Liquidity and Credit Risks in the UK's Financial Crisis: How 'Quantitative Easing' changed the relationship

Abstract

This paper investigates the relationship between credit and liquidity risk components in the UK interbank spread during the recent financial crisis and sheds light on the transmission mechanism of the quantitative easing (QE) carried out by the Bank of England on short term interest rates. Specifically, we find that prior to the Bank's intervention counterparty risk was a major factor in the widening of the spread and also caused a rise in liquidity risk. However, this relationship was reversed during the period when QE was implemented. Using the accumulated value of asset purchases as a proxy for the central bank's liquidity provisions, we provide evidence that the QE operations were successful in reducing liquidity premia and ultimately, and indirectly, credit risk. We also find evidence that suggests liquidity schemes provided by other central banks and international market sentiment contributed to the reduction of interbank spread.

Keywords: interbank spreads, liquidity premia, credit risk, quantitative easing, financial crisis.

1. Introduction

The main purpose of this paper is to analyse developments in the UK interbank market after the beginning of the financial crisis in August 2007 and in particular to examine the effect of the Bank of England's asset purchase or 'quantitative easing' (QE) policy on spreads in the interbank market. While Butt *et al.* (2014) and Joyce and Spaltro (2014) find little or no evidence of a QE effect via a bank lending channel, others such as Joyce *et al.* (2010) and Gagnon *et al.* (2010) show that asset purchases operated through a portfolio rebalancing channel, thereby lowering interest rates on longer term assets. Our study supports and extends these latter findings by providing evidence linking QE to the reduction of the UK interbank or Libor spread, defined in this paper as 3-month Libor minus 3-month Overnight Index Swap. Our results also help resolve some of the controversy in the literature with regard to the question of whether it is liquidity risk or credit risk that was responsible for the widening of the Libor spread, and whether liquidity provisions by central banks would be useful at all if it was the latter that caused the interbank spread to widen dramatically at the beginning of the crisis.

With regard to the dramatic rise in interbank spreads, Taylor and Williams (2009) argue that counterparty risk was the main driver of the widening of the Libor spread and, that during the crisis the fall in liquidity was not a major determinant. Further, the exceptional funding provisions by the Federal Reserve did not cause a sizeable fall in the spread. In a recent study, Angelini *et al.* (2011) corroborate Taylor and Williams' findings and show that the most important determinant of the widening spread is the change in aggregate factors, notably risk aversion, and that central bank liquidity provisions are ineffective. In contrast, the Bank of England (2007), McAndrew *et al.* (2008), Wu (2008), Upper (2008) and Nobili (2009) found that both, credit and liquidity risk drove the interbank spread and that central bank liquidity provision effectively reduced it.

This paper addresses this controversy by showing that in the pre-QE period, credit risk was indeed the major factor and that it caused a rise in liquidity risk. Such a result supports the arguments put forward by Taylor and Williams in that asymmetric information in the unsecured interbank market can increase the likelihood of liquidity hoarding by banks.[1] In the later part of the crisis, during the QE operations (February 2009 to June 2010), we find evidence that suggests this relationship is reversed. Moreover, the purchase of gilts by the Bank of England was found to reduce first only the liquidity spread, which in turn subsequently reduced credit risk, a finding that is consistent with other studies which show QE is effective in reducing interbank spreads.

[1] See also Heider *et al.* (2009) and Ashcraft *et al.* (2011) for theoretical analysis and empirical evidence respectively.

One possible interpretation of this finding is that liquidity funding risk results in greater risk of default by banks. Hence, a reduction in liquidity premia as a result of the QE operations ultimately, but indirectly, reduces credit risk premia. Consistent with the findings of Angelini *et al.* (2011), another possible explanation is that the concerted efforts by major central banks eventually convinced the financial markets the worst was over and market sentiment and thus risk aversion improved, causing interbank spreads to fall. This line of argument is supported by our further analysis that finds improvement in both US and Euro interbank spreads and lower option-implied volatilities also contributed to the reduction in the UK interbank spread.

Although it is not reported in the paper, our results also indicate that the role of credit default swaps (CDS) as a measure of credit risk in the decomposition of the Libor spread changed during the crisis period. Possibly due to their much longer maturity than the interbank spreads, the QE interventions did not seem able to lower the CDS rates at all, and thus extreme care must be taken if CDS rates are used to determine counterparty risk in the Libor spread.[2]

Two further innovations in this paper deserve to be mentioned. Firstly, existing studies of the effects of QE and similar programmes in the USA and EMU have used dummy variables to capture the impact of central bank liquidity provisions during the crisis. Instead, we use the ratio of the cumulated value of asset purchases by the Bank, to banks' assets. The cumulated value not only provides a better measure for the *extent* of the QE operations at any particular moment, it also represents the increasing likelihood of meeting the liquidity needed in the interbank market. Furthermore, McAndrew *et al.* (2008) found a unit root in the Libor spread and proceeded to study the effect of the 'Term Auction Facility' (TAF) by using an OLS regression model in first differences. Since such an approach reveals only the short run effect, we estimate an error correction model which distinguishes between level and difference effects, as well as shedding light on the transmission mechanism of QE.

