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Decomposing changes in the functioning of the sterling repo market

Joseph Noss and Rupal Patel

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Abstract

We identify the degree to which changes in gilt repo market functioning have been driven by changes in the supply of — and the demand for — market intermediation. To do so, we use a structural vector auto regression (SVAR) model with sign and zero restrictions. We find that changes in gilt repo market functioning over the past five years have been driven largely by changes in the supply of repo market intermediation by dealers, rather than by changes in the demand of end-users. Following the introduction of the UK leverage ratio, our model suggests that an increase in demand for repo by end-users results in a larger increase in the cost of repo transactions and a smaller increase in their volume. This effect is stronger in the case of transactions that are not nettable via central counterparties. These findings are consistent with the notion that the leverage ratio may reduce dealers' ability and/or willingness to act as repo market intermediaries. This may have implications for the resilience of repo markets in future periods of stress.

Key words: Repo market, capital regulation, leverage ratio, non-bank financial institutions.

JEL classification: C58, G10, G12, G18, G23.

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1 Introduction

A repurchase agreement (repo) is an agreement to sell securities (collateral) at a given price, coupled with an agreement to repurchase these securities at a pre-specified price at a later date. Repo transactions play an important role in facilitating the flow of cash and securities around the financial system, both in normal times and in stress. In doing so, repo markets support a wide range of investment and risk management activities for banks and other financial market participants.

Small changes in the cost or availability of repo could therefore have a significant impact on financial markets and the real economy. In recent years there has been a sharp deterioration, and then improvement, in the functioning of sterling repo markets in the UK (Bank of England (2018)). The most significant changes have been observed in the 'gilt' repo market, which is secured against UK government bonds. Between January 2014 and January 2016, the outstanding amount of gilt repo transactions decreased by 20%, but increased by 44% between mid-2016 and April 2018. There were also sharp changes in the cost of borrowing experienced by end-users of the gilt repo, where spreads increased five-fold relative to risk-free rates between 2014 and 2016, but then reduced by 60% between mid-2016 April 2018.

These changes likely arose due to a combination of both changes in dealers' supply of – and end users' demand for – repo market intermediation. Changes in dealers' supply of intermediation may, in part, have been driven by regulatory reforms that – whilst they increase firms' resilience – might also affect the cost dealers' incur in acting as intermediaries (Allahrakha, Cetina and Munyan (2016); Duffie (2016)). At the same time, there has been a reduction in demand for dealer intermediation, which might have been due to market participants increasing their use of transaction structures that are economically similar to repo but that have lower regulatory capital requirements (Bank of England (2018)). It is, however, difficult to disentangle the relative effect of these factors on repo market functioning from looking at the data on prices and volumes of transactions alone. This is in part due to a myriad of other factors affecting the functioning of the repo, and many other, financial markets.

This paper offers means of identifying the degree to which recent changes in repo market functioning have been driven by changes in the supply of – versus the demand for – intermediation. We disentangle these effects by using a structural vector auto regression model (SVAR) that identifies changes in the price and quantity of repo transactions that match a set of assumed directional responses consistent with changes in the supply and demand of market intermediation. This technique is used widely in monetary policy literature to identify the effects of changes in the supply of – versus the demand for – goods and services on output and inflation (Uhlig (2005)). But to the best of our knowledge this is the first time it has been used to examine the functioning of repo markets.

The findings of this paper are broadly three-fold:

First, we find that changes in gilt repo market functioning over the past five years have been driven largely by changes in the supply of repo market intermediation by dealers, rather than by changes in demand for repo intermediation by end-users. We estimate that around two thirds of the increase in the cost of repo experienced by end users between 2014 and beginning of 2016

can be explained by a *reduction* in the supply of intermediation. These changes in dealers' ability/willingness to intermediate in repo markets may, in part, have been due to the introduction of regulation that constrains dealers' balance sheets (Allahrakha, Cetina and Munyan (2016)).

Similarly, the improvement in repo conditions between 2016 and 2018 was driven mostly by an *increase* in the supply of dealer intermediation. Some of the change in repo spreads can also be attributed to variation in general market conditions that might affect the level of uncertainty around the future value of gilts. This is particularly the case during the period surrounding the UK's EU referendum. This increase in intermediation may follow from dealers' drive to optimise their balance sheets following the introduction of regulation.

Second, we also use our model to assess the degree to which the sterling repo market is able to accommodate increases in the demand for cash and collateral, and how this has changed over time. To do so, we compare how the prices and volumes of repo transactions respond to a positive shock to demand for repo market intermediation before and after the introduction of the UK leverage ratio. We find that an increase in demand results in a larger increase in the cost of repo, and a smaller increase in transaction volumes, following the implementation of the UK's regulatory minimum leverage ratio in 2016. This is consistent with a more inelastic supply of repo intermediation by regulated market intermediaries.

Third, we find that the response of the cost and volume of repo transactions that follow an increase in demand depends on *how* such transactions are intermediated. Repo transactions that can be netted via a central counterparty (CCP) in the calculation of intermediaries' balance sheets experience larger increases in volume – and smaller increases in cost – in response to an increase in demand, compared to transactions that take place bilaterally between end-users. This may be due to how some such 'nettable' transactions qualify for a reduction in regulatory capital under the UK's leverage ratio.

These findings have important implications for policymakers. First, they advance our understanding of the drivers of changes in the functioning of sterling repo markets. Second, they offer an insight into how recent changes in the structure of repo markets have might affected their resilience in periods of stress when there may be large increases in demand for cash and collateral. In particular, our results are consistent with the notion that post-crisis regulation such as the UK's leverage ratio might constrain dealers' willingness and/or ability to intermediate in the repo market, and thereby reduce the degree to which they can respond to increases in demand for intermediation.

The paper proceeds as follows. The next section sets out the structure and functions of repo markets. Section 3 describes recent developments in the UK gilt repo market. The SVAR methodology and the data used in our model are set out in Section 4. Section 5 gives empirical results relating to this model, and Section 6 extends the analysis to look at how results differ depending on whether repo transactions are eligible for netting. A final section concludes. Technical details can be found in the Appendix.

2 Recent developments in the gilt repo market

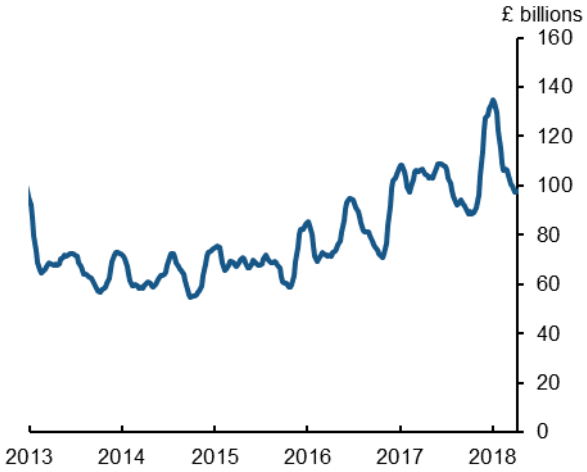
Repo markets bring together two end-users who typically transact via dealer intermediaries.[1] Such dealers intermediate between cash lenders and borrowers. This activity is known as matched book repo and facilitates the two-way flow of cash and collateral using bilateral transactions.[2, 3]

Repo transactions can also take place via CCPs. In doing so, a CCP becomes a counterparty to both sides of a repo transaction, acting as a buyer/seller of collateral. This is known as the cleared repo market. CCPs have become increasingly important in the sterling repo market in recent years – a period which has also seen the finalisation of a number of post-crisis regulatory reforms. In the UK, 70% of interdealer gilt repo transactions are cleared though a CCP.

