, the dealer-level analysis does not provide convincing evidence of a causal link between the leverage ratio and the reduction in gilt and repo liquidity. Banks with leverage ratios below 3% at the time of the first UK leverage ratio policy announcement did reduce their liquidity provision relative to control banks over the adjustment period. But this result is not statistically significant and is robust neither to the inclusion of control variables nor to alternative regression specifications.

10 Conclusion

This paper assesses the impact of the leverage ratio – a key component of the Basel III package of post-crisis regulatory reform – on the liquidity of the gilt and gilt repo markets.

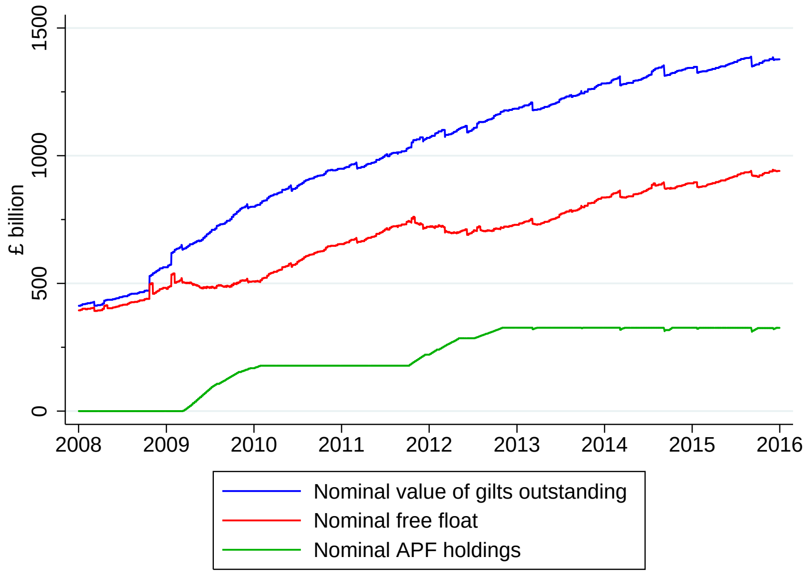
High-level trends in these markets are indicative of reductions in liquidity during the period when UK leverage ratio policy was introduced. Over the period 2010-2015, there were falls in gilt turnover ratios, gilt repo trading volumes, and the average gilt repo trade size. These patterns are consistent with market participants reducing their activity and breaking up trades in response to higher costs. But they are not definitive evidence of reduced liquidity because they might reflect other trends, such as structural changes in the investor base. We therefore compute several more direct measures of liquidity from transaction-level data, and use principal components analysis to combine these into two liquidity indices, one for the gilt market and one for the gilt repo market. Time series regressions using these liquidity indices suggest that gilt repo liquidity indeed worsened during the period when leverage ratio policy was announced, and that gilt liquidity worsened conditional on factors such as funding costs and inventory risk. This suggests that, were funding conditions to become less benign or interest rate volatility to increase, gilt liquidity could fall to lower levels than previously would have been the case. For both markets, the timing of the reduction in liquidity shown by the regressions is consistent with results from structural break tests (Andrews, 1993).

We also find evidence that the resilience of liquidity has deteriorated since leverage ratio policy was announced, particularly in the gilt repo market. First, quantile regressions suggest that the conditional reduction in liquidity has been larger in times of poor liquidity than in times of median liquidity, although this difference is not always statistically significant. Second, the frequency of sudden reductions ('jumps') in gilt repo liquidity has increased, although we do not observe this trend in the gilt market.

While the market-level analysis indicates that liquidity in these markets has reduced, and has potentially became less resilient, evidence on whether the regulatory leverage ratio *caused* these changes is inconclusive. In the gilt repo market, the market-level regressions show that the deterioration in liquidity has been particularly pronounced at quarter-ends – when we would expect dealer behaviour to be especially sensitive to regulatory constraints (consistent with the results in Munyan, 2015 for the US tri-party repo market). This provides preliminary evidence of a causal role for the leverage ratio in the reduction in repo liquidity. Such a pattern is not, however, observed in the gilt market. We also use heterogeneity in dealer-level liquidity provision to identify any causal role for the leverage ratio. The evidence here is again inconclusive. In both the gilt and gilt repo markets, banks with leverage ratios below 3% at the time of the first UK leverage ratio policy announcement did reduce their liquidity provision relative to control banks, consistent with a causal role for the leverage ratio. But this result is not statistically significant and is robust neither to the inclusion of control variables nor to alternative regression specifications.

In summary, while a reduction in market liquidity appears to have occurred alongside the introduction of leverage ratio regulation, the evidence on a causal connection is inconclusive. In this paper we do not attempt to quantify the benefits of the leverage ratio. By leading to an increase in the capitalisation of banks, the leverage ratio is likely to have increased their resilience to shocks. Assessing the overall impact of the leverage ratio on financial stability and welfare is beyond the scope of this paper, but is likely to be an important area for future research.

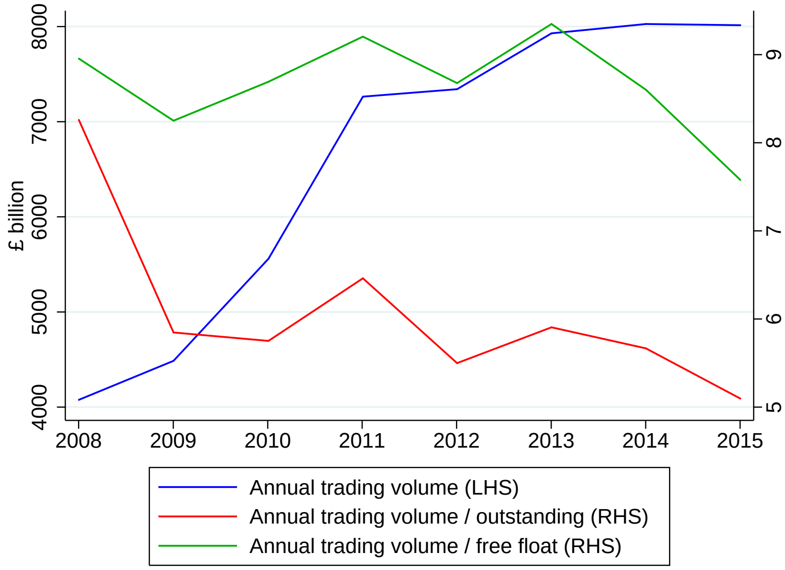
Figure 1: Nominal value of gilts outstanding



Notes: The blue line shows the nominal value of gilts outstanding. The green line shows the nominal value of gilts held by the Asset Purchase Facility (APF) under the Bank of England's quantitative easing (QE) programme. The red line shows the nominal 'free float', defined as the value of gilts outstanding minus government holdings, APF holdings and other Bank of England holdings. Daily frequency.

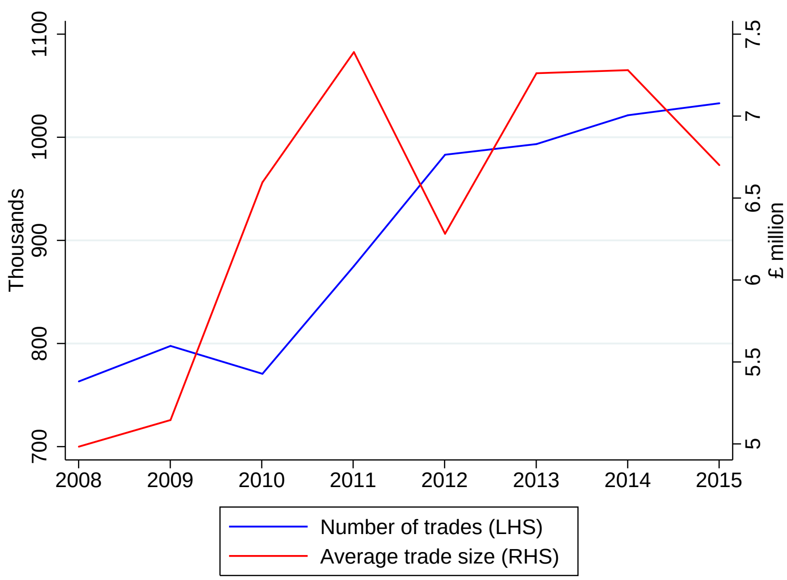
Sources: UK Debt Management Office, Bank of England.

