

Wong, Woon K.; Biefang-Frisancho Mariscal, Iris; Yao, Wanru; Howells, Peter G. A.

**Working Paper**

## Liquidity and credit risks in the UK's financial crisis: How "quantitative easing" changed the relationship

Cardiff Economics Working Papers, No. E2016/9

**Provided in Cooperation with:**

Cardiff Business School, Cardiff University

*Suggested Citation:* Wong, Woon K.; Biefang-Frisancho Mariscal, Iris; Yao, Wanru; Howells, Peter G. A. (2016) : Liquidity and credit risks in the UK's financial crisis: How "quantitative easing" changed the relationship, Cardiff Economics Working Papers, No. E2016/9, Cardiff University, Cardiff Business School, Cardiff

This Version is available at:

<https://hdl.handle.net/10419/174122>

**Standard-Nutzungsbedingungen:**

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

**Terms of use:**

*Documents in EconStor may be saved and copied for your personal and scholarly purposes.*

*You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.*

*If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.*

# Cardiff Economics Working Papers



Working Paper No. E2016/9

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

*Woon K. Wong, Iris Biefang-Frisancho Mariscal,  
Wanru Yao and Peter Howells*

August 2016

ISSN 1749-6010

Cardiff Business School  
Cardiff University  
Colum Drive  
Cardiff CF10 3EU  
United Kingdom  
t: +44 (0)29 2087 4000  
f: +44 (0)29 2087 4419  
[business.cardiff.ac.uk](http://business.cardiff.ac.uk)

This working paper is produced for discussion purpose only. These working papers are expected to be published in due course, in revised form, and should not be quoted or cited without the author's written permission.

Cardiff Economics Working Papers are available online from:

<http://econpapers.repec.org/paper/cdfwpaper/> and

[business.cardiff.ac.uk/research/academic-sections/economics/working-papers](http://business.cardiff.ac.uk/research/academic-sections/economics/working-papers)

Enquiries: [EconWP@cardiff.ac.uk](mailto:EconWP@cardiff.ac.uk)

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

Woon Wong<sup>1</sup>, Iris Biefang-Frisancho Mariscal<sup>2</sup>, Wanru Yao<sup>2</sup> and Peter Howells<sup>2</sup>

<sup>1</sup>Cardiff Business School, University of Cardiff

<sup>2</sup>Centre for Global Finance, Bristol Business School, UWE Bristol

## **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.

Contact author:  
Dr Woon Wong  
Cardiff Business School  
Aberconway Building  
Colum Drive  
Cardiff CF10 3EU  
Email: wongwk3@cf.ac.uk

# 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, 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 extraordinary 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 (2008, 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.<sup>1</sup> 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

---

<sup>1</sup> See also Heider *et al.* (2009) and Ashcraft *et al.* (2011) for theoretical analysis and empirical evidence respectively.

credit risk, a finding that is consistent with other studies which show QE is effective in reducing interbank spreads.

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. As mentioned above, Angelini *et al.* (2011) find that rising risk aversion explained the widening interbank spread. Hence 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 that lower option-implied volatilities also contributed to the reduction in the UK interbank spread.

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.

Two further innovations in this paper deserve mention. 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 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 enabling us to shed light on the transmission mechanism of QE.

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 interbank spreads. Finally, section 6 concludes.

## **2. MODEL AND METHODOLOGY**

The main objective here is to investigate the relationship between credit risk and liquidity components in the interbank spread and understand how this relationship unfolded during the financial crisis. To do this, 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:

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

where  $ib$ , the interbank spread, is measured by Libor-OIS;  $cr$ , credit risk by Libor-Repo; and  $lr$ , or liquidity risk, by Repo-OIS.

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).<sup>2</sup> 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.<sup>3</sup>

However, any form of decomposition is intrinsically problematic since the two risks are closely related.<sup>4</sup> 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. Similarly, the uncertainty over creditworthiness of banks could lead some banks to withdraw from the interbank market, thereby raising liquidity premia. 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

---

<sup>2</sup> 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.

<sup>3</sup> 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).

<sup>4</sup> For a demonstration of how banks' asset risk affects funding liquidity in the interbank market, see Heider *et al.* (2009).



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 (Bank, 2007). Therefore, notwithstanding the problem described, it may still be useful to use terms which describe a discrete form of risk to 'explain' changes in spreads.<sup>5</sup>

Finally, perhaps more importantly, 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***

Taylor and Williams (2009) study the efficacy of the US Term Auction Facility (TAF) on the interbank spread by regressing the Libor-OIS spread on dummies of TAF, Libor-Repo and credit default swaps. 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. Thus we use error correction models (ECM) to study the relationship between liquidity

---

<sup>5</sup> 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.

and credit risk premia in the interbank spread as well as the impact of QE on its components. In particular, we consider the following single equation ECM of Banerjee *et al.* (1998).

$$(2) \quad \Delta y_t = a_0 + b'_0 \Delta x_t + \gamma y_{t-1} + \lambda' x_{t-1} + ct + \sum_{j=1}^p a_j \Delta y_{t-j} + \sum_{j=1}^p b_j \Delta x_{t-j} + \varepsilon_t$$

In (2),  $\gamma$  measures the speed of adjustment in response to disequilibrium errors.<sup>6</sup> If the  $\gamma$ -coefficient is significant and negatively signed, the variables are said to be cointegrated and we can infer long-run Granger causality with  $x$  described as the long run forcing variable for  $y$ . If variables are cointegrated, there exists at least uni-directional Granger causality and identifying the long run forcing variable enables us to understand better 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:

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

---

<sup>6</sup> The disequilibrium error is given by  $y_t + \gamma^{-1}(\lambda' x_t + ct)$  plus a constant.