[2] The results on CDS are reported in the working paper available at: https://ideas.repec.org/p/cdf/wpaper/2016-9.html

The paper is structured as follows. Section 2 presents the argument for the decomposition of the Libor spread and the model we use. This is followed by some descriptive analysis of the data in section 3. Section 4 reports and discusses the estimation results on the UK interbank spreads and section 5 carries out further analysis to investigate the possible contribution of international factors to lowering the interbank spreads. Finally, section 6 concludes.

2. MODEL AND METHODOLOGY

To investigate the relationship between credit risk and liquidity components in the interbank spread, we decompose the interbank spread into its credit and liquidity components. Since our method of decomposition differs from that in the existing literature, its details are presented below.

2.1 Decomposition of the Interbank Spread

The interbank spread (*ib*) is decomposed into its credit risk (*cr*) and its liquidity risk (*lr*) components as follows:

(1) $$ib = cr + lr$$

where *ib, cr* and *lr* are measured by Libor-OIS, Libor-Repo and Repo-OIS respectively. The credit risk component is proxied by the Libor-Repo spread, since this represents the difference between unsecured and secured (i.e. default-free) lending rates between banks at the same maturity; see, e.g., Taylor and Williams (2009) and Angelini *et al.* (2011).

The choice of the Repo-OIS spread as a measure of the liquidity premium is implicit in the decomposition as the literature generally regards the non-credit portion of the Libor spread as liquidity risk; see, e.g., Taylor and Williams (2009). That the risk embedded in the repo spread may be regarded as mostly liquidity in nature may be justified as follows. Like any other financial market, the repo market is subject to a variety of risks, such as credit risk, liquidity risk and operational risk (BIS, 1999).[3] Given its institutional nature, we can regard operational as constant and hence irrelevant over the time period we are considering here. A major potential for the development of counterparty risk exposure is the volatility of the price of the collateral and the quality of the collateral. Since in the UK the collateral is 'risk-free' gilts, counterparty risk may be regarded as negligible.[4]

However, any form of decomposition is intrinsically problematic since the two risks are closely related.[5] For example, Poskitt (2011) points out that a bank finding it difficult to raise funds is also in greater risk of default and its liquidity problems will likely be factored into credit default swap (CDS) premia and higher interbank rates. The problem is widely-recognised and the Bank of England (2007) warns that liquidity and credit risks may not be independent and sometimes avoids the specific term 'liquidity risk' in favour of the vaguer 'non-credit risk' when referring to residual influences behind the LIBOR-OIS spread. Interestingly, however, the Bank also uses its market contacts to corroborate the implications in the data and these do confirm, at least for the period leading up to the crisis, that market participants felt that the credit premium was driven by risk of default unconnected with liquidity and that the residual premium was accounted for largely by liquidity factors. Therefore, notwithstanding the

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[3] Readers are also recommended to see ch.2 of Simon Gray, *Repo of Government Securities* (London: Bank of England, 1998) for a useful discussion of the way in which risk (of various kinds) can enter into repo deals.

[4] Note that in normal practice, counterparty risk is minimised through a variety of risk management tools, including initial margins, daily marking-to-market of the collateral, position limits with counterparties and concentration limits for specific securities (Hoerdahl and King, 2008).

[5] For a demonstration of how banks' asset risk affects funding liquidity in the interbank market, see Heider *et al.* (2009).

problem described, it may still be useful to use terms which describe a discrete form of risk to 'explain' changes in spreads.[6]

Finally, we would like to point out an advantage of decomposing the Libor spread by (1). Basically, it does not involve any estimation but is directly based on yields of financial instruments. This helps to shed light on the channel through which QE reduces the interbank spreads. As the evidence provided in the next section shows, the large scale purchase of gilts (as is the case for QE in UK) helped lower the repo rate (and hence *lr*), which in turn caused a fall in the Libor rate (and hence *cr*).

2.2 The econometric model

Since a unit root is found to be present in the interbank spreads during the financial crisis, McAndrews *et al.* (2008) focus on the changes in the interbank spread and investigate whether the announcements and operations of TAF are associated with short term, 1-day reductions in the interbank spread. However, in order to judge its effectiveness, Taylor (2012) points out that it is important to consider the longer term effects of asset purchase programs. In this paper, we use error correction models (ECM) to study the long and short term relationship between liquidity and credit risk premia in the interbank spread as well as the impact of QE on its components. Since Gonzalo and Lee (1998) find that the single equation based test of Engle and Granger is more robust than the system based approach of Johansen, we consider the following single equation ECM of Banerjee *et al.* (1998).

$$\Delta y_t = a_0 + b_0'\Delta x_t + \gamma y_{t-1} + \lambda' x_{t-1} + ct + \sum_{j=1}^{p} a_j \Delta y_{t-j} + \sum_{j=1}^{p} b_j \Delta x_{t-j} + \varepsilon_t \tag{2}$$

[6] Indeed, an article in the same issue (Bank of England, 2007, 533-541) decomposes corporate bond spreads into measures of credit and liquidity risk, expresses no reservations or warnings about cross-contamination and treats credit and liquidity risk as independent factors in the spreads.