In recent years there has been a sharp deterioration, followed by a subsequent improvement, in the functioning of the gilt repo market. Between January 2014 and June 2016, there was a steady decline in the availability of repo and increases in its cost. However, between July 2016 and April 2018, some of this deterioration reversed. These changes can be observed through both the volume of repo market transactions and the price at which these take place.

Chart 1: Spread between the three-month gilt repo rate and risk-free rate expectations[1]

Chart 2: Three month gilt reverse repo amounts outstanding



[1] Expectations of risk-free interest rates are measured by overnight index swap rates.

Between January 2014 and June 2016, the spread between the three-month repo rate paid by end-users and expectations of risk-free rates increased from close-to-zero to around 20 basis points. This peak coincided with the UK's EU referendum on 23 June 2016 (Chart 1). The stock of outstanding three-month reverse repo transactions amounts remained roughly flat during the same period (Chart 2). In contrast, during 2016, repo market conditions improved. The stock of repo grew by 55% in the period between mid-2016 and April 2018 and spreads narrowed.

[1] Repo markets can also be disintermediated via electronic platforms that directly connect borrowers and lenders via entities not subject to prudential regulation; however, such activity is currently relatively nascent (Baranova, Liu and Noss (2016)).
[2] 'Matched book' refers to dealers matching the bonds borrowed with the bonds lent; these transactions need not be of matching maturity.
[3] Dealers can also be end-users of repo and reverse repo transactions as part of their own activities, for example funding their inventories and borrowing securities in order to sell securities short.

3 Potential drivers of change in the functioning of the gilt repo markets

There are a number of candidate explanations for these changes in the cost and availability of repo. These were documented in detail by the report by the Committee on the Global Financial System (CGFS (2017)).

This section offers a summary of those explanations most pertinent to recent changes in the functioning of the gilt repo market and to the analysis that follows. It is organised into those factors that (i) affect the supply of repo market intermediation; (ii) affect the demand for intermediation by end-users, and (iii) that pertain to broader conditions in gilt markets. This categorisation is chosen due to its relevance to the identification scheme used in the model of Section 4.

3.1 Factors affecting the supply of repo market intermediation

(i) Balance sheet constraining regulation might reduce the supply intermediation

In recent years, a number of post-crisis regulatory reforms have been finalised and/or implemented that may affect dealers' incentives to intermediate in repo markets (Duffie (2016)). Some such reforms – such as the regulatory minimum leverage ratio – impose a constraint on banks' capital that is based on the size, rather than the composition, of their balance sheets (Kotidis and van Horen (2018) and Allahrakha, Cetina and Munyan (2016)). Repo transactions lead to an expansion of a banks' balance sheet, and – at least to the extent that the leverage ratio binds on banks' activities – therefore attract a capital charge under such regulation. [4]

Although these regulatory reforms have increased dealers' resilience, they might have reduced their ability and/or willingness to act as repo market intermediaries, or increased the compensation they require for doing so. This is because intermediation in repo markets is typically an activity that is relatively low-risk, but that also yields relatively low profit margins – i.e. has a relatively low return per unit of balance sheet. As such, it might be a natural activity for dealers to reduce in the face of regulation that constrains the size of their balance sheet (Cipriani et al (2017)). [5] In the UK, the Prudential Regulatory Authority's regulatory leverage ratio was announced in October 2014 and formally implemented in January 2016 (PRA (2015)).

(ii) Balance sheet netting might increase the supply of intermediation

There is evidence that dealers have begun to adjust how they conduct their repo business in order to minimise the costs associated with holding regulatory capital (Bank of England (July 2018)). One means of doing so is by making greater use of repo transactions that can be netted against reverse repo transactions.

Although netting rules differ in their details, they generally allow for cash received and cash payable to net for the purposes of calculating regulatory capital, providing the payment dates

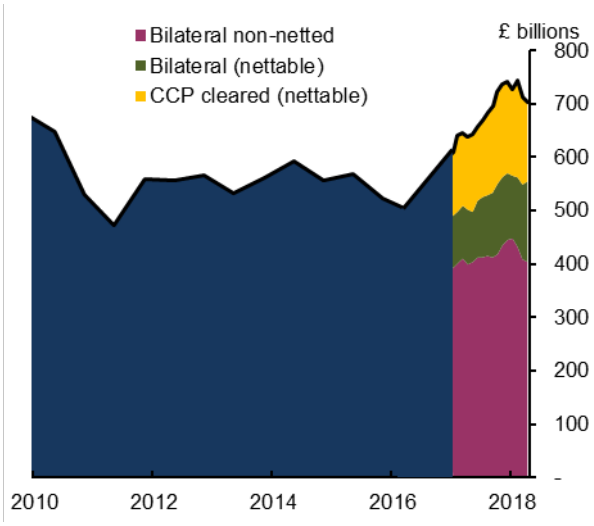
[4] Other examples of regulation that might reduce dealers' incentives to act as repo market intermediaries include the capital surcharge on global systemically important banks (GSIBs) as well as the liquidity coverage ratio (LCR) and net stable funding ratio (NSFR); see CGFS (2017) and Bank of England (2016).

[5] Changes in how market participants assess and manage risk may also have brought about both a reduction in the supply of – and demand for – repo market intermediation (Bank of England (2016)).

and settlement mechanisms match. As such, two matching repo/reverse repo transactions can be structured so as not to incur an additional regulatory capital charge under certain regulation, including the leverage ratio (CGFS (2017)).

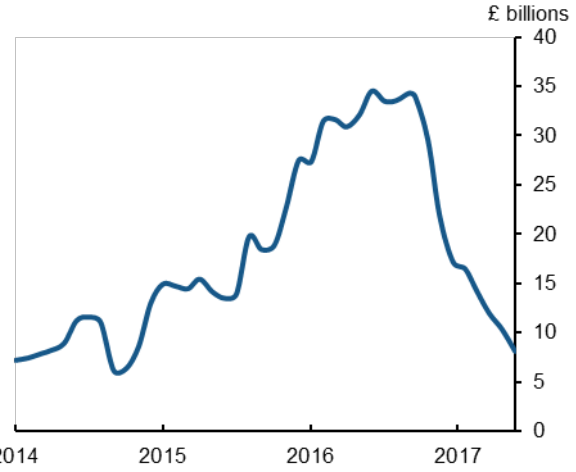
Repo market intermediaries can increase the scope of transactions which are eligible for netting by transacting via a CCP. This is because centrally cleared transactions are deemed nettable under regulatory requirements if they take place with the same counterparty (i.e. a CCP), even if the underlying end-users of the transactions differ. Centrally cleared gilt repo transactions increased from the start of 2017 (Chart 3). Repo/reverse repo transactions between dealers and their clients can also be netted bilaterally, although this is less common (Chart 3).

Chart 3: Total amounts outstanding of gilt repo and reverse repo split by CCP-cleared, bilaterally netted and non-netted trades



Source: Sterling Money Market Data and Bank of England calculations.