Figure 2: Gilt trading volume and turnover ratios



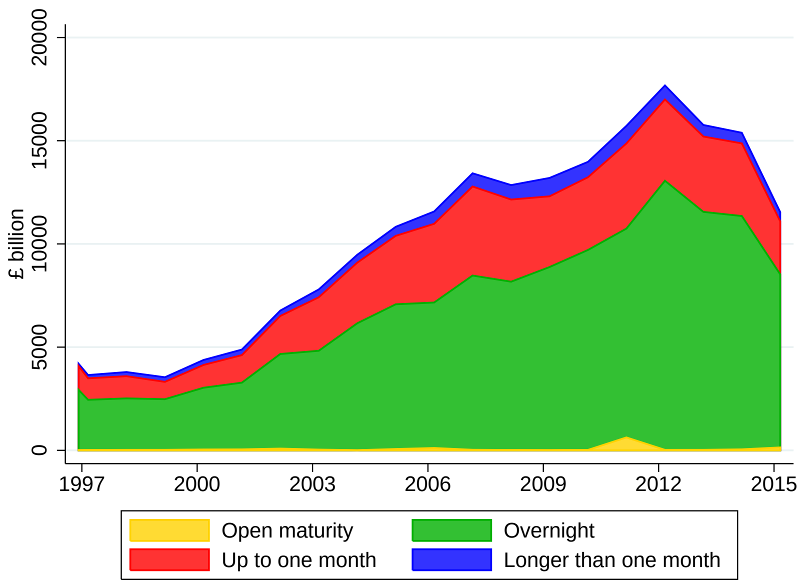
Notes: The blue line shows the annual sum of gilt trading volumes (market value). The red and green lines divide this by the market value of gilts outstanding and the market value of free float, respectively, to give annual 'turnover ratios'. Annual frequency.
Sources: Zen dataset, UK Debt Management Office, Bank of England.

Figure 3: Number of gilt trades and average trade size



Notes: The blue line shows the total number of gilt trades per year. The red line shows the market value of the average trade. Annual frequency.
Source: Zen dataset.

Figure 4: Gilt repo trading volume

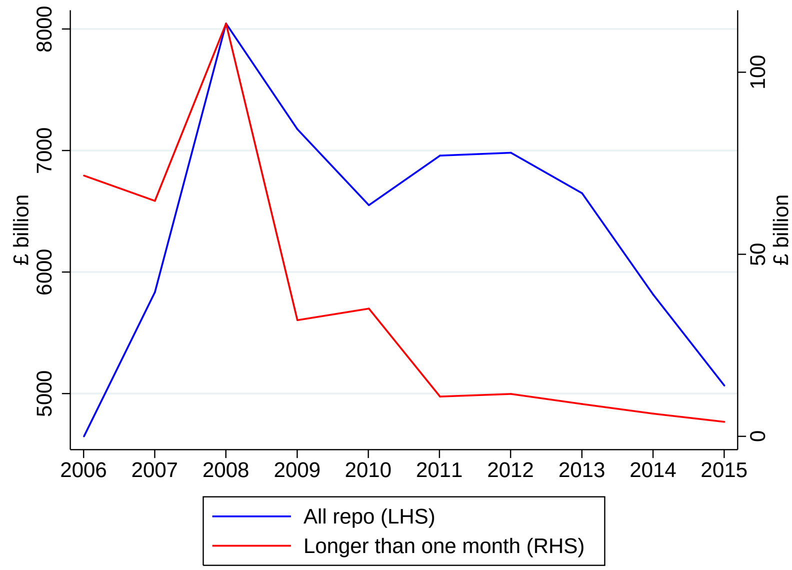


Notes: The chart shows the annual sum of gilt repo trading volumes, by maturity at trade date. Annual frequency.
Source: Form RSL.

Figure 5: Number of gilt repo trades and average trade size

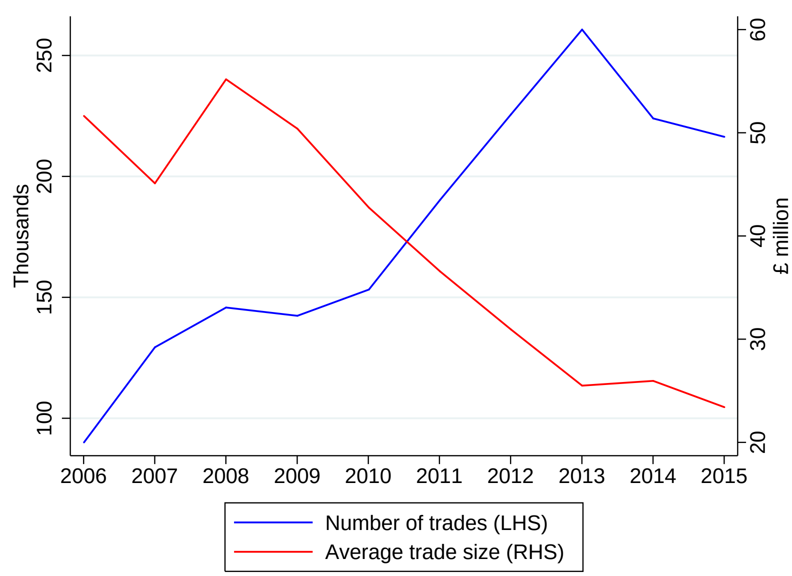
Notes: The blue line shows the total number of gilt repo trades per year. The red line shows the value of the average trade. Annual frequency.
Source: Form RSL.

Figure 6: Interdealer gilt repo trading volume



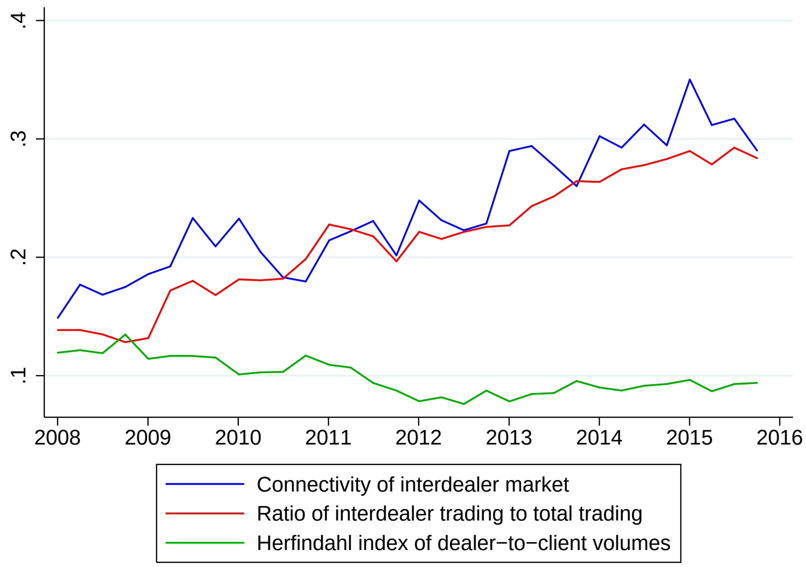
Notes: The chart shows the annual sum of gilt repo trading volumes transacted through BrokerTec, which is the largest electronic platform for interdealer gilt repo. Annual frequency.
Source: BrokerTec.

Figure 7: Number of interdealer gilt repo trades and average trade size



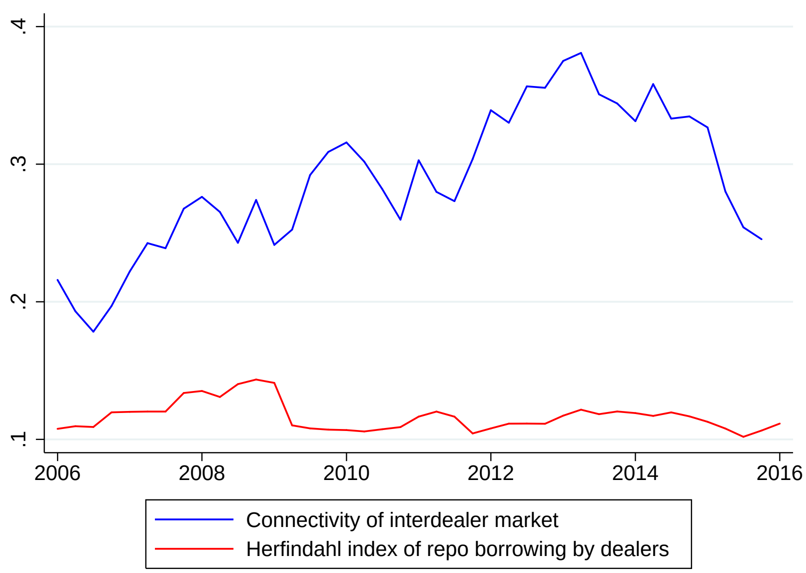
Notes: The blue line shows the total number of gilt repo trades transacted through BrokerTec per year. The red line shows the value of the average trade. Annual frequency.
Source: BrokerTec.