In (2), γ measures the speed of adjustment in response to disequilibrium errors.[7] If the γ-coefficient is significant and negatively signed, the variables are said to be cointegrated and we can infer x as the long run forcing variable for y. Identifying the long run forcing variable helps us to understand the process by which the interbank spreads were brought down during the QE operations.

Unlike existing studies which use dummies to proxy for central banks' intervention, the liquidity provisions by the Bank of England are calculated as the *ratio* of the accumulated money spent on buying gilts to banks' total asset value (a variable we denote hereafter as *qe*). The rationale for using accumulated money is firstly, that it is more informative than a dummy variable. Second, assuming hypothetically there is a fixed level of liquidity shortage in the interbank market, the accumulated value represents the increasing likelihood of providing sufficient funds to remove that illiquidity. So, for example, to study whether the quantitative easing (as proxied by *qe*) conducted by the Bank of England is effective in lowering the liquidity premium (as proxied by *lr*) in the interbank spread, the ECM equation may be:

(3) $$\Delta lr_t = a_0 + b_0 \Delta qe_t + \gamma lr_{t-1} + \lambda qe_{t-1} + ct + \sum_{j=1}^{p} a_j lr_{t-j} + \sum_{j=1}^{p} b_j qe_{t-j} + \varepsilon_t$$

If γ in (3) is found to be significantly negative, we are interested to see whether *qe* error-corrects to its long run equilibrium as determined by the spreads. Such consideration renders vector error correction models (VECM) the obvious framework for studying the long run interrelationship between variables of interest while taking into account the issue of endogeneity. In this paper, we follow the two-step procedure of Engle and Granger (1987) by first estimating the cointegrating vector, which in turn is used to estimate the short-run dynamics of VECM, as shown below:

(4) $$\Delta z_t = \mu + AE_{t-1} + Ct + \sum_{j=1}^{p} B_j \Delta z_{t-j} + u_t$$

[7] The disequilibrium error is given by $y_t + \gamma^{-1}(\lambda' x_t + ct)$ plus a constant.

The advantage of this approach is that the heteroscedasticity and autocorrelation consistent (HAC) t-statistics can be obtained easily. For the QE period, $z = (lr \quad cr \quad qe)'$ in (4) is found to have two cointegrating vectors. Thus E is a 2×1 vector of residuals from the two cointegrating vectors whereas A is a 3×2 matrix of error correction coefficients.

3. DATA AND DESCRIPTIVE ANALYSIS

Here we carry out some descriptive analysis that will help justify the choice of our econometric model. We use daily 3-month Libor, 3-month Repo and 3-month OIS to construct the credit risk (*cr*) and liquidity risk (*lr*) components of the interbank spread. The 5-year credit default swap (CDS) is also considered as it is widely used as a proxy for credit risk.

< Figure 1: Interbank and repo spreads and CDS >

Figure 1 shows how the time series properties of the credit risk and liquidity risk components of the Libor-OIS spread as well as CDS have changed over time. This suggests a possible presence of unit roots and structural change across different time periods, which is confirmed by the unit root test results over the different sample periods provided in Table 1 below.

< Table 1: Unit Root Statistic for Level of Spreads >

In the pre-crisis period, a stochastic trend was rejected for all variables, except CDS. During the crisis period, all risk components follow a random walk and this remains so for the post crisis period with the exception of the liquidity risk variable. The change in its time series properties may be due to the immense easing of monetary policy during the crisis period. As our estimation results later on show, the size of the QE effect is large on the *lr* component. Indeed in the post QE period, the liquidity premium has fallen but the credit risk premium shows signs of rising. Finally, *qe*, the proxy for liquidity provision by Bank of

England, is found to contain a unit root with trend, for its first difference is trend stationary with a negative slope.

Turning to the correlations between the interbank spreads over time, Panel A in Table 2 shows how the relationship between the liquidity and credit risk components evolved over time. In the pre-crisis period, there is some very small negative correlation between *cr* and *lr* and positive correlation between CDS and *cr*. Over time, the correlation rises steadily between the individual components and it peaks during the QE period. In the post-crisis period, correlations between credit and liquidity spreads become negative, indicating the change of the relationship between liquidity and credit risk components compared to the pre-crisis period.

< Table 2: Correlation between liquidity risk and credit risks >

According to (1), the Libor spread is decomposed as the sum of liquidity and credit risks. Thus any change in liquidity spread must be followed by an opposite change in credit spread if the Libor spread remains at the same level. Thus a positive correlation (0.10) between the liquidity and credit risk premia during the pre-QE crisis period in Panel B of Table 2 suggests both spreads were rising together. During QE when both spreads fell drastically, the correlation becomes significantly negative at -0.30. One conjecture is that the BoE's asset purchase activity lowered the Repo rate but not directly the Libor rate; the latter fell with a delay, thereby giving rise to negative correlation. Such conjecture is consistent with the analyses carried out in sections 4 and 5 which find that *qe* is the long run forcing variable on *lr* but not *cr*.