Chart 4: Notional amounts of gilt total return swaps



Sources: DTCC Trade Repository and Bank of England calculations.

3.2 Factors affecting the demand for repo market intermediation

(iii) Off-balance sheet alternatives to repo might have the potential to decrease demand for repo market intermediation

In an effort to reduce costs associated with regulation, some UK dealers have recently increased their provision of off-balance sheet transactions that are economically similar to repo, but qualify for a lower regulatory capital charge (CGFS (2017)). These include gilt total return swaps (TRS). The volume of gilt TRS increased fivefold between 2014 and 2017 (Chart 4). During the same period, the amount of repo transactions outstanding fell by 8%, as end-users may have substituted obtaining their funding from repo to TRS. More recently, while repo volumes have been increasing, TRS volumes have fallen significantly from its peak in mid-2017 at £35 billion to £8 billion (Chart 4).

(iv) Non-bank intermediation might have the potential to decrease demand for traditional repo market intermediation

There have been reports of an increase in the use of repo matching platforms that seek to match borrowers and lenders of cash without dealer intermediation (CGFS (2017)). Currently the market share of such repo is relatively small.

3.3 Broader financial markets conditions and their effect on repo market intermediation

Broader conditions in financial markets may also impact repo markets in a manner beyond that explained directly by the supply and demand dynamics mentioned above. Changes in financial conditions may alter market participants' uncertainty as to the future value of gilts, and hence the cost of repo transactions that use them as collateral (Bicu, Chen and Elliot (2017)). Relevant changes in financial conditions might be brought about by the changing stance of monetary policy, as well as a myriad of other factors that have bearing on gilt prices, including market participants' risk appetite.

4 Methodology

It is not possible to disentangle the extent to which changes in headline measures of repo market functioning are driven by changes in the supply of , or demand for, dealer intermediation by looking at repo price and volumes data alone. This is because is it difficult to control for the myriad of factors moving price and quantities, including the effect of broader changes in financial market conditions (see section 3.3 above).

This section describes the model used to disentangle the supply, demand and broader financial market effects described in Section 3 that influence repo market conditions. We use a structural vector auto regression (SVAR) model with sign and zero restrictions. This technique identifies shocks through their assumed direction (sign) of response to changes in the cost and volume of repo transactions. We identify two principle types of shocks: one that corresponds to a change in demand for repo intermediation by end users, and one that corresponds to a change in its supply by intermediaries.

The strength this approach is that it allows us to disentangle the effect of changes in the supply of, versus demand for, intermediation on headline measures of repo market functioning. At the same time it also allows us to control for changes in broader financial market conditions (discussed above in Section 3.3), which affect repo prices and volumes but that have no direct effect on the supply of/demand for intermediation (see Section 3.4).

4.1 Data and summary statistics

We estimate the model on three variables:

(i) The cost of repo transactions, as given by the spread between the three-month gilt repo rate and the three-month overnight interest rate swap (OIS) rates (Chart 1).[6] This represents the cost end-users experience in borrowing cash via repo. The Bank of

[6] Three month gilt repo transactions are analysed here because they experienced the most significant changes from 2014 to 2018 compared to shorter term repo.

England collects these data on a daily basis. We transform these data from a daily to weekly frequency by taking averages from end-Monday to end-Monday.

(ii) The volume of gilt repo transactions, which we represent by the total stock of three-month gilt reverse repos (Chart 2). These data are collected by the UK's Prudential Regulatory Authority on a weekly basis from seventeen banks that are active in the gilt repo market.

(iii) General gilt market conditions, which are proxied by the difference between actual gilt yields and estimated fitted gilt yield, based on the yield curve model of Anderson and Sleath (2001) (sometimes referred to as a measure of 'gilt noise') (Chart 5). This is a measure of gilt market liquidity, with a higher value corresponding to a worsening in liquidity. The measure reflects that in periods where gilt markets are liquid, arbitrageurs 'smooth out' the yield curve by eradicating anomalies between the prices of economically similar securities. But when funding and liquidity conditions tighten and risk appetite increases, the ability and willingness of market participants to keep gilt prices aligned through arbitrage declines and consequently the difference between actual gilt yields and estimated gilt yield increases (Hu, Pan and Wang (2013)).

Chart 5: Measure of gilt market conditions: average difference between actual gilt yields and those estimated by a yield curve model

Source: Bank of England

Table 1: Summary Statistics

Variable	Observations	Mean	Minimum	Maximum	Standard Deviation
Spread between three-month gilt repo rate and three-month overnight interest rate swap rate	379	4.7bps	-4.4bps	20.2bps	4.4bps
Three-month gilt reverse repo transaction amounts outstanding	379	£78.4 billion	£34.6 billion	£173.6 billion	£21.1 billion
Variable representing gilt market conditions	379	3.8bps	1.6bps	6.7bps	1.1bps

According to this measure, gilt market conditions have improved significantly since the 2007-9 crisis, despite seeing some deterioration during the euro-are debt crisis in 2012 and during the UK's referendum on EU membership in 2016.

Again, we transform the data from daily to weekly frequency by taking averages from end-Monday to end-Monday, given that the data series are volatile.

All data span the period January 2011 to April 2018. Summary statistics are given in Table 1.

4.2 Structural VARs with sign restrictions

The SVAR model allow us to decompose changes in the above variables according the effects of economically interpretable structural shocks.[7] In this setting, we seek to identify three structural shocks that correspond to changes in (i) the supply of repo market intermediation, (ii) demand for intermediation by end users and (iii) changes in gilt market conditions. The sign restriction methodology identifies our structural shocks by exploiting differences in the relative movement between the variables described above.

SVARs with sign restrictions have been applied to study shocks elsewhere in the econometric literature. They have become increasingly popular in the field of monetary policy to isolate changes in the demand and supply of credit by their different effects on the price and quantity of lending (Canova and De Nocolo (2002), Faust (1998) and Uhlig (2005)). To the best of the authors' knowledge, however, this is the first time this technique has been applied to analyse changes in conditions in repo markets.

The identifying restrictions used in our model are outlined in Table 2. We assume that:

- An increase in the supply of dealer intermediation in repo markets is assumed to lower the cost of repo transactions (i.e. narrows the repo spread), and increases the amount of transactions outstanding.

  We remain agnostic as to what drives such an increase in supply of intermediation. To the extent that regulation constrains banks' ability to act as repo market intermediaries, this may come about by dealers by dealers optimising their balance sheets to regulation by the use of netting. An increase in supply of intermediation might also come about from new market entrants (see Section 3).

- An increase in demand for repo intermediation increases the cost of transactions experienced by end-users, widening the spread between three month repo-rates and the three-month OIS rates. This is because, absent any concomitant change in supply, dealers would likely demand greater compensation for meeting this greater demand for their intermediation services.

  Again, our model remains agnostic as to the drivers of such changes in demand. Some variation in demand may come about as end-users of repo market vary the intensity of the

[7] For further discussion and references, see Kilian and Lutkepohl (2017).

various activities reliant on repo (see Section 2). Other variation in demand may also occur as end-users substitute their use of traditional dealer intermediated repo transactions for off-balance sheet alternatives, or for that intermediated by non-banks (see Section 3.3).

- An improvement in gilt market conditions is assumed to reduce the cost of repo transactions, given that it might be associated with greater certainty over future collateral values. We also assume it to increase the availability of intermediation. This might be brought about due to an improvement in market sentiment and increase in risk appetite on the part of intermediaries.