Figure 8: Gilt market network statistics



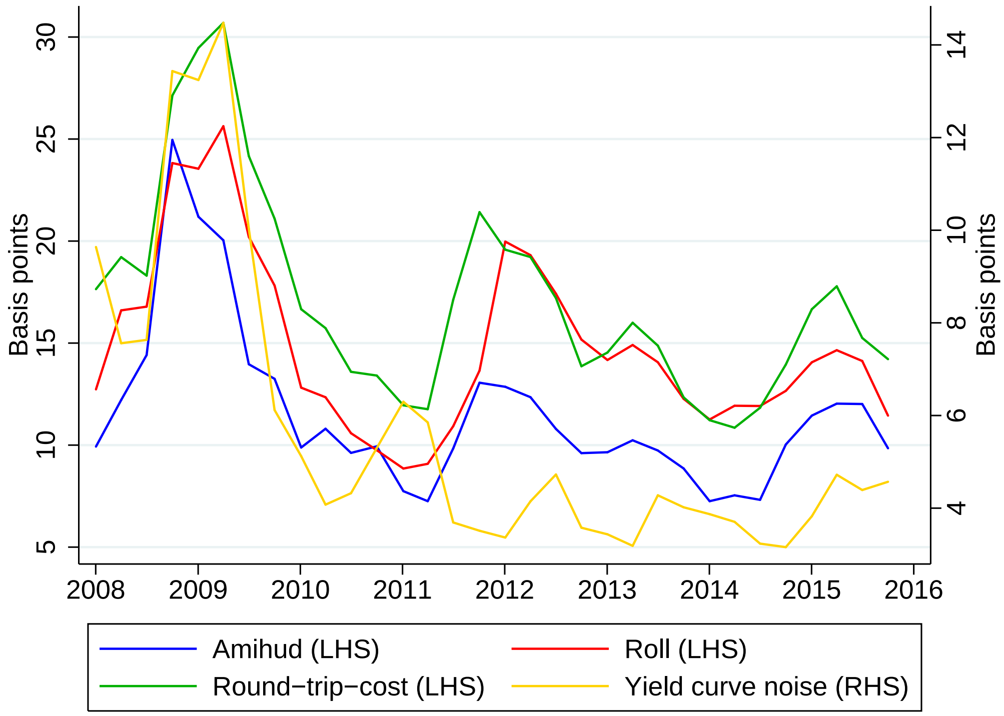
Notes: The chart shows network statistics for the gilt market, as defined in Section 5. Quarterly averages.
Source: Zen dataset.

Figure 9: Gilt repo market network statistics



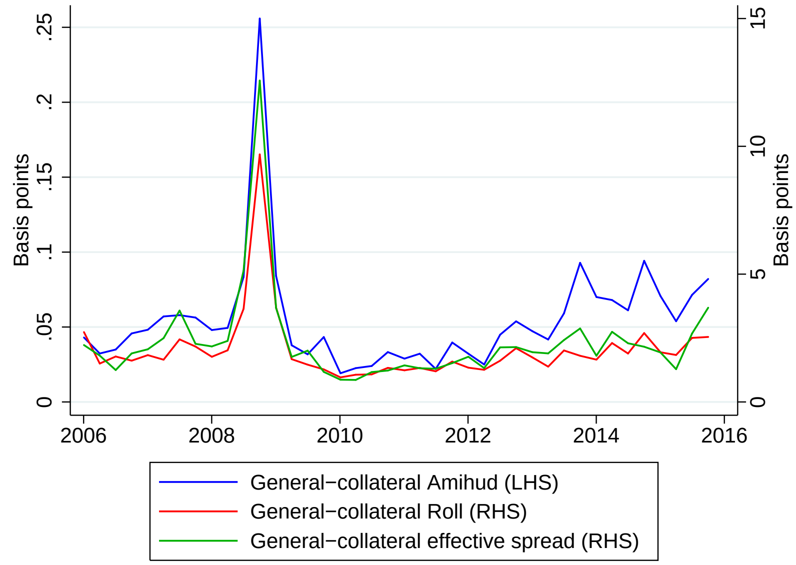
Notes: The chart shows network statistics for the gilt repo market, as defined in Section 5. Quarterly averages.
Sources: BrokerTec, Form RSL.

Figure 10: Gilt liquidity measures



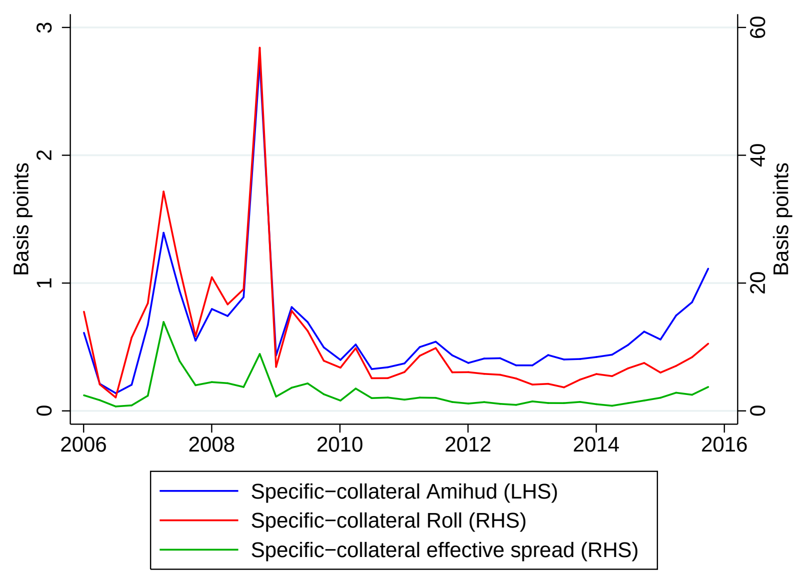
Notes: The chart shows liquidity measures for the gilt market, as defined in Section 6.1. Higher values indicate worse liquidity. The units of Amihud, Roll and round-trip cost are basis points in price space. For these measures, we show the median across gilts. The units of yield curve noise are basis points in yield space. Quarterly averages.
Sources: Zen dataset, Bank of England, Bloomberg.

Figure 11: General collateral repo liquidity measures (full sample)



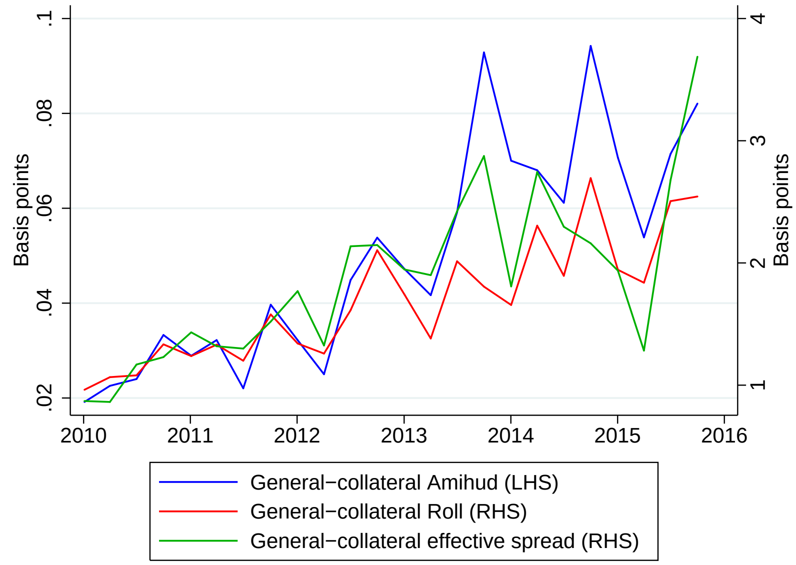
Notes: The chart shows liquidity measures for the general collateral interdealer gilt repo market, as defined in Section 6.2. Higher values indicate worse liquidity. For all measures, the units are basis points in repo rate space. Quarterly averages.
Source: BrokerTec.

Figure 12: Specific collateral repo liquidity measures (full sample)



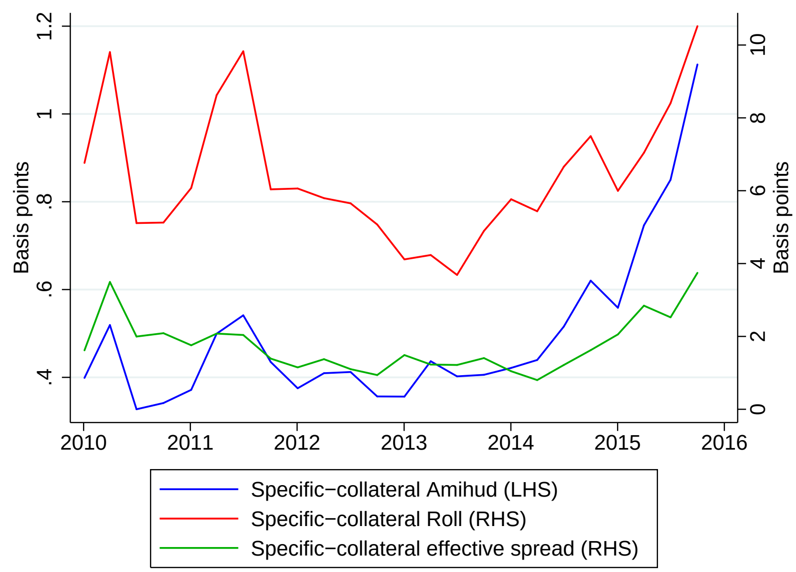
Notes: The chart shows liquidity measures for the specific collateral interdealer gilt repo market, as defined in Section 6.2. Higher values indicate worse liquidity. For all measures, the units are basis points in repo rate space. Quarterly averages.
Source: BrokerTec.