To sum up, a unit root is found in the variables of interest during the crisis period, justifying the use of an ECM for our analyses. Furthermore, there is significant change in the correlation structure between liquidity and credit risk measures as a result of asset purchase activities, prompting us to investigate whether the QE operation changed the relationship between the two risk components. Finally, during the QE period, very high correlations between *qe, lr* and *cr* are observed. Hence the next section begins the ECM analysis in a pairwise manner for the three variables of interest.

4. ESTIMATION RESULTS

The relevant results are reported in tables 3 to 5. The impact of the credit default swap on the relationship is found to be insignificant and hence is not reported here.[8] Unless stated otherwise, lag length p = 2 is used for the differences in the estimation.

4.1 Liquidity and credit risks before and during QE

Equations 1 and 2 in Panel A of Table 3 describe the behaviour of our key spreads in the period after the onset of the crisis but before the Bank of England began its programme of QE. Only coefficients relevant to the cointegration test, i.e. γ and λ in (2), are reported.

< Table 3: Liquidity and credit risk before and during QE >

The first equation shows the error correction terms of the liquidity spread (lr). We can see a positive and significant long-run relationship between liquidity and credit spreads, in the form of $lr = 0.014/0.109cr$. Equation 2 shows the results of the error correction terms with Δcr as the dependent variable. There is no cointegration and the R-square is low compared to the previous estimation results. The reported results thus support the claim made by Taylor and Williams (2009) and Angelini *et al.* (2011) that the main driver of the rise in interbank spreads was the large credit premium required by the banks to lend funds. That is, during the pre-QE period, we find that a widening of credit risk premia Granger causes a widening of the liquidity risk premium. Panel B of Table 3 reveals the reversed roles of liquidity and credit spreads under QE. That is, liquidity risk now drives credit risk but not *vice versa*.

< Table 4: How the intervention of the BoE lowers liquidity and credit risks>

[8] For results on the CDS, please see the working paper available at: https://ideas.repec.org/p/cdf/wpaper/2016-9.html

Table 4 shows that the massive liquidity provision by the Bank of England narrowed both liquidity and credit spreads. Equation 5 demonstrates that *qe* is now the long-run forcing variable in the determination of the liquidity spread. In particular, the interventions reduce the liquidity spread by 0.958/0.114 = 8.4 basis points for gilt purchases equivalent to one percentage point of banks' asset value. Furthermore, Equation 6 shows that the additional provision of liquidity does not change the credit risk premium directly. Therefore, in conjunction with the results given in Panel B of Table 3, we conclude that QE narrows the credit spread indirectly through a narrowing of the liquidity spread.

These findings also explain the negative correlation between changes in credit and liquidity spreads observed in Table 2 during the QE period when both spreads were falling substantially: according to the error correction model, the credit spread falls a day later in response to a reduced liquidity spread as a result of asset purchase activity by the Bank of England. A final note for Table 4 is that equations 7 and 8 suggest the BoE reacts to changes in credit risk premium but not to changes in liquidity risk premium.

4.2 VECM Results

The single equation ECM analyses in the previous section ignore the issue of endogeneity and assume that the critical values provided by Banerjee *et al.* (1998) would hold despite the presence of heteroscedasticity in financial time series. This section therefore estimates the VECM given by (4) using OLS and reports *t*-statistics that are consistent with the presence of heteroscedasticity and autocorrelation. Lag of differences up to 2 is used for the system as a whole; additional lags are added to an individual variable until its residuals pass the Ljung-Box test for serial correlation. The required cointegrating vectors (E_{t-1}) are obtained using Engle and Granger (1987) procedure.

In terms of VECM, the single equation analyses in the previous section establish the following long-run relationships

(5) $$lr_t = a_0 + a_1 qe_t + a_2 t + E1_t$$

(6) $$cr_t = b_0 + b_1 lr_t + E2_t$$

(7) $$qe_t = c_0 + c_1 cr_t + c_{2t} + E3_t$$

with the following error correction term:

(8) $$\alpha\beta' \begin{bmatrix} lr_{t-1} \\ cr_{t-1} \\ qe_{t-1} \end{bmatrix} = \begin{bmatrix} -d_1 & 0 & \alpha_{13} \\ \alpha_{21} & -d_2 & 0 \\ 0 & \alpha_{32} & -d_3 \end{bmatrix} \begin{bmatrix} 1 & 0 & -a_1 \\ -b_1 & 1 & 0 \\ 0 & -c_1 & 1 \end{bmatrix} \begin{bmatrix} lr_{t-1} \\ cr_{t-1} \\ qe_{t-1} \end{bmatrix}.$$

Note that the elements of α are determined by the single equation ECM results. It is not difficult to see that in (8) there are two cointegrating vectors, which is confirmed by Johansen's trace and max-eigenvalue tests. Since any row of β' can be obtained from linear combination of the other two rows, we have $a_1 b_1 c_1$ = 1. Based on the coefficients obtained from significant ECM equations 4 (in Panel B of Table 3), 5 and 8 (in Table 4), we have $a_1 b_1 c_1$ = 0.73.