Table 2: Identifying Sign Restrictions

Variable	Sign restriction assumed to correspond to structural shock of an…		
	…increase in demand for repo	…increase in the supply of repo	…improvement in gilt market conditions
Repo cost	*Increases*	*Decreases*	*Decreases*
Transaction volume	*Increases*	*Increases*	*Increases*
Gilt market conditions	*No response*	*No response*	*Increases*

One important caveat is that our methodology focuses only on the dealer-intermediated segment of the repo market. As described in Section 3, non-bank matching platforms have recently emerged that allow for the matching of end-users of UK repo/reverse repo transactions without relying on intermediaries (see CGFS (2017)). Though such activity is currently relatively small, it might mean that our methodology leads us to overestimate the impact of the above structural shocks, because some of the demand for repo transactions is met outside of intermediaries.

On the other hand, our choice of sign restrictions also implicitly imply that dealers are able to respond to changes in demand for intermediation by expanding/shrinking their balance sheets and/or changing their prices contemporaneously. In reality, there may be a variety of frictions that prevent dealers from responding rapidly to changes in customer demand. If this is this case, then our results may underestimate the effects of our structural shocks.

4.3 Model estimation

The VAR is estimated over the period January 2011-April 2018 on weekly data. We include four lags of each variable and a constant term. This choice of lag structure is selected to optimise the behaviour of the residual errors terms as judged by deviance information criteria (DIC) that measures the goodness-of-fit and complexity of fitted Bayesian models (Spiegelhalter, Best, Carlin and Van Der Linde (2002)).[8]

The model identifies three structural shocks on three variables. This allows all fluctuations in our variables to be explained by our choice of structural shocks.

Further technical details of the model are given in the Appendix.

[8] Our chosen model has a DIC of 19262.

5 Empirical Results

5.1 Impulse Response Functions

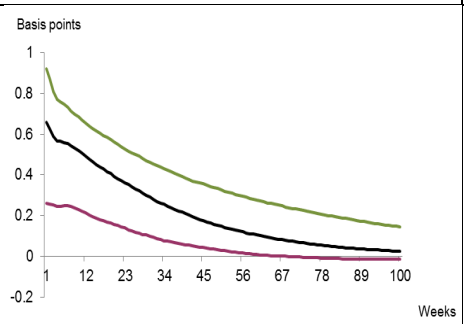
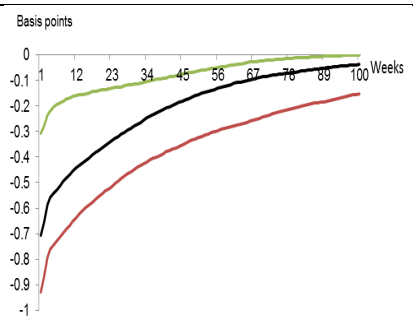
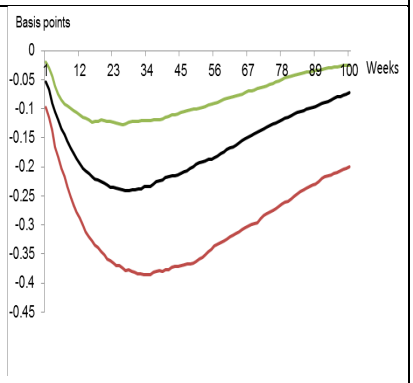
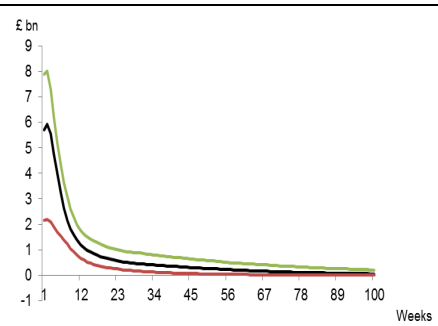
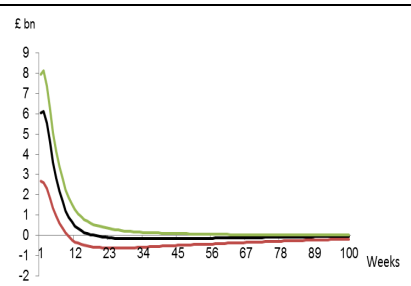
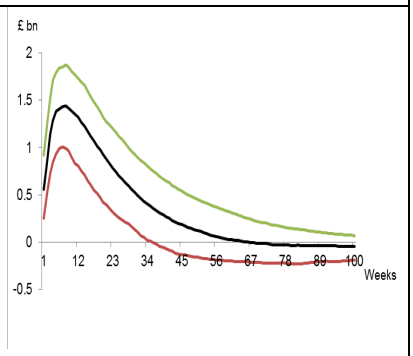
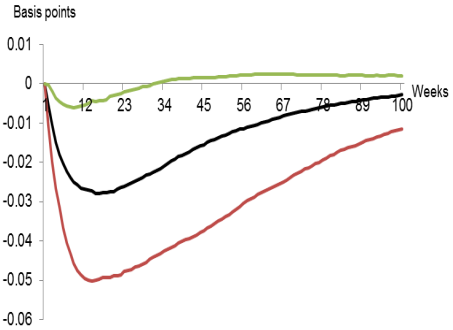
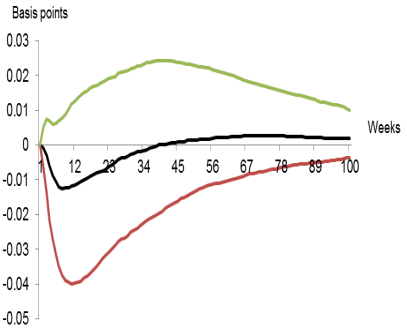
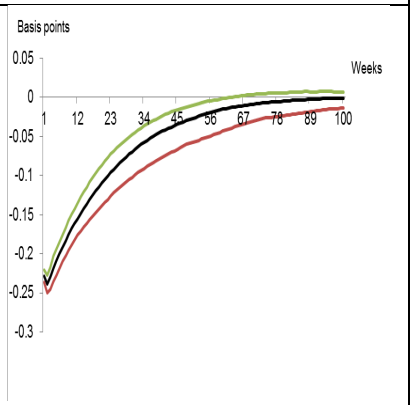
This section discusses the impulse response functions (IRFs) that result from our model. The interpretation of, and uncertainty bounds around, the IRFs obtained under this model varies to those under a standard VAR. This is because our use of sign restrictions involves generating a number of different sets of parameters and corresponding possible responses of repo prices, volumes and market conditions. The IRFs shown here are the median of the subset of IRFs that correspond to parameters that meet our choice of sign restrictions. This is important because these median IRFs are not necessary the most probable, and do not necessarily coincide with true impulse responses (see Appendix for details).

Chart 6 shows the impulse response functions plotted over a 100 week period. The green and red lines illustrate uncertainty with respect to the distribution of IRFs across the possible distribution of parameters and corresponding models.[9] Consistent with our sign restrictions, the IRFs show that a positive one-standard deviation demand shock spreads leads to a 0.6bps increase in the spread between the three-month repo rate and risk-free rate and a £6 billion increase in the amount outstanding. In contrast, a positive supply shock is associated with a 0.7bps narrowing of the repo spreads, but a £6 billion increase in transaction volumes. A positive shock to gilt market conditions has little significant effect on repo spreads and outstanding transaction volumes, but the direction of responses are consistent with our choice of sign restrictions.