Figure 13: General collateral repo liquidity measures (since 2010)



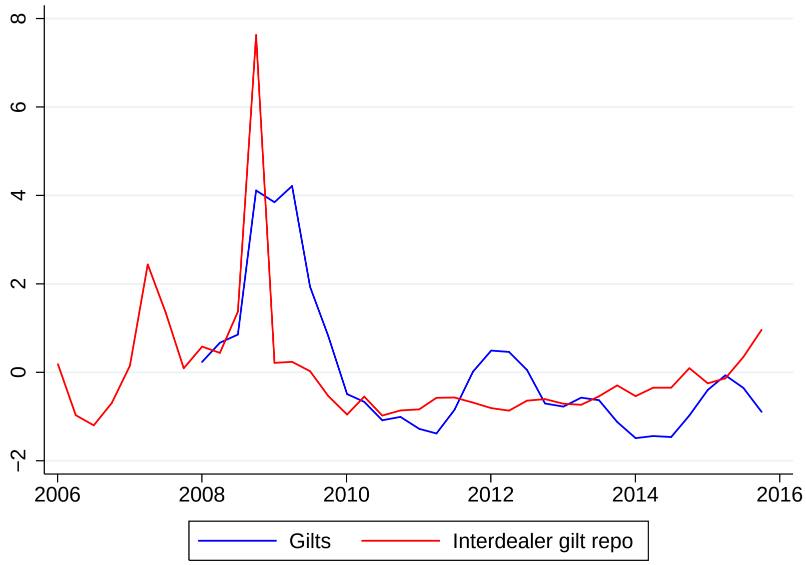
Notes: For details, see Figure 11.
Source: BrokerTec.

Figure 14: Specific collateral repo liquidity measures (since 2010)



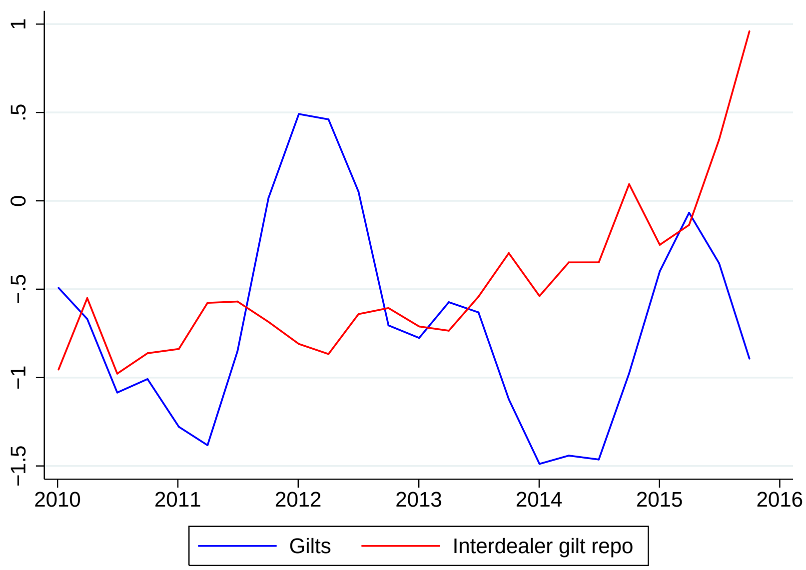
Notes: For details, see Figure 12.
Source: BrokerTec.

Figure 15: First principal component of liquidity measures (full sample)



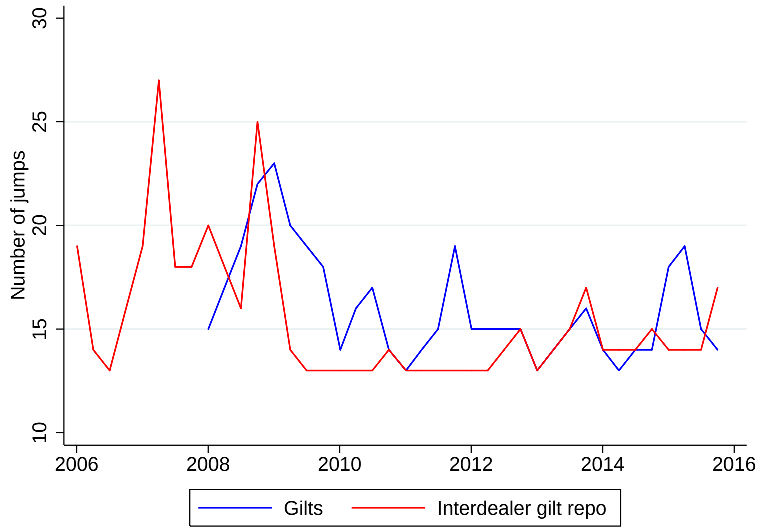
Notes: The chart shows the first principal component of the four gilt liquidity measures in Figure 10 and of the six gilt repo liquidity measures in Figures 11 and 12. The individual liquidity measures are standardised prior to the principal components analysis. Higher values indicate worse liquidity. Quarterly averages.
Sources: Zen dataset, Bank of England, Bloomberg, BrokerTec.

Figure 16: First principal component of liquidity measures (since 2010)



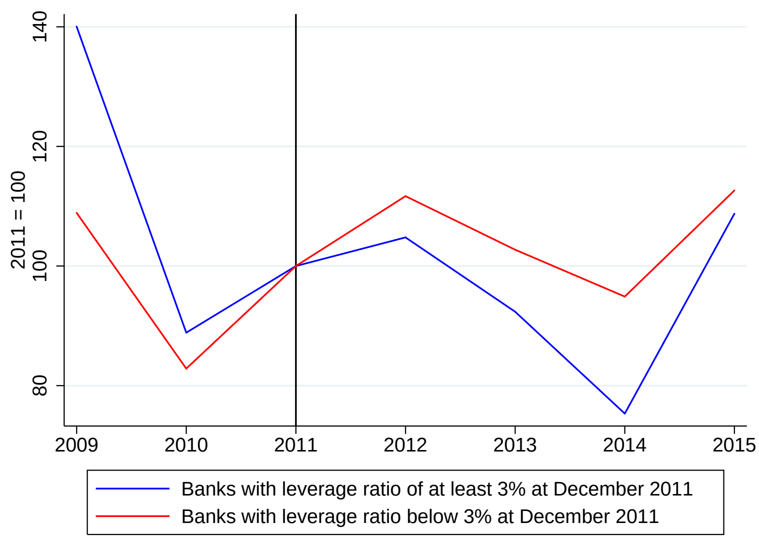
Notes: For details, see Figure 15.
Sources: Zen dataset, Bank of England, Bloomberg, BrokerTec.

Figure 17: 'Jumps' in liquidity measures



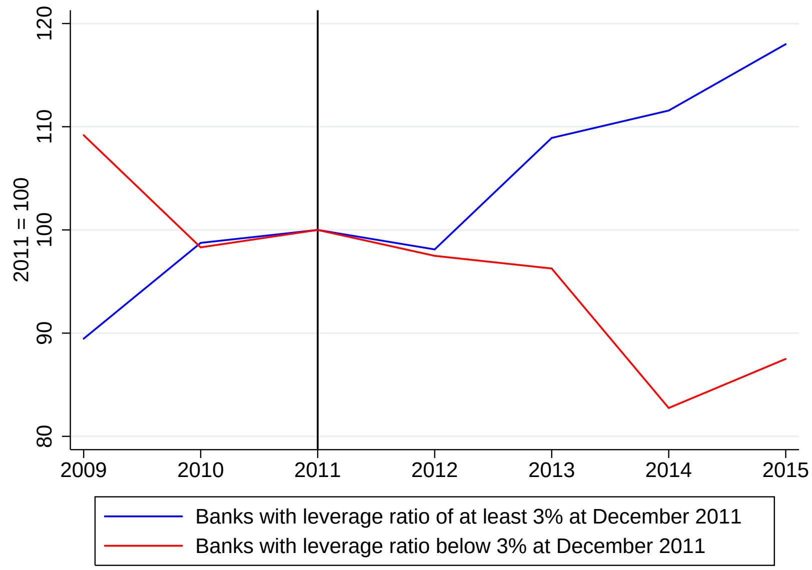
Notes: The chart shows quarterly sums of the number of upward 'jumps' in the first principal component of the liquidity measures, where a 'jump' is defined to be a one-day increase in the principal component that is at least as large as the standard deviation of the (level of the) principal component over the full sample period. Quarterly frequency.
Sources: Zen dataset, Bank of England, Bloomberg, BrokerTec.