For the VECM as described in (4), *E1* and *E3* are used because the correlation between them is low, at -0.08.[9] By virtue of (8), the error correction term in (4) takes the form:

(9) $$AE_{t-1} = \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \\ \alpha_{31} & \alpha_{32} \end{bmatrix} \begin{bmatrix} E1_{t-1} \\ E3_{t-1} \end{bmatrix} = \begin{bmatrix} -d_1 & \alpha_{13} \\ \alpha_{21} & 0 \\ 0 & -d_3 \end{bmatrix} \begin{bmatrix} E1_{t-1} \\ E3_{t-1} \end{bmatrix}.$$

[9] The other two correlations are -0.83 (between *E1* and *E2*) and -0.43 (between *E2* and *E3*).

α_{21} in (9) is to be determined. Since error correction is established for *cr*, $\alpha_{21} \neq 0$. Now a large and positive $E1_{t-1}$ implies a high *lr* value at time *t-1*, which in turn means *cr* would tend to error correct upwards in the next time period. This implies a positive α_{21}.

< Table 5: The effect of QE on liquidity and credit spreads (VECM)>

The estimated VECMs are reported in Table 5. The results broadly agree the above analysis culminated in (9), and thus confirm the single equation ECM results.

5. THE EFFECT OF INTERNATIONAL FACTORS ON UK INTERBANK SPREADS

The focus of this paper is on the effects of the so-called QE programme. However, throughout the crisis, central banks provided a range of liquidity support schemes in core funding markets, nationally and internationally. In the UK, major liquidity provision was carried out through schemes such as the 'extended collateral long-term repos' (ELTR), the 'special liquidity scheme' (SLS) and the 'asset purchase facility' (APF) or QE. Globally, massive amounts of liquidity were also provided by the Federal Reserve and other central banks through schemes and rescue packages such as the 'US dollar swap line', the 'Term Auction Facility' (TAF) and the Large Scale Asset Purchasing Programme' (LSAP).

From the empirical evidence of various studies (e.g., McAndrews *et al.,* 2008; Wu, 2008) and the fact that financial markets are highly inter-linked, it is likely that these international factors would have contributed to the reduction of UK interbank spreads. Nevertheless, it is beyond the scope of this paper to disentangle these various liquidity schemes from each other and judge their efficacy on reducing the Libor spread. This section therefore carries out the relatively simple and yet informative single-equation analysis described in Section 2 to shed light on the role of international factors in reducing the UK liquidity and credit spreads. Instead of using direct measures of the various liquidity schemes, we consider interbank spreads of US and the euro area as well as option implied volatilities, which are widely regarded as proxies for market sentiment; see, e.g., Baker and Wurgler (2007).

Figure 2: Interbank spreads and option implied volatilities

Figure 2 shows how closely interrelated the interbank markets of the UK, US and the euro area were during the crisis. This is possibly due to the fact that banks operate internationally and thus have also access to liquidity schemes and core funding markets abroad. We also find that option implied volatilities are highly correlated with the interbank spreads, which suggests that the rise in the interbank spreads was closely associated with worsening market sentiments. Possibly due to the wave of rescue actions from major central banks, which finally convinced the financial markets that the worst was over, market sentiment improved and interbank spreads came down. Interestingly, the study by Angelini *et al.* (2011) finds that the initial widening of interbank spreads was due to a higher price of risk rather than specific bank risk. It may thus be conjectured that a lower price of risk, as a result of extraordinary liquidity provisions by central banks, is a factor in the reduction of interbank spreads and improvement in market sentiment.

Following the analysis earlier in the paper, the US and euro interbank spreads are decomposed into their respective liquidity and credit components. This gives rise to six interest rate spreads, three option implied volatilities and the Bank's QE variable, a total of ten variables to be considered. Since these variables are highly correlated with each other, we restrict our ECM analysis to only pairwise and the associated *t*-statistics of the single-equation tests are provided in Table 6 below.

< Table 6: Effects of international interbank spreads and market sentiments >

The test results show that none of the other variables except the UK liquidity component significantly drives the credit component, *cr*. This, however, does not mean that the international liquidity schemes did not contribute to reduction in UK credit spread, for we can see that (UK) *lr* is also significantly driven by the credit component of both dollar and Euro interbank spreads as well as *qe*, which are in turn driven by other variables including option implied volatilities. Thus, we can infer that liquidity provisions by other central banks did contribute to reduction in UK interbank spreads.