The IRFs also show that, regardless the origin of the shock, repo prices take longer to return to their original level compared to repo volumes. This might be because dealers may face greater frictions setting prices than in changing the size of their balance sheet.

[9] Again this differs to the interpretation of confidence intervals in a standard VAR model which correspond to uncertainty around the value of parameters.

Chart 6: Impulse Response Functions

Variable	Structural shock		
	Increase in demand for repo intermediation	Increase in supply of repo intermediation	Improvement in gilt market conditions
Spread between three month repo rate and three month OIS (bps)			
Three months repo amounts outstanding (£bn)			
Gilt market conditions indictor (bps)			

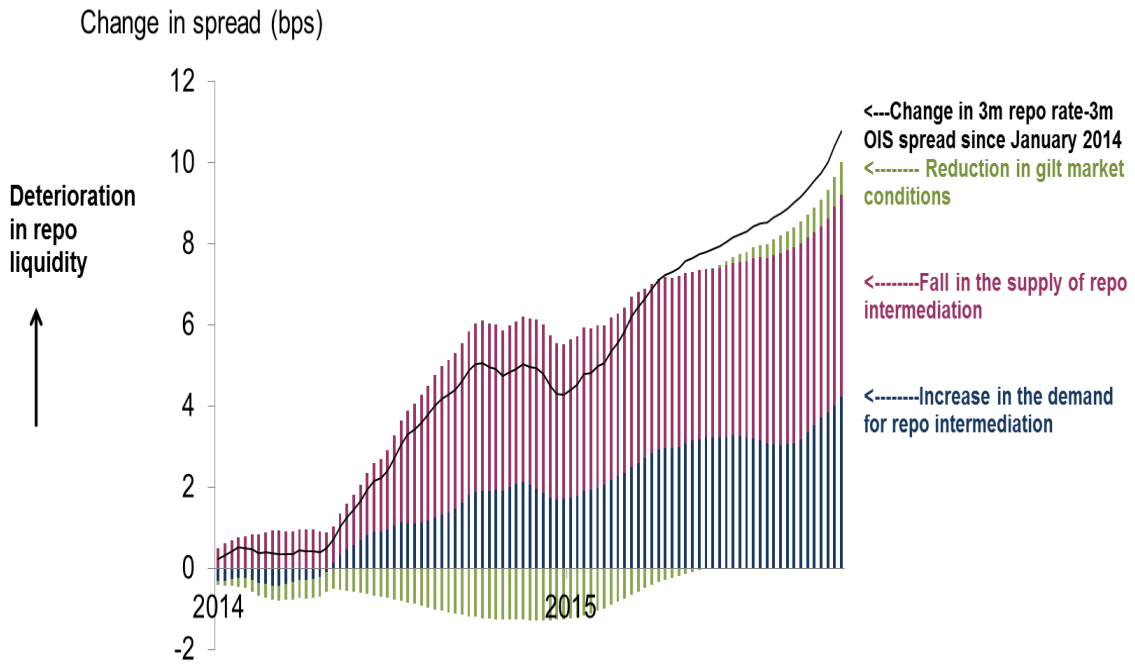
Source: Bank calculations.

(a) Blue line illustrates the median impulse response to identified structural shocks.
(b) Green line illustrates the upper bound responses to identified structural shocks.
(c) Red line illustrates the lower bound responses to identified structural shocks.

5.2 Historical decompositions of changes in the gilt repo spread

This section examines the degree to which historical changes in repo spreads have been driven by the structural shocks identified in the model (i.e. changes in the supply and demand of intermediation, and gilt market conditions) between 2014 and 2018. To do so we decompose changes in the historical time series of repo spreads into components that relate to each type of shock (see Appendix for methodological details).

Chart 7: Historical decomposition of the change in the level of the three month repo rate- three month OIS spread from 2014 to 2015[(a)(b)]



Source: Bloomberg and Bank of England.

(a) Moving quarterly averages.

(b) The difference between the sum of structural shocks and change in repo spreads is due to the Gibbs sampling algorithm used in the estimation of the model parameters (see Appendix).

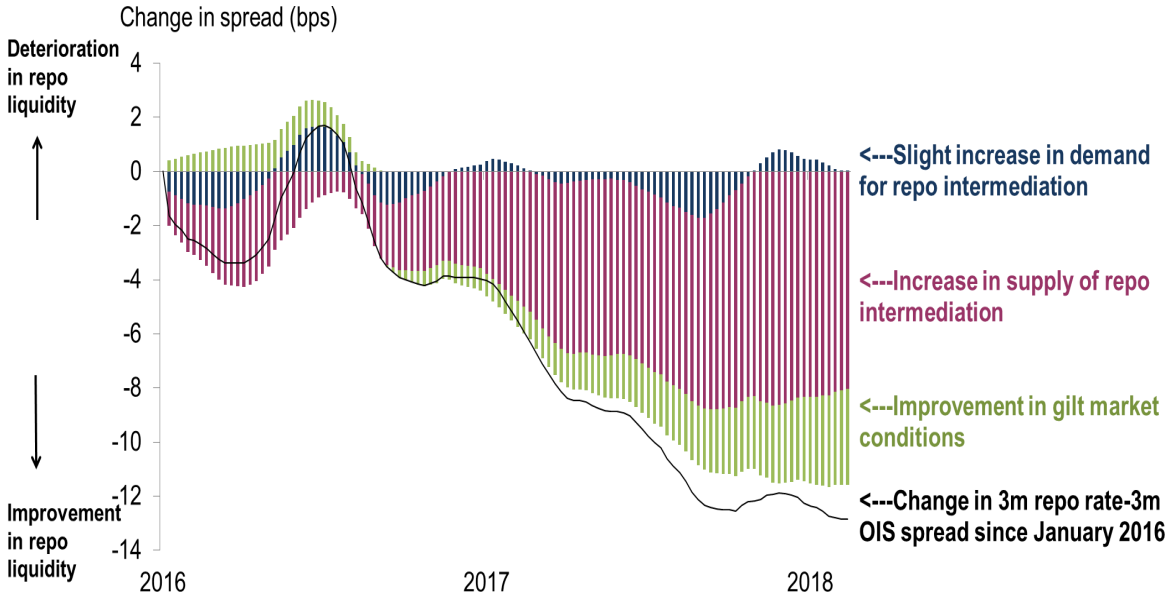
Chart 7 shows the cumulative historical decomposition of the change in the level of the spread between January 2014 and December 2015 – a period in which this spread was steadily increasing (see commentary in Section 2). The black line represents the changes in the spread compared to its level in January 2014; coloured bars represent the cumulative contribution of supply, demand and gilt market conditions shocks identified by our model. The bulk of the increase in the spread over this period was driven by a reduction in the supply of dealer repo intermediation (pink bars).[10] This may in part be due to the announcement of, and banks' preparations for, the formal introduction of the UK leverage ratio in 2014, which increased the cost of repo intermediation (see Section 3). That said, some of the increase in the spread is also driven by an increase in the demand for repo intermediation. This might be a result of dealers increasing their trading activity which may have been funded through repo following the end of the Eurozone debt crisis (Bank of England (2012)).