Figure 18: Gilt round-trip cost, by dealer type



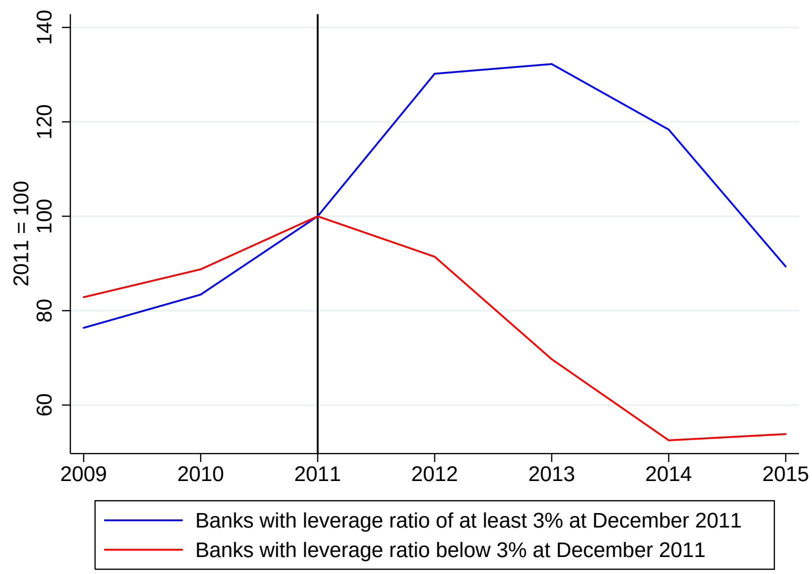
Notes: The chart shows average round-trip cost by dealer type, indexed to 2011. The sample consists of 12 banks (only banks that were GEMMs throughout the sample period are included). Annual frequency.
Source: Zen dataset.

Figure 19: Dealer-to-client volume in the gilt market, by dealer type



Notes: The chart shows average dealer-to-client volume by dealer type, indexed to 2011. The sample consists of 12 banks (only banks that were GEMMs throughout the sample period are included). Annual frequency.
Source: Zen dataset.

Figure 20: Borrowing in the gilt repo market, by dealer type



Notes: The chart shows average borrowing in the gilt repo market, indexed to 2011. The sample consists of 17 banks (only banks that reported Form RSL throughout the sample period are included). Annual frequency.
Source: Form RSL.

Table 1: Leverage ratio timeline

Date	Jurisdiction	Summary
16 December 2010	BCBS	BCBS proposes a 3% regulatory leverage ratio (disclosure from 2015, minimum requirement from 2018)
6 December 2011	UK	FPC recommends that FSA encourage banks to disclose their leverage ratios not later than the beginning of 2013; FSA implements this by asking large UK banks to publish their leverage ratios in their 2012 annual reports and on a bi-annual basis thereafter
7 June 2012	USA	Proposed rule on new capital framework for large US banks, including draft supplementary leverage ratio
20 June 2013	UK	Results of capital shortfall exercise published; large UK banks with a CET1 leverage ratio below 3% required to submit plans to reach this level
2 July 2013	USA	Final rule on supplementary leverage ratio (full implementation from 2018), and proposal on enhanced supplementary leverage ratio
29 November 2013	UK	PRA issues supervisory expectation that eight major UK banks and building societies meet a 3% leverage ratio by January 2014
1 March 2014	EU	PRA-regulated firms start to report regulatory leverage ratios through COREP on the basis of month-end balance sheets
11 July 2014	UK	FPC consultation paper on the design of the UK leverage ratio framework; FPC considers applying the framework to all PRA-regulated firms
8 April 2014	USA	Final rule on enhanced supplementary leverage ratio (full implementation from 2018)
31 October 2014	UK	FPC review of the leverage ratio framework published; review recommends that the framework apply only to major UK banks and building societies
10 July 2015	UK	PRA consultation paper on implementing the UK leverage ratio framework
1 December 2015	UK	PRA publishes finalised UK leverage ratio framework, to apply to major to UK banks and building societies from the start of 2016
1 January 2018	EU	All PRA-regulated firms expected to become subject to a 3% minimum leverage ratio under CRD IV

Notes: The table describes key dates in the development of UK leverage ratio policy, and selected dates in the development of global, US and EU leverage ratio policy.

Table 2: Gilt liquidity measures - annual averages and PCA factor loadings

Liquidity measure	Average 2000-06	2008	2009	2010	2011	2012	2013	2014	2015	Loading
Amihud	-	15.4	17.0	10.1	9.5	11.4	9.6	8.0	11.3	0.52
Roll	-	17.5	21.7	11.4	10.6	17.9	13.8	11.9	13.6	0.52
Round-trip cost	-	20.6	26.3	14.8	15.6	17.4	14.4	12.0	16.0	0.51
Yield curve noise	4.2	9.6	10.9	4.7	4.8	4.0	3.7	3.5	4.4	0.44

Notes: The table shows annual averages of the estimated liquidity measures for the gilt market. Higher values indicate worse liquidity. The units of Amihud, Roll and round-trip cost are basis points in price space. For these measures, we show the median across gilts. The units of yield curve noise are basis points in yield space. The last column shows the factor loadings of the measures in the first principal component. The first principal component explains 71% of the sample variance.
Sources: Zen dataset, Bank of England, Bloomberg.

Table 3: Gilt repo liquidity measures - annual averages and PCA factor loadings

Liquidity measure	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Loading
GC Amihud	0.04	0.05	0.11	0.05	0.02	0.03	0.04	0.06	0.07	0.07	0.35
GC Roll	1.91	2.03	4.31	2.02	1.11	1.34	1.59	1.74	2.14	2.21	0.37
GC effective spread	1.80	2.60	5.61	2.15	1.04	1.39	1.85	2.29	2.25	2.41	0.37
SC Amihud	0.29	0.88	1.30	0.61	0.39	0.46	0.39	0.40	0.50	0.82	0.52
SC Roll	8.35	21.14	28.44	10.69	6.66	7.65	5.64	4.23	6.35	8.01	0.47
SC effective spread	1.42	6.94	5.38	3.20	2.29	1.82	1.14	1.33	1.18	2.79	0.33

Notes: The table shows annual averages of the estimated liquidity measures for the interdealer gilt repo market. Higher values indicate worse liquidity. For all measures, the units are basis points in repo rate space. The last column shows the factor loadings of the measures in the first principal component. The first principal component explains 47% of the sample variance.
Source: BrokerTec.

Table 4: Summary statistics

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max	(6) p1	(7) p10	(8) p25	(9) p50	(10) p75	(11) p90	(12) p99
Gilt liquidity (standard deviations)	1,514	-0.695	1.000	-2.846	4.362	-2.321	-1.786	-1.400	-0.859	-0.190	0.596	2.652
Repo liquidity (standard deviations)	1,513	-0.475	1.000	-1.967	12.48	-1.547	-1.217	-0.982	-0.673	-0.260	0.343	2.570
3m Libor-OIS spread (%)	1,514	0.209	0.144	0.0834	0.604	0.0896	0.0967	0.107	0.124	0.243	0.482	0.589
3m GG repo-OIS spread (%)	1,514	0.0357	0.0326	-0.0600	0.150	-0.0327	-0.00880	0.0171	0.0349	0.0523	0.0807	0.127
VIX (%)	1,514	0.183	0.0605	0.103	0.480	0.113	0.127	0.140	0.166	0.202	0.261	0.398
FTSE 100 (% change)	1,514	0.0145	1.004	-4.667	5.161	-2.771	-1.143	-0.498	0.0398	0.564	1.135	2.756
10y gilt yield (%)	1,514	2.649	0.765	1.387	4.399	1.580	1.792	1.994	2.506	3.157	3.835	4.284
1m10y interest rate implied volatility (%)	1,514	0.798	0.153	0.453	1.282	0.486	0.609	0.694	0.784	0.900	0.982	1.229
UK sovereign 5y CDS premium (%)	1,514	0.475	0.250	0.146	1.049	0.158	0.190	0.208	0.464	0.695	0.822	0.976
3m Euro Libor-OIS spread (%)	1,514	0.211	0.197	0.0131	0.938	0.0343	0.0506	0.103	0.142	0.245	0.461	0.890
10y Italian bond spread (%)	1,514	2.217	1.133	0.693	5.507	0.789	1.065	1.364	1.704	3.004	3.929	5.065
Free float (£bn, market value)	1,514	931.5	158.4	592.7	1,221	600.2	716.2	834.0	925.3	1,017	1,177	1,207
Share of gilts held by ICPFs (%)	1,514	27.71	1.302	26.25	32.07	26.25	26.61	26.89	27.16	28.33	29.32	32.07
Gilt interdealer ratio (%)	1,511	23.87	5.528	5.787	45.90	11.27	16.92	20.04	23.91	27.74	30.86	36.84
Gilt market connectivity (%)	1,511	25.81	7.474	1.905	46.90	6.433	16.43	20.71	25.83	30.95	35.48	42.62
Gilt Herfindahl index (%)	1,511	9.257	2.450	6.090	39.35	6.725	7.388	7.907	8.698	9.834	11.44	19.55
Repo market connectivity (%)	1,512	31.72	4.903	15.00	50	21.29	25.23	28.11	31.90	35.30	38.00	42.58
Repo Herfindahl index (%)	1,514	11.28	0.656	10.09	12.36	10.09	10.39	10.64	11.22	11.89	12.10	12.36
APF purchase date	1,514	0.118	0.323	0	1	0	0	0	0	0	1	1
DMO issuance date	1,514	0.219	0.414	0	1	0	0	0	0	0	1	1