Table 6 also presents other notable results with regard to the QE program undertaken by BoE. The *qe* variable is found to be a significant long-run forcing variable for all three liquidity components but none of the credit components. This may be regarded as further evidence for the likely transmission mechanism whereby a central bank's asset purchases could lower interbank spreads through a portfolio rebalancing channel. Also, all three option implied volatilities were significantly driven by the *qe* variable, which is consistent with the conjecture that BoE's QE program also helped improve market sentiment. Finally, it is interesting to see that all variables except the Euro liquidity component act as a long run forcing variable for *qe*. It may be surmised that the asset purchase program is not a purely exogenous activity, but one that is dependent on the dynamics of interbank spreads and market sentiments.

To sum up the results of this section, we find evidence that suggests international liquidity schemes did contribute to the reduction of UK interbank spreads, albeit indirectly in the sense that no statistically significant pairwise ECM dynamic is detected between the UK credit component and international factors.

6. Conclusion

The results of our study show that QE has reversed the relationship between credit and liquidity premia depends. While credit risk is the driver of the liquidity spread in the pre-QE period, causation is reversed during QE. In this period, BoE intervention reduces the liquidity spread greatly with no direct effect on the credit spread. However, the narrowing of the liquidity spread causes a fall in the credit spread. To our knowledge, the existing literature has overlooked the possibility and the importance of the change in the role of the credit and liquidity spread in pre-QE and QE periods.

Our results provide some indicative evidence that BoE intervention changed money market relationships beyond the financial crisis. Unit root tests suggest that the time series property of the liquidity spread has changed in the post-crisis period compared to the crisis period. The massive injection of liquidity by the Bank may have led to the stationarity of the liquidity spread, while credit premia maintain a unit root, possibly indicating that credit risk may become the major concern in the post-crisis period.

Finally, we also investigated the possibility that the above findings may be due to spillovers from other liquidity schemes both in the UK and overseas rather than to the QE programme alone. We found high correlations between these variables, suggesting that interbank markets are highly connected and that market sentiment or price of risk is associated with the rise and fall of the Libor spreads; see Angelini *et al.* (2011). Our empirical evidence suggests that other liquidity schemes do not appear to affect our earlier findings to any significant degree.

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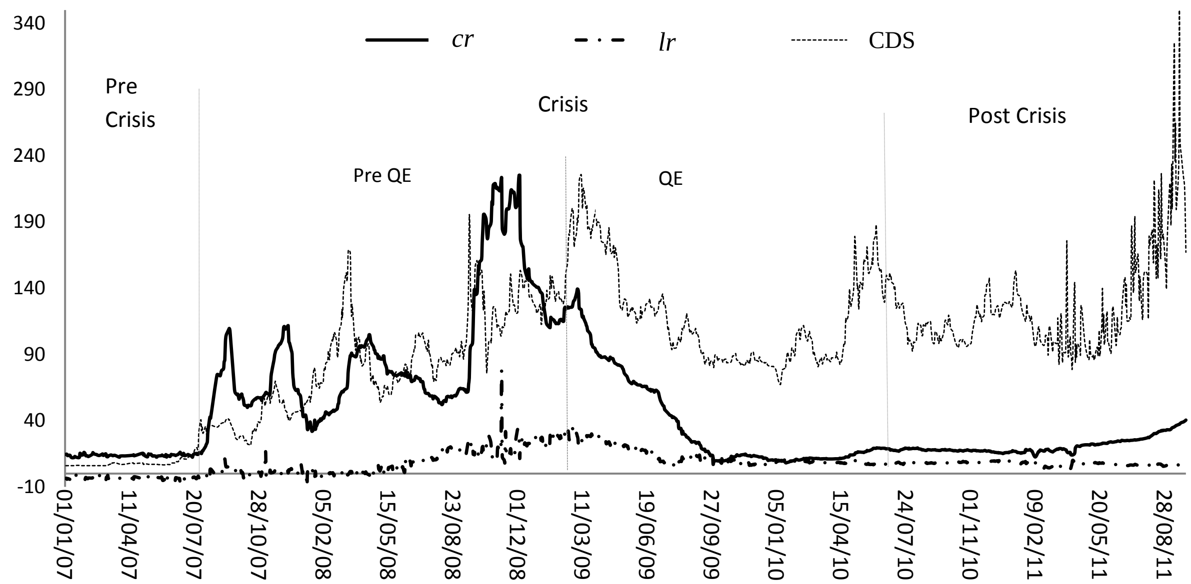
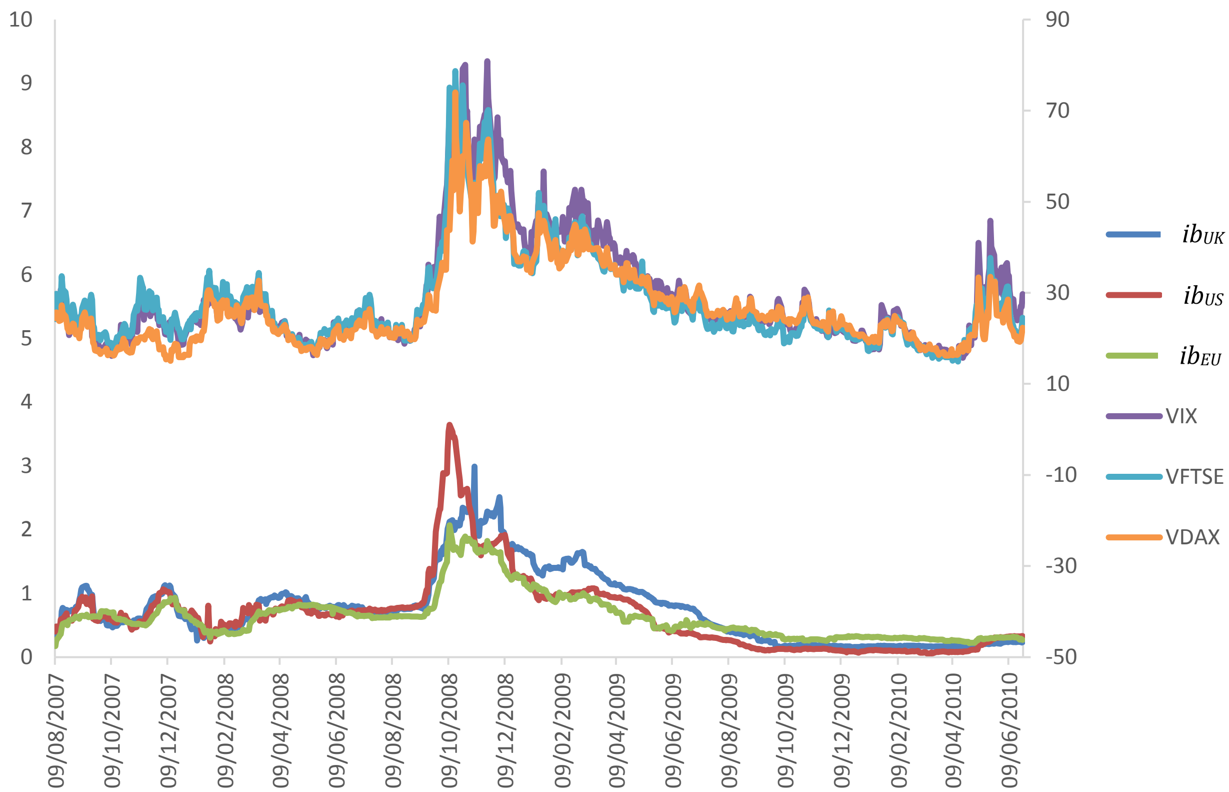
Figures and Tables