[10] Similarly our results find that changes in the stock of 3 month gilt repo are largely driven by changes in the supply of dealer intermediation.

We also examine the drivers behind the improvement in repo market functioning between 2016 and 2018, during which the repo spread decreased (black line in Chart 8). During this period the repo spread peaked around June 2016 – around the time of the UK's EU referendum. We estimate that around 70% of the subsequent improvement in the spread was driven by an increase in the supply of intermediation (purple bars in Chart 8). This increase in intermediation may follow from dealers' drive to optimise their balance sheets in light of the introduction of the regulatory leverage ratio (see Section 3 and Bank of England (2016)). Such optimisation might have included the increased use of balance sheet netting, including via the use of central clearing – a hypothesis we explore further in Section 6. Either way, it may have allowed dealers to increase the degree to which they were able to intermediate in the gilt repo market, without incurring additional regulatory costs.

In aggregate over this period, demand factors play almost no role in explaining the narrowing – compared to the earlier widening – of the spreads (blue bars in Chart 9). That said, they account for a relatively large proportion of the widening in the spread around the UK EU referendum. This increase in demand may stem from end-users taking positions designed to insure against or profit from the outcome of this event

Chart 8: Historical decomposition of the change in the level of the three month repo rate-three month OIS spread from 2016 to 2018[(a)(b)]



Source: Bloomberg and Bank of England.

(a) Moving quarterly averages.

(b) The difference between the sum of structural shocks and change in repo spreads is due to the Gibbs sampling algorithm used in the estimation of the model parameters (see Appendix).

In contrast, around 20% of the overall reduction in spread during this period is estimated to arise due to an improvement in gilt market conditions. This might also have come about following the result of the EU referendum in June 2016, which may have increased market participants' certainty as to the further path of UK monetary policy, and hence the value of gilt collateral (Bank of England (2016)).

5.3 Robustness Checks

We perform three checks on these results. First, we run the model using data from different sample periods in order to check the stability of our estimated coefficients. Reassuringly, results are unchanged, indicating our estimated parameters are relatively stable and stationary over the sample period.

Second, we run a version of the model where we substitute the MOVE and the VIX indices – measures of option-implied volatility in bond and equity markets – as alternative measures of market conditions.[11] Changes in these indices may serve as an alternative proxy for market sentiment and conditions. Reassuringly, we find that results are more or less invariant to this change.

Finally, we estimated a version of the model using variants of the sign and zero restrictions relating to our indicator of gilt market conditions. Under one alternative identification scheme, where a zero sign restriction is imposed, the response of repo spreads to a deterioration in market conditions was weakly negative, but not with any significance. Other variants of sign and zero restrictions deliver models that lack stationarity.

Together, the outcome of these checks gives us confidence in the validity of the above results.

5.4 Further investigation of the possible impact of regulation

The results above suggest that changes in the supply of repo market intermediation have been a key driver of changes in the functioning sterling repo market functioning in recent years. As we highlight above, one possibility is that these changes in intermediation have come about due to changes in regulation – such as the leverage ratio – that constrain intermediaries' balance sheets.

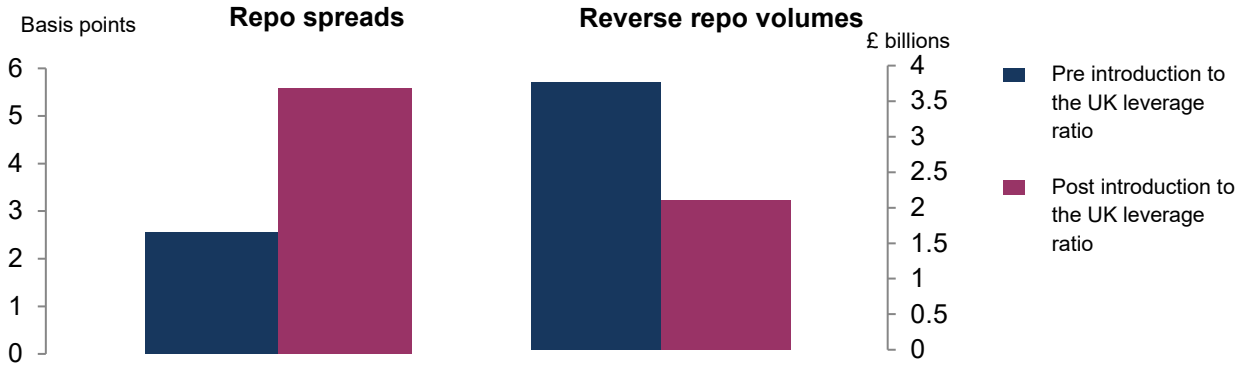
We use the results of the model to assess the impact of regulation by analysing how an increase in demand for intermediation might impact repo volumes and prices before and after the introduction of the UK leverage ratio in January 2016 (PRA (2015)). To the extent that it is this regulation that affected the provision of repo intermediation, this provides an indication of the degree to which such regulation – whilst increasing the resilience of banks – might have reduced their ability to respond to an increase in demand for repo. Such an increase in demand for repo might be analogous to the sort that might occur during stressed market conditions, for example if market participants were seeking to raise funding to meet a margin call.

We run the model on similar data described in Section 4 but use the overnight repo spread and overnight repo amounts outstanding instead of analysing the market for three-month contracts. This is because end-users are likely to demand shorter maturity repo in stressed market conditions (e.g. to meet margin calls) than term repo. We also split our sample into subsamples that relate to the period before and after the introduction of the UK leverage ratio on 1 January 2016. We use the same sign restrictions as in our original results. Summary statistics relating to both subsample periods are given in the Appendix.

[11] Merrill Lynch Option Volatility Estimate (MOVE) is a weighted index of the normalised implied volatility on one-month Treasury options of a range of maturities. The Volatility Index (VIX) is an index that proxies market expectation of volatility implied by the prices of options on the S&P 500 index.

Chart 9 compares the response of repo spreads and amounts outstanding to a one-standard deviation increase in demand for intermediation before and after the implementation of the UK leverage ratio requirement. We estimate that after the implementation of the UK leverage ratio, repo prices respond more (3.5 bps) than before the implementation of the leverage ratio (2 bps). In contrast dealers increase their provision of intermediation by less (£6 billion of transactions outstanding compared to £9 billion). In other words, despite the overall reduction in repo spreads during this period, repo markets are less able to accommodate an increase in demand compared to in the period prior to the introduction of the UK leverage ratio.

Chart 9: Sensitivity of overnight repo markets to a positive demand shock before and after the introduction of the UK regulatory leverage ratio[(a)(b)(c)]



Source: Bloomberg, PRA regulatory returns and Bank calculations.
(a) First week response to a one standard deviation increase in demand for intermediation.
(b) Period prior to the introduction of the UK regulatory leverage ratio: 2011-2015.
(c) Period following the introduction of the UK regulatory leverage ratio: 2016-2018.

These results are consistent with the introduction of the UK leverage ratio having resulted in a reduction in the ability of the sterling repo market to respond to increases in demand for intermediation. This is consistent with other findings in the literature as to the effect of the regulatory minimum leverage ratio. For example, Kotidis and van Horen (2018) find that dealers subject to the UK leverage ratio after the implemention of averaged reporting of reduced repo volumes by up to 133 percentage points more, compared to those not subject to the UK leverage ratio and averaged reporting. In addition, Bicu, Chen and Elliot (2017) find evidence of worsening gilt repo market liquidity in the period following the announcement of the UK regulatory leverage ratio. They also find evidence that repo market liquidity has become less resilient after the introduction of this regulation.