Notes: The table shows summary statistics for the variables used in the market-level regressions. The sample period is 1 January 2010 to 31 December 2015, at daily frequency.
Sources: Bloomberg, Bank of England, Zen dataset, BrokerTec, Form RSL, UK Debt Management Office, UK Office for National Statistics.

Table 5: Market-level gilt regressions (continued on next page)

VARIABLES	(1) Gilt liquidity	(2) Gilt liquidity	(3) Gilt liquidity
2012 indicator	0.461***	0.775***	0.706***
	(0.121)	(0.112)	(0.0901)
2013 indicator	0.0405	0.526***	0.509***
	(0.0742)	(0.128)	(0.100)
2014 indicator	-0.201***	0.336***	0.341***
	(0.0700)	(0.125)	(0.102)
2015 indicator	0.230**	0.599***	0.635***
	(0.0966)	(0.161)	(0.134)
Month-end	0.483**	0.468*	0.465*
	(0.243)	(0.250)	(0.244)
Month-end and 2014-2015	-0.497*	-0.481	-0.467
	(0.295)	(0.303)	(0.301)
Quarter-end	-0.0553	-0.124	-0.0880
	(0.266)	(0.253)	(0.245)
Quarter-end and 2012-2015	-0.343*	-0.260	-0.290
	(0.201)	(0.203)	(0.189)
Repo liquidity (standard deviations)		0.0399	
		(0.0244)	
3m Libor-OIS spread (%)		1.277***	1.286***
		(0.351)	(0.350)
3m GG repo-OIS spread (%)		2.222*	2.204*
		(1.163)	(1.150)
VIX (%)		0.678	
		(0.642)	
FTSE 100 (% change)		0.00802	
		(0.0263)	
Change in 10y gilt yield (%)		0.837*	0.861**
		(0.442)	(0.422)
1m10y interest rate implied volatility (%)		1.065***	1.118***
		(0.266)	(0.253)
Change in UK sovereign 5y CDS premium (%)		2.614*	2.777*
		(1.539)	(1.486)
Change in 3m Euro Libor-OIS spread (%)		1.094	
		(1.268)	
Change in 10y Italian bond spread (%)		-0.623**	-0.641**
		(0.252)	(0.254)
Change in share of gilts held by ICPFs (%)		-0.153	
		(0.217)	
Change in free float (£bn, market value)		0.00262	
		(0.00482)	

Table 5: Market-level gilt regressions (continued)

Gilt interdealer ratio (%)		-0.0237***	-0.0211***
		(0.00586)	(0.00591)
Gilt market connectivity (%)		0.00577	
		(0.00466)	
Gilt Herfindahl index (%)		0.00207	
		(0.00872)	
APF purchase date		-0.108	
		(0.0666)	
DMO issuance date		-0.109**	-0.0804*
		(0.0509)	(0.0429)
Constant	-0.434***	-1.707***	-1.550***
	(0.0758)	(0.309)	(0.271)
Observations	1,514	1,510	1,511
R^2	0.318	0.369	0.365
Quarter-end fixed effects	YES	YES	YES
Number of lags of dependent variable	3	3	3
Wald statistic for null hypothesis that year indicators are jointly zero	36.77***	60.35***	81.57***
	(0.00)	(0.00)	(0.00)

Notes: The table shows the results of time series regressions of liquidity in the gilt market. The regressions are at daily frequency and the sample period is 1 January 2010 to 31 December 2015. The regression specification is given by equation (1). The dependent variable, 'Gilt liquidity', is the first principal component of the four liquidity measures in Table 2, normalised to have standard deviation equal to one over the sample period. Higher values indicate worse liquidity. 'Repo liquidity' is the first principal component of the six liquidity measures in Table 3. '2012 indicator' is an indicator variable equal to one if the year is 2012 and zero otherwise. Similarly for '2013 indicator', '2014 indicator' and '2015 indicator.' 'Month-end' and 'Quarter-end' are indicator variables for the last day of the month and quarter, respectively. 'Month-end and 2014-2015' is an indicator variable for the last day of the month if the date is 1 January 2014 or later. 'Quarter-end and 2012-2015' is an indicator variable for the last day of the quarter if the date is 1 January 2012 or later. 'APF purchase date' and 'DMO issuance date' are indicator variables for the dates of Bank of England APF purchases and DMO gilt auctions and syndications, respectively. All potentially endogenous regressors are lagged by one day. Quarter-end fixed effects are constrained to sum to zero. HAC standard errors are shown in parentheses. 'Wald statistic for null hypothesis that year indicators are jointly zero' shows the χ^2-statistic from the Wald test that the coefficients on '2012 indicator', '2013 indicator', '2014 indicator' and '2015 indicator' are all equal to zero, with p-values in parentheses. *** indicates significance at the 1% level, ** at the 5% level, and * at the 10% level.

Table 6: Market-level repo regressions (continued on next page)

VARIABLES	(1) Repo liquidity	(2) Repo liquidity	(3) Repo liquidity
2012 indicator	0.00403	-0.0282	0.00455
	(0.0655)	(0.0900)	(0.0655)
2013 indicator	0.0583	0.0960	0.0610
	(0.0525)	(0.100)	(0.0528)
2014 indicator	0.194**	0.216**	0.198**
	(0.0776)	(0.102)	(0.0774)
2015 indicator	0.336***	0.291***	0.340***
	(0.0913)	(0.111)	(0.0906)
Month-end	0.816***	0.826***	0.829***
	(0.276)	(0.270)	(0.276)
Month-end and 2014-2015	-0.0589	-0.0517	-0.0666
	(0.362)	(0.355)	(0.362)
Quarter-end	0.177	0.180	0.175
	(0.270)	(0.260)	(0.269)
Quarter-end and 2012-2015	3.865***	3.828***	3.872***
	(0.231)	(0.222)	(0.231)
Gilt liquidity (standard deviations)		-0.00386	
		(0.0190)	
3m Libor-OIS spread (%)		0.283	
		(0.319)	
3m GG repo-OIS spread (%)		1.627	
		(1.279)	
VIX (%)		0.0598	
		(0.432)	
FTSE 100 (% change)		-0.0305	
		(0.0189)	
Change in 10y gilt yield (%)		-0.149	
		(0.379)	
1m10y interest rate implied volatility (%)		-0.183	
		(0.198)	
Change in UK sovereign 5y CDS premium (%)		-0.650	
		(0.679)	
Change in 3m Euro Libor-OIS spread (%)		0.612	
		(0.820)	
Change in 10y Italian bond spread (%)		0.193	
		(0.161)	
Change in share of gilts held by ICPFs (%)		0.0679	
		(0.166)	
Change in free float (£bn, market value)		-0.000347	
		(0.00259)	

Table 6: Market-level repo regressions (continued)

Repo market connectivity (%)		0.000813	
		(0.00485)	
Repo Herfindahl index (%)		-0.0192	
		(0.0470)	
APF purchase date		0.0352	
		(0.0731)	
DMO issuance date		0.0701**	0.0681**
		(0.0312)	(0.0299)
Constant	-0.416***	-0.222	-0.432***
	(0.0774)	(0.672)	(0.0780)
Observations	1,488	1,486	1,488
R^2	0.664	0.669	0.664
Quarter-end fixed effects	YES	YES	YES
Number of lags of dependent variable	23	23	23
Wald statistic for null hypothesis that year indicators are jointly zero	22.71***	18.38***	23.70***
	(0.00)	(0.00)	(0.00)