Figure 1: Credit and liquidity spreads and CDS



cr stands for the three-month Libor-Repo spread, *lr* the three-month Repo-OIS spread, and CDS the five-year credit default swap.

Figure 2: Interbank spreads and option implied volatilities



ib_{UK}, ib_{US} and ib_{EU} refers to the Libor minus OIS spreads in the UK, US and euro areas respectively. VIX, VFTSE and VDAX are respectively the option implied volatility index of S&P-500, FTSE-100 and DAX.

Table 1: Unit Root Statistic for Level of Spreads

	Whole period (1/1/04 – 30/9/10)	Pre Crisis (1/1/04 – 8/8/07)	Crisis (9/8/07 – 24/6/10)	Post Crisis (25/6/10 – 4/2/11)	Pre-QE (9/8/07 – 18/2/09)	QE (19/2/09 – 24/6/10)
lr	-1.28 [0.64]	-3.87 [0.00]	-1.56 [0.50]	-3.81 [0.00]	-0.70 [0.99]	-1.92 [0.32]
cr	-2.43 [0.13]	-3.10 [0.03]	-2.06 [0.26]	3.58 [1.00]	-1.73 [0.41]	-2.40 [0.14]
CDS	-0.75 [0.83]	-1.45 [0.56]	-2.35 [0.16]	-1.09 [0.72]	-1.63 [0.46]	-1.81 [0.38]
qe						-3.63 [0.01]
qe(t)						-2.05 [0.57]

Augmented Dickey-Fuller tests are applied and reported figures are t-statistics with p-values given in brackets. All tests assume presence of an intercept except for $qe(t)$ which assumes presence of both intercept and trend. Further unit root tests indicate that all differences do not contain a unit root.

Table 2: Correlation between liquidity risk and credit risks

	Pre Crisis		Crisis Pre QE		Crisis QE			Post Crisis	
Panel A: Level	*lr*	*cr*	*lr*	*cr*	*lr*	*cr*	CDS	*lr*	*cr*
cr	-0.08		0.58		0.91			-0.39	
CDS	0.36	0.30	0.65	0.55	0.71	0.78		-0.16	0.73
qe					-0.93	-0.97	-0.71		
Panel B: Difference	Δ*lr*	Δ*cr*	Δ*lr*	Δ*cr*	Δ*lr*	Δ*cr*	ΔCDS	Δ*lr*	Δ*cr*
Δ*cr*	-0.35		0.10		-0.30			-0.09	
ΔCDS	-0.01	0.04	0.05	0.06	-0.02	-0.03		0.03	-0.05
Δ*qe*					0.00	-0.20	-0.09		

Reported figures are correlation between spreads and qe during different periods of the sample studied.