6 A ‘satellite’ model of the differences between centrally cleared and bilateral transactions

We also consider how repo prices and quantities respond to increases in demand for repo transactions that are subject to different forms of intermediation; that is those that are transacted via a central counterparty and those that are conducted bilaterally. As discussed in Section 3, transactions that are centrally cleared are more likely to qualify for ‘netting’ in firms’ balance sheet calculations because they take place with the same counterparty (i.e. a CCP). They thereby qualify for a more lenient treatment under the leverage ratio. The differing response of centrally

cleared and bilateral trades therefore offers further insight into the effects of the leverage ratio on repo markets.

6.1 Data, summary statistics and satellite model

We estimate two versions of the SVAR model described in Section 4: one on the cost and volume of centrally cleared repo transactions, and the other on bilateral transactions. Data on both types of transactions are taken from a new regulatory database called the Sterling Money Market Database (SMMD), collected by the Bank of England on UK gilt repo transactions from January 2015 onwards. Such data are collected for regulatory purposes (further details are given in Harris and Taylor (2018)). The database contains all transactions of a maturity between overnight and one year, conducted in the secured and unsecured sterling money markets and reported by the most active market participants. The dataset is estimated to cover around 95% of the overall value of transactions. The database includes transactions in both the interdealer and the dealer-to-client repo markets. The data also include identities of both repo market intermediaries and their counterparties.

Chart 10: Spread between the overnight CCP nettable and non-nettable gilt repo and reverse repo rates [(a)]

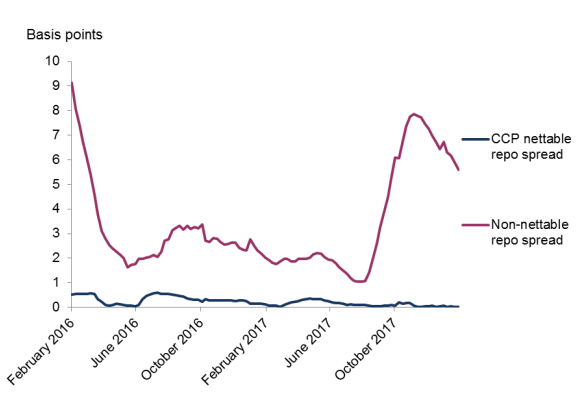
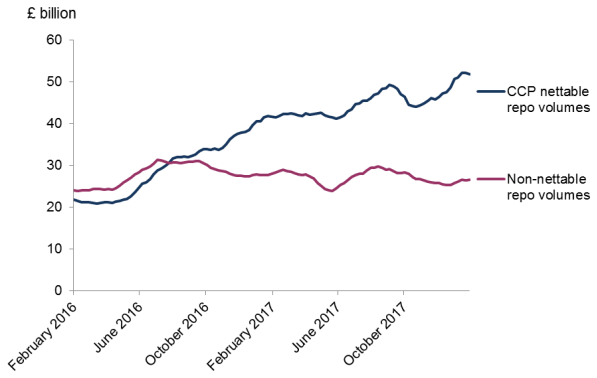


Chart 11: Overnight CCP nettable and non-nettable gilt repo and reverse repo amounts outstanding [(a)]



Source: Sterling Money Markets Dataset
(a) Moving quarterly average

We assume that all transactions conducted with a CCP are 'nettable' under the terms of the leverage ratio. These are referred to as 'CCP nettable' transactions in what follows. Such transactions provide an upper bound for the true volume of centrally cleared transactions that are eligible for more a more lenient capital treatment under the leverage ratio. This is because, not all centrally cleared repo transactions will quality for netting, because some will not match the maturity of centrally cleared *reverse* repo transactions and some transactions conducted by the CCP will be on its own behalf, for example for its own cash management operations.

We assume that transactions that cannot be netted via a CCP or netted bilaterally[12] between two non-CCP participants to be 'non-nettable' under the terms of the leverage ratio. Chart 10 shows the time series of spreads on CCP nettable and non-nettable repo/reverse repo transactions.[13]

[12] Bilaterally nettable transactions are trades between dealers and their clients where the cash legs net off. We estimate these by matching two trades between the same counterparty, of the same maturity and notional amount conducted on the same day.
[13] In this section, for the purpose of this satellite model, we use the spread between borrowing (repo rate) and lending (reverse repo) rate. This gives a more precise indication of the cost of repo market intermediation than the spread between the repo rate and

The spread for CCP nettable trades is substantially lower than that for non-nettable transactions, which might reflect their more lenient treatment under the UK leverage ratio.Chart 11 shows the stock of outstanding overnight CCP nettable and non-nettable transactions. The proportion of nettable repo trades has increased steadily since 2016. This might reflect the increasing cost of intermediating non-nettable repo trades due to the introduction of new regulations.

Table 3: Summary statistics

Variable	Observ-ations	Mean	Min	Max	Standard Deviation
Spread between the overnight CCP-nettable gilt repo rate and CCP gilt reverse repo	116	0.12 bps	-1.7 bps	1.7 bps	0.53 bps
Spread between the overnight non-nettable gilt repo rate and non-nettable gilt reverse repo rate	116	3.86 bps	-3.16 bps	14.4 bps	3.16 bps
Overnight gilt CCP nettable repo amounts outstanding	116	£37.4 bn	£18 bn	£60.1 bn	£1074.6 bn
Overnight gilt non-nettable repo amounts outstanding-	116	£27.3bn	£20.4bn	£35.1 bn	£316.1 bn
Gilt market conditions measure	116	3.0 bps	1.4 bps	4.86 bps	0.93 bps

All data are once again transformed from a daily to weekly frequency by taking averages from end-Monday to end-Monday. Summary statistics are given in Table 3. We estimate our 'satellite model' using the same specification and sign restrictions as described in Section 4, over the period between February 2016 and April 2018.This also includes the measure of gilt market conditions described in Section 4.

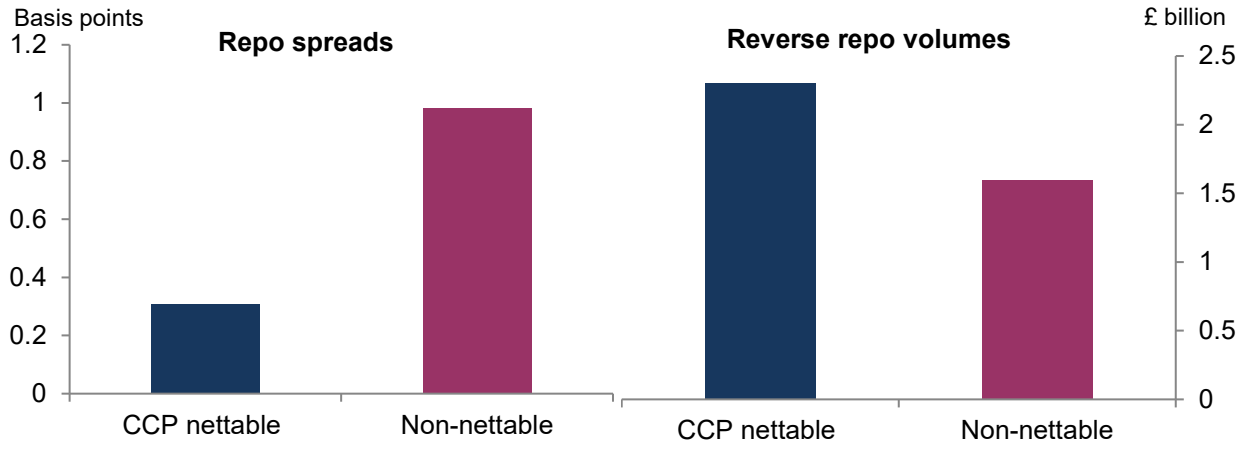
6.2 Empirical results

Similar to the exercise in Section 5.4, we compare the response of repo spreads and amounts outstanding to an increase in demand for intermediation, roughly analogous to the sort of shock that might occur in stressed market conditions. Here, however, our interest lies in the response of spreads and volumes of nettable versus non-nettable repo transactions.