Notes: The table shows the results of time series regressions of liquidity in the gilt repo market. The regressions are at daily frequency and the sample period is 1 January 2010 to 31 December 2015. The regression specification is given by equation (1). The dependent variable, 'Repo liquidity', is the first principal component of the six liquidity measures in Table 3, normalised to have standard deviation equal to one over the sample period. Higher values indicate worse liquidity. 'Gilt liquidity' is the first principal component of the four liquidity measures in Table 2. '2012 indicator' is an indicator variable equal to one if the year is 2012 and zero otherwise. Similarly for '2013 indicator', '2014 indicator' and '2015 indicator.' 'Month-end' and 'Quarter-end' are indicator variables for the last day of the month and quarter, respectively. 'Month-end and 2014-2015' is an indicator variable for the last day of the month if the date is 1 January 2014 or later. 'Quarter-end and 2012-2015' is an indicator variable for the last day of the quarter if the date is 1 January 2012 or later. 'APF purchase date' and 'DMO issuance date' are indicator variables for the dates of Bank of England APF purchases and DMO gilt auctions and syndications, respectively. All potentially endogenous regressors are lagged by one day. Quarter-end fixed effects are constrained to sum to zero. HAC standard errors are shown in parentheses. 'Wald statistic for null hypothesis that year indicators are jointly zero' shows the χ^2-statistic from the Wald test that the coefficients on '2012 indicator', '2013 indicator', '2014 indicator' and '2015 indicator' are all equal to zero, with p-values in parentheses. *** indicates significance at the 1% level, ** at the 5% level, and * at the 10% level.

Table 7: Gilt quantile regressions (continued on next page)

VARIABLES	(1) Gilt liquidity 0.5 quantile	(2) Gilt liquidity 0.9 quantile	(3) Gilt liquidity Difference
2012 indicator	0.673***	0.759***	0.0855
	(0.127)	(0.210)	(0.213)
2013 indicator	0.430***	0.724***	0.295
	(0.1000)	(0.202)	(0.199)
2014 indicator	0.179*	0.487**	0.308
	(0.0952)	(0.227)	(0.218)
2015 indicator	0.411***	1.097***	0.686**
	(0.116)	(0.313)	(0.295)
Month-end	0.207	0.434	0.226
	(0.242)	(1.068)	(1.030)
Month-end and 2014-2015	-0.126	-0.710	-0.584
	(0.331)	(1.035)	(1.014)
Quarter-end	0.424	-0.0614	-0.485
	(0.454)	(1.117)	(1.112)
Quarter-end and 2012-2015	-0.655	-0.675	-0.0198
	(0.519)	(1.023)	(1.048)
Repo liquidity (standard deviations)	0.0624*	-0.00785	-0.0703
	(0.0359)	(0.0519)	(0.0539)
3m Libor-OIS spread (%)	1.046***	1.692**	0.646
	(0.367)	(0.666)	(0.677)
3m GG repo-OIS spread (%)	1.503	2.402	0.898
	(1.048)	(2.465)	(2.410)
VIX (%)	0.188	2.933*	2.745*
	(0.618)	(1.756)	(1.659)
FTSE 100 (% change)	-0.00244	0.101	0.103
	(0.0307)	(0.0782)	(0.0750)
Change in 10y gilt yield (%)	0.450	1.789	1.338
	(0.553)	(1.242)	(1.197)
1m10y interest rate implied volatility (%)	0.900***	1.258**	0.358
	(0.227)	(0.564)	(0.544)
Change in UK sovereign 5y CDS premium (%)	3.849**	2.132	-1.717
	(1.687)	(3.666)	(3.589)
Change in 3m Euro Libor-OIS spread (%)	1.126	2.913	1.788
	(2.078)	(2.700)	(2.993)
Change in 10y Italian bond spread (%)	-0.999***	-0.0473	0.951
	(0.305)	(0.811)	(0.793)
Change in share of gilts held by ICPFs (%)	-0.340	-0.0426	0.297
	(0.486)	(0.405)	(0.529)
Change in free float (£bn, market value)	0.00215	0.00195	-0.000199

Table 7: Gilt quantile regressions (continued)

	(0.00625)	(0.00923)	(0.00913)
Gilt interdealer ratio (%)	-0.0229***	-0.0275**	-0.00462
	(0.00616)	(0.0119)	(0.0119)
Gilt market connectivity (%)	0.0126***	0.00319	-0.00946
	(0.00453)	(0.0107)	(0.0102)
Gilt Herfindahl index (%)	-0.0115	0.00644	0.0179
	(0.00975)	(0.0271)	(0.0264)
APF purchase date	-0.0852	0.0745	0.160
	(0.0759)	(0.189)	(0.183)
DMO issuance date	-0.0937*	-0.227*	-0.134
	(0.0559)	(0.120)	(0.116)
Constant	-1.501***	-1.357**	0.144
	(0.270)	(0.607)	(0.602)
Observations	1,510	1,510	1,510
Pseudo-R^2	0.229	0.231	n/a
Quarter-end fixed effects	NO	NO	NO
Number of lags of dependent variable	3	3	3
Wald statistic for null hypothesis	12.06***	5.88***	1.46
that year indicators are jointly zero	(0.00)	(0.00)	(0.21)

Notes: The table shows the results of time series quantile regressions of liquidity in the gilt market. The regressions are at daily frequency and the sample period is 1 January 2010 to 31 December 2015. The regression specification is given by equation (1). Column (1) shows the results from the conditional median regression, column (2) shows the results from the conditional 0.9 quantile regression, and column (3) shows the estimated difference between the coefficients from the two regressions. The dependent variable, 'Gilt liquidity', is the first principal component of the four liquidity measures in Table 2, normalised to have standard deviation equal to one over the sample period. Higher values indicate worse liquidity. 'Repo liquidity' is the first principal component of the six liquidity measures in Table 3. '2012 indicator' is an indicator variable equal to one if the year is 2012 and zero otherwise. Similarly for '2013 indicator', '2014 indicator' and '2015 indicator.' 'Month-end' and 'Quarter-end' are indicator variables for the last day of the month and quarter, respectively. 'Month-end and 2014-2015' is an indicator variable for the last day of the month if the date is 1 January 2014 or later. 'Quarter-end and 2012-2015' is an indicator variable for the last day of the quarter if the date is 1 January 2012 or later. 'APF purchase date' and 'DMO issuance date' are indicator variables for the dates of Bank of England APF purchases and DMO gilt auctions and syndications, respectively. All potentially endogenous regressors are lagged by one day. Bootstrapped standard errors are shown in parentheses. 'Wald statistic for null hypothesis that year indicators are jointly zero' shows the F-statistic from the Wald test that the coefficients on '2012 indicator', '2013 indicator', '2014 indicator' and '2015 indicator' are all equal to zero, with p-values in parentheses. In column (3), the null hypothesis is that the coefficients from the 0.9 quantile regression are equal to the coefficients from the median regression. *** indicates significance at the 1% level, ** at the 5% level, and * at the 10% level.

Table 8: Repo quantile regressions (continued on next page)

VARIABLES	(1) Repo liquidity 0.5 quantile	(2) Repo liquidity 0.9 quantile	(3) Repo liquidity Difference
2012 indicator	-0.0945*	0.0964	0.191*
	(0.0562)	(0.116)	(0.113)
2013 indicator	0.0184	0.0143	-0.00409
	(0.0576)	(0.115)	(0.115)
2014 indicator	0.0732	0.339**	0.265**
	(0.0610)	(0.136)	(0.134)
2015 indicator	0.251***	0.353*	0.103
	(0.0807)	(0.186)	(0.178)
Month-end	0.532***	2.854**	2.322**
	(0.147)	(1.180)	(1.146)
Month-end and 2014-2015	0.0325	-1.430	-1.462
	(0.395)	(1.380)	(1.346)
Quarter-end	0.365	-1.668	-2.033
	(0.291)	(1.514)	(1.458)
Quarter-end and 2012-2015	2.120	10.84***	8.717***
	(1.929)	(2.736)	(2.900)
Gilt liquidity (standard deviations)	0.00614	-0.0316	-0.0377
	(0.0165)	(0.0285)	(0.0290)
3m Libor-OIS spread (%)	0.201	-0.343	-0.544
	(0.189)	(0.386)	(0.381)
3m GG repo-OIS spread (%)	0.639	0.299	-0.339
	(0.809)	(1.682)	(1.600)
VIX (%)	0.390	-0.251	-0.642
	(0.314)	(0.534)	(0.540)
FTSE 100 (% change)	-0.00685	-0.0177	-0.0108
	(0.0160)	(0.0329)	(0.0325)
Change in 10y gilt yield (%)	-0.478	0.306	0.784
	(0.303)	(0.773)	(0.732)
1m10y interest rate implied volatility (%)	-0.267**	0.203	0.469*
	(0.123)	(0.281)	(0.276)
Change in UK sovereign 5y CDS premium (%)	0.0768	-0.0757	-0.152
	(0.758)	(1.518)	(1.517)
Change in 3m Euro Libor-OIS spread (%)	0.160	0.984	0.824
	(0.789)	(1.362)	(1.391)
Change in 10y Italian bond spread (%)	-0.0269	0.301	0.328
	(0.156)	(0.268)	(0.266)
Change in share of gilts held by ICPFs (%)	-0.0693	-0.0834	-0.0140
	(0.241)	(0.412)	(0.410)
Change in free float (£bn, market value)	1.39e-05	-0.00273	-0.00274