Table 3: Liquidity and credit risk before and during QE

	Panel A		Panel B	
Variables	Eqn 1 Δlr	Eqn 2 Δcr	Eqn 3 Δlr	Eqn 4 Δcr
lr_{t-1}	-0.109*	0.037	-0.039	0.047
	[-3.30]	[0.98]	[-1.52]	[2.50]
cr_{t-1}	0.014	-0.015	0.002	-0.013*
	[2.18]	[-2.01]	[0.36]	[-3.46]
$\bar{R}^2$	0.25	0.06	0.11	0.38
Durbin-Watson	2.15	2.00	2.22	2.01

All equations include an intercept and short-run dynamics up to lag two. Only the coefficients of the error correction terms with *t*-values in squared brackets are reported. * indicates significance of single-equation ECM test at 5% level; see Banerjee *et al.* (1998, Table 1) for relevant critical values. Note that the trend term in (2) is not used since the variables considered do not contain a deterministic trend.

Table 4: How the intervention of the BoE lowers liquidity and credit risks

Variables	Eqn 5 Δlr	Eqn 6 Δcr	Eqn 7 Δqe	Eqn 8 Δqe
lr_{t-1}	-0.114*		-0.0001	
	[-3.88]		[-0.27]	
cr_{t-1}		-0.009		-0.0006
		[-0.91]		[-5.01]
qe_{t-1}	-0.958	-0.324	-0.0010	-.0250**
	[-3.10]	[-0.70]	[0.28]	[-4.39]
$\bar{R}^2$	0.06	0.16	0.23	0.25
D-W	2.02	2.02	2.01	2.00

All equations include an intercept and short-run dynamics up to lag two. Only the coefficients of the error correction terms with *t*-values in squared brackets are reported. * and ** indicate significance of single-equation ECM test at 5% and 1% level respectively; see Banerjee *et al.* (1998, Table 2) for relevant critical values.

Table 5: The effect of QE on liquidity and credit spreads (VECM)

	Eqn 9 Δlr	Eqn 10 Δcr	Eqn 11 Δqe
$E1_{t-1}$	-0.094**	0.080*	0.0002
	(-2.58)	(2.17)	(0.50)
$E3_{t-1}$	-0.763	-0.042	-0.016**
	(-1.16)	(-0.14)	(-3.29)
$\bar{R}^2$	0.08	0.39	0.58
D-W	2.03	2.03	1.99
Ljung-Box test:			
Q(10)	14.2	8.84	4.69
p-value	0.16	0.55	0.91

The figures in Table 5 correspond to the elements of the transpose of matrix *A* in (9). HAC t-statistics are reported brackets. The residuals E1 and E3 are obtained respectively from the static OLS regression: $lr = 0.166 – 8.635qe + 0.0215\text{Trend} + E1$ and $qe = –2.096 – 0.0189cr + 0.00343\text{Trend} + E3$. The lag length of the VECM is 2, with additional lags up to 6 and 11 for Δcr and Δqe in Eqn 10 and 11 respectively. * and ** indicate significance of *t*-test at 5% and 1% level respectively.

Table 6: Effects of international factors

Dependent variable (y)

Long run forcing variable (x)	cr	lr	cr_{US}	lr_{US}	cr_{EU}	lr_{EU}	VIX	VFTSE	VDAX	qe
cr		-1.60	-1.03	-5.34**	-3.18	-4.50**	-3.71*	-4.00**	-4.38**	-7.50**
lr	-3.68*		-0.22	-4.31**	-1.92	-4.73**	-3.66*	-3.91*	-3.95**	-4.45**
cr_{US}	-2.62	-3.48*		-3.28*	-2.32	-3.22	-3.97**	-3.85*	-3.99**	-6.08**
lr_{US}	-1.25	-3.26	-1.14		-1.91	-4.00**	-2.91	-3.19	-3.49*	-8.55**
cr_{EU}	-0.13	-3.58*	-2.43	-7.82**		-2.29	-3.35*	-3.39*	-3.90*	-9.73**
lr_{EU}	-0.93	-1.91	-0.01	-3.59*	-3.31*		-2.68	-2.81	-2.93	-2.22
VIX	-2.63	-2.41	-4.56**	-5.23**	-3.54*	-3.09		-6.25**	-3.13	-6.74**
VFTSE	-2.53	-2.22	-4.54**	-5.15**	-3.92**	-3.28*	-6.09**		-3.08	-6.78**
VDAX	-1.76	-2.56	-2.68	-5.06**	-3.48*	-4.10**	-3.05	-3.07		-4.83**
qe	-1.36	-3.87*	-1.91	-5.97**	-3.03	-7.34**	-3.95*	-3.88*	-4.37**	

Reported figures are t-statistics of the pairwise single equation ECM test proposed by Banerjee *et al.* (1998). * and ** indicate significance at 5% and 1% level respectively.