Chart 12 compares the response of spreads and amounts outstanding to a one standard deviation positive demand shock to our nettable and non-nettable transactions. Non-nettable transaction spreads respond three times as strongly as those that are nettable (0.3 bps compared to 1bps). In contrast, nettable transact volumes respond by around a third more (£2.3 billion) than those that are non-nettable (£1.6 billion). In other words, nettable transactions are more able expand to meet an increase in demand than those that are non-nettable.

expectations of the policy rates. We were unable to use this measure in the analysis of Section 5 as we did not have access to data on reverse repo rates for that data sample.

Chart 12: Sensitivity of the cost and volume of centrally cleared and bilateral gilt repo transactions to a positive demand shock



Source: Sterling Money Markets Dataset and Bank calculations.
(a) First week response to a one standard deviation positive demand shock

This finding is consistent with the notion that dealers may be less willing/able to expand their balance sheets to accommodate non-nettable repo transactions because they incur greater cost under the leverage ratio.

To the extent that, in future periods of stress, end-users are able to transact in a way that is amenable to intermediaries' balance sheet netting, this might give us increased confidence that repo markets will be able to accommodate their demand. There remain, however, a number of users of repo markets, such as non-banks, that generally lack access to central clearing, and so might find it harder to transact in a nettable manner, particularly during stress.

As such, this result may support the case for extending membership of CCPs so that the maximum number of repo market end-users can benefit from increased access to transactions that are nettable under the terms of the leverage ratio. For example, the London Clearing House (LCH) recently extended its membership to non-bank financial firms.[14] This may allow a broader range of market participants to access repo markets at lower cost during future periods of stress.

[14] See https://www.lch.com/resources/news/lch-launches-new-model-buy-side-repo-clearing

7 Conclusion

This paper offers a framework to assess the degree to which recent changes in the functioning of the gilt repo market have been due to changes in the supply of – versus the demand for – intermediation by dealers. It does so using a structural VAR approach to identify changes in the price and volume of repo transactions that match a set of assumed directional responses in these variables consistent with changes in the supply and demand for intermediation.

It concludes that the majority of recent changes in market functioning have occurred due to changes in the supply of intermediation. It also finds that the cost of repo increases more, and transaction volumes by less, in response to increases in demand for intermediation since the introduction of the UK leverage ratio. Transactions that are centrally cleared – and more likely to be eligible for a more lenient treatment under the terms of this regulation – are able to expand by more in response to a posive demand shocks. This is consistent with the introduction of the UK leverage ratio having imposed constraints on the ability and/or willingness of dealers to act as intermediaries in the gilt repo market.

These results may be of use to policymakers seeking to advance their understanding of the drivers of changes in repo market functioning. Our analysis sheds light on recent changes in the structure of repo markets, including the degree to which post-crisis regulations – whilst increasing firms' resilience – might have reduced the degree to which the capacity of repo markets can respond to shocks in stress. It also suggests that nettable centrally cleared repo transactions may benefit market resilient. This could support the case for widening access to central clearing.

There are numerous possible future extensions to this work. The model offered here could be expanded to include data on different segments of the repo markets, including variables that capture more precisely the effect of the use of off-balance sheet alternatives to repo transactions (see Section 3). An extension of the model could also be used to compare the response of UK repo market intermediaries to demand for transactions from foreign and domestic banks. This may be particularly revealing given recent evidence that some foreign banks may reduce their lending by more during stress compared to domestic banks (De Haas and Van Horen (2013); Cetorelli and Goldberg (2011); Giannetti and Laeven (2012)). Such extensions are, however, left as further work.

8 Appendix

8.1 Technical details of model and impulse response functions

The VAR (1) model we use has the following form:

$$y_t \equiv \begin{pmatrix} Repo\ spread_t \\ Reverse\ repo\ volumes_t \\ Gilt\ liquidity_t \end{pmatrix} = \begin{pmatrix} A_{11} & A_{12} & A_{13} \\ A_{21} & A_{22} & A_{23} \\ 0 & 0 & A_{33} \end{pmatrix} \begin{pmatrix} Repo\ spread_{t-1} \\ Reverse\ repo\ volumes_{t-1} \\ Gilt\ liquidity_{t-1} \end{pmatrix} + u_t$$

where $A_{i,j}$ are coefficients, and u_t are time varying unit normal innovations.

We estimate the coefficients using a Bayesian approach. This allows for improved inference and requires no additional restrictions on the value of coefficients besides our choice of sign restrictions.[15] We use a normal-diffuse prior which assumes no particular structure of the variance covariance matrix. The VAR is estimated using 2000 Gibbs sampler draws, the first 1000 of which are discarded as burn-in-sample.

We run the model using the European Central Bank's Bayesian Estimation Analysis and Regression (BEAR) toolbox.[16] This calculates impulse response functions using the Gibbs sampling algorithm by stimulating a large number of models (2000 Gibbs sampler draws) based on our identifying sign restrictions. The algorithm discards models which do not fit our restrictions and keeps those which do. It then uses all models which are consistent with our sign restrictions to construct an empirical distribution, the median point estimate of which is used to calculate impulse response functions. These are then used to construct historical decompositions – see Dieppe, Legrand and van Roye (2016) for further information.

8.2 Summary statistics relating to subsamples in Section 5.4

Table 4: Summary statistics

Variable	Observations	Mean	Min	Max	Standard Deviation
Spread between the overnight gilt repo rate and risk-free rate (**Period 1**)	256	0.6 bps	-18.7 bps	9.3 bps	4.2 bps
Spread between the overnight gilt repo rate and risk-free rate (**Period 2**)	118	1.4 bps	- 33.1 bps	13.2 bps	5.0 bps
Overnight gilt reverse repo amount outstanding (**Period 1**)	256	£43,932,053,565	£10,180,140,913	£72,290,283,048	£12,977,918,971
Overnight gilt reverse repo amount outstanding **(Period 2)**	118	£35,448,292,009	£11,860,586,462	£54,330,431,404	£9,048,837,644
Gilt market conditions variable (**Period 1**)	256	4.1 bps	2.6 bps	6.7 bps	0.9 bps
Gilt market conditions variable (**Period 2**)	118	3.0 bps	1.4 bps	4.9 bps	0.9 bps

[15] See Miranda-Agrippino & Ricco, (2018) for further information
[16] See https://www.ecb.europa.eu/pub/pdf/scpwps/ecbwp1934.en.pdf

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