For this single equation ECM test to hold, the regressors in (2) need to be weakly exogenous for the parameters of interest, which in our case are  $\lambda$ ,  $\gamma$  and  $c$ . Moreover, for instance, if  $\gamma$  in (3) is found to be significantly negative, we are also 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:

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

The advantage of this approach is that the heteroscedasticity and autocorrelation consistent (HAC)  $t$ -statistics can be obtained easily, for daily financial time series are known to have a changing volatility structure. For the QE period,  $z = (lr \quad cr \quad qe)'$  in (4) is found to have two cointegrating vectors. Thus  $E$  is a  $2 \times 1$  vector of residuals from the two cointegrating vectors whereas  $A$  is a  $3 \times 2$  matrix of error correction coefficients. In section 5, we discuss how the findings of the single equation ECM based on (2) can be used to construct  $E$  and VECM.

### 3. DATA AND DESCRIPTIVE ANALYSIS

Here we carry out some descriptive analysis that will help justify the choice of our econometric model in this paper. 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. The liquidity risk problem may be solved, but the credit risk worry is on the rise. 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; see Figure 2 below.

**< Figure 2: *qe* and its first differences >**

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, until the end of the QE period, 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 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**

In this section, the single equation error correction model given by (2) is used to investigate the pairwise relationships between spreads and liquidity provisions by the central bank. The relevant results are reported in tables 3 to 5. Since the credit default swap is widely used to proxy for credit risk, its possible impact on the relationship is also considered and the associated results are reported in Panel B of the tables. Lag length  $p = 2$  is used for the differences in the estimation.

### ***4.1 Liquidity and credit risk before QE***

Equations 1 to 4 in 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.  $\gamma$  and  $\lambda$  in (2), are reported.

#### **< Table 3: Liquidity and credit risk before the intervention of the BoE >**

The first equation in Table 3 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.<sup>7</sup> Equation 2 shows the results of the error correction terms with  $\Delta cr$  as the dependent variable. There is no cointegration and the R-square is low compared to the previous estimation results. The inclusion of the long-term credit default swap (CDS) in equations 3 and 4 does not change this conclusion. It can be seen from equation 3, however, that CDS takes up the role of the  $cr$  spread, whose coefficient has been reduced.

In summary, the above results 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 in the long-run. Moreover, this causality is unidirectional and there is no feedback from a widening of the liquidity risk premium to credit risk.

### ***4.2 Liquidity and credit risk during QE***

In this section we address three main questions: Firstly, would the Granger causal relationship found in the previous subsection remain the same under QE? Secondly, has the massive liquidity provision by the Bank of England narrowed any of the spreads? And finally, if QE were successful in reducing spreads, how was the reduction in spreads achieved?

---

<sup>7</sup> The long-run relationship can be written as:  $lr = 0.014/0.109cr$ .

**< Table 4: Liquidity and credit risk during the period of BoE's intervention >**

Turning to the first question, Panel A of Table 4 shows that during QE the roles of liquidity and credit spreads have changed compared to the pre-QE period. The order of long-run Granger causation is reversed: liquidity risk drives credit risk but not *vice versa*. Again, Panel B shows that the inclusion of CDS as a regressor does not change the outcome.

As for the second question, equation 9 in Table 5 demonstrates that  $qe$  is the long-run forcing variable in the determination of the liquidity spread. In the long-run relationship between liquidity provision and  $lr$ , 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 10 shows that the additional provision of liquidity does not change the credit risk premium directly. Therefore, in conjunction with the results given in Table 4, we conclude that QE narrows the credit spread indirectly through a narrowing of the liquidity spread.

**< Table 5: How the intervention of the BoE lowers liquidity and credit risks >**

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 Panel A of Table 5 is that equations 11 and 12 suggest the BoE reacts to changes in credit risk premium but not to changes in liquidity risk premium.

Panel B of Table 5 considers the case when CDS is included as an additional regressor. The relevant coefficients in equations 13 and 16 are only significant at the 10% level. Nevertheless, the estimated coefficients and associated  $t$ -statistics of CDS are small. Moreover, inclusion of CDS as a regressor does not alter much the other coefficients. Thus the drop in significance level is more likely due to the addition of an irrelevant variable, than to vital information conveyed by CDS. This is an important issue, since CDS is frequently used in the literature as a measure of credit risk in the decomposition of the  $ib$  spread.

Essentially, it is the narrowing of the liquidity spread that reduces the credit spread in the long run and CDS does not play any significant role in the process. Also here, it is the central bank's intervention rather than CDS that triggers the fall in the liquidity spread. Furthermore, equation 14 indicates that  $cr$  and CDS are driven by different stochastic trends and cannot be exchanged against each other in the determination of the risk premia. To sum up, decomposing the  $ib$  spread into its credit risk component and approximating the latter with CDS may be inappropriate, particularly during the period with central bank intervention.

### **4.3 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



$$(5) \quad lr_t = a_0 + a_1qe_t + a_2t + E1_t$$

$$(6) \quad cr_t = b_0 + b_1lr_t + E2_t$$

$$(7) \quad qe_t = c_0 + c_1cr_t + c_2t + E3_t$$

with the following error correction term:

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

Note that the elements of  $\alpha$  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  $\beta'$  can be obtained from linear combination of the other two rows, we have  $a_1b_1c_1 = 1$ . Based on the coefficients obtained from significant ECM equations 6 (in Table 4), 9 and 12 (in Table 5), we have  $a_1b_1c_1 = 0.73$ . Using the Engle-Granger static OLS approach, the triple product is 0.75.

For the VECM as described in (4),  $E1$  and  $E3$  are used because the correlation between them is low, at -0