Table 8: Repo quantile regressions (continued)

	(0.00213)	(0.00468)	(0.00459)
Repo market connectivity (%)	0.00194	-0.00265	-0.00459
	(0.00379)	(0.00726)	(0.00723)
Repo Herfindahl index (%)	-0.0112	0.0349	0.0461
	(0.0299)	(0.0513)	(0.0522)
APF purchase date	0.00226	0.154*	0.151*
	(0.0446)	(0.0898)	(0.0881)
DMO issuance date	0.0447	0.161**	0.117*
	(0.0325)	(0.0681)	(0.0662)
Constant	-0.230	-0.129	0.101
	(0.419)	(0.750)	(0.754)
Observations	1,486	1,486	1,486
Pseudo-R^2	0.238	0.414	n/a
Quarter-end fixed effects	NO	NO	NO
Number of lags of dependent variable	23	23	23
Wald statistic for null hypothesis	3.94***	2.31*	1.84
that year indicators are jointly zero	(0.00)	(0.06)	(0.12)

Notes: The table shows the results of time series quantile regressions of liquidity in the gilt repo market. The regressions are at daily frequency and the sample period is 1 January 2010 to 31 December 2015. The regression specification is given by equation (1). Column (1) shows the results from the conditional median regression, column (2) shows the results from the conditional 0.9 quantile regression, and column (3) shows the estimated difference between the coefficients from the two regressions. The dependent variable, 'Repo liquidity', is the first principal component of the six liquidity measures in Table 3, normalised to have standard deviation equal to one over the sample period. Higher values indicate worse liquidity. 'Gilt liquidity' is the first principal component of the four liquidity measures in Table 2. '2012 indicator' is an indicator variable equal to one if the year is 2012 and zero otherwise. Similarly for '2013 indicator', '2014 indicator' and '2015 indicator.' 'Month-end' and 'Quarter-end' are indicator variables for the last day of the month and quarter, respectively. 'Month-end and 2014-2015' is an indicator variable for the last day of the month if the date is 1 January 2014 or later. 'Quarter-end and 2012-2015' is an indicator variable for the last day of the quarter if the date is 1 January 2012 or later. 'APF purchase date' and 'DMO issuance date' are indicator variables for the dates of Bank of England APF purchases and DMO gilt auctions and syndications, respectively. All potentially endogenous regressors are lagged by one day. Bootstrapped standard errors are shown in parentheses. 'Wald statistic for null hypothesis that year indicators are jointly zero' shows the F-statistic from the Wald test that the coefficients on '2012 indicator', '2013 indicator', '2014 indicator' and '2015 indicator' are all equal to zero, with p-values in parentheses. In column (3), the null hypothesis is that the coefficients from the 0.9 quantile regression are equal to the coefficients from the median regression. *** indicates significance at the 1% level, ** at the 5% level, and * at the 10% level.

Table 9: Sizes and market shares of groups of dealers

	Gilt market		Gilt repo market	
	Number of dealers	Market share	Number of dealers	Market share
LargeUK	5	43%	7	59%
SubsidiaryUS	5	28%	4	21%
OtherUK	6	29%	8	20%

Notes: The table shows the size and market shares of different groups of dealers over the sample period 2008Q1 to 2015Q4. *LargeUK* refers to the group of banks that were subject to the FSA's implementation of the FPC's December 2011 recommendation on disclosure and the PRA's November 2013 supervisory expectation that banks meet a 3% leverage ratio. *SubsidiaryUS* refers to UK subsidiaries of US banks. *OtherUK* refers to smaller UK banks and to the UK subsidiaries of (non-US) foreign banks.

Table 10: Dealer-level panel regression results: gilt market

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	Round-trip cost (basis points)				Log(Trading volume with clients)			
$Dec11\_Constrained$	1.219	0.366			-0.177	0.0824		
	(2.128)	(1.248)			(0.235)	(0.0795)		
$-Dec11\_PTLR$			-0.365				0.0509	
			(0.248)				(0.0427)	
$Treated$				-2.256**				0.180*
				(1.051)				(0.0997)
$-PTLR$				0.0623				-0.0468
				(0.709)				(0.0315)
Observations	461	382	382	382	461	382	382	382
R^2	0.424	0.629	0.635	0.637	0.715	0.919	0.922	0.921
Time fixed effects	YES	YES	YES	YES	YES	YES	YES	YES
Bank fixed effects	YES	YES	YES	YES	YES	YES	YES	YES
Country controls	NO	YES	YES	YES	NO	YES	YES	YES
Bank controls	NO	YES	YES	YES	NO	YES	YES	YES
Frequency	Quarterly	Quarterly	Quarterly	Quarterly	Quarterly	Quarterly	Quarterly	Quarterly
Number of banks	16	16	16	16	16	16	16	16

Notes: The table shows the results of panel regressions of dealer-level liquidity provision in the gilt market. The regressions are at quarterly frequency and the sample period is 2008Q1 to 2015Q4. The regression specification is given by equation (2). In columns (1)-(4), $LiquidityProvision$ is measured as round-trip cost (RTC) estimated at the dealer level, which is a measure of the average bid-ask spread that the dealer charges its clients on gilt trades (higher numbers indicate less liquidity provision, and the units are basis points). In columns (5)-(8), $LiquidityProvision$ is measured as the log of the dealer's trading volume with clients (higher numbers indicate more liquidity provision). In columns (1), (2), (5) and (6), the key explanatory variable ($Dec11\_Constrained$) is defined in equation (3). In columns (3) and (7), the key explanatory variable ($Dec11\_PTLR$) is defined in equation (4). In columns (4) and (8), the key explanatory variables ($Treated$ and $PTLR$) are defined in equation (5). 'Country controls' are the GDP growth rate and equity index growth rate in the country where the dealer has its main headquarters. 'Bank controls' are the first lag of liquidity provision; log of total assets; return on assets; the share of the bank's assets that are recorded as being in the trading book; the share of the bank's assets that are cash or government bonds; and the bank's risk-weighted capital ratio. The sample consists of UK banks and UK subsidiaries of foreign banks. Standard errors (double-clustered at the bank and time level) are shown in parentheses. *** indicates significance at the 1% level, ** at the 5% level, and * at the 10% level.

Table 11: Dealer-level panel regression results: repo market

VARIABLES	(1)	(2)	(3)	(4)
	Log(Repo borrowing)			
$Dec11\_Constrained$	-0.685	-0.165		
	(0.755)	(0.138)		
$-Dec11\_PTLR$			-0.0331	
			(0.0367)	
$Treated$				0.252
				(0.207)
$-PTLR$				0.00395
				(0.0399)
Observations	558	434	434	434
R^2	0.8508	0.969	0.969	0.970
Time fixed effects	YES	YES	YES	YES
Bank fixed effects	YES	YES	YES	YES
Country controls	NO	YES	YES	YES
Bank controls	NO	YES	YES	YES
Frequency	Quarterly	Quarterly	Quarterly	Quarterly
Number of banks	19	18	18	18

Notes: The table shows the results of panel regressions of dealer-level liquidity provision in the gilt repo market. The regressions are at quarterly frequency and the sample period is 2008Q1 to 2015Q4. The regression specification is given by equation (2). $LiquidityProvision$ is measured as the log of total repo borrowing (higher numbers indicate more liquidity provision). In columns (1) and (2), the key explanatory variable ($Dec11\_Constrained$) is defined in equation (3). In column (3), the key explanatory variable ($Dec11\_PTLR$) is defined in equation (4). In column (4), the key explanatory variables ($Treated$ and $PTLR$) are defined in equation (5). 'Country controls' are the GDP growth rate and equity index growth rate in the country where the dealer has its main headquarters. 'Bank controls' are the first lag of liquidity provision; log of total assets; return on assets; the share of the bank's assets that are recorded as being in the trading book; the share of the bank's assets that are cash or government bonds; and the bank's risk-weighted capital ratio. The sample consists of UK banks and UK subsidiaries of foreign banks. Standard errors (double-clustered at the bank and time level) are shown in parentheses. *** indicates significance at the 1% level, ** at the 5% level, and * at the 10% level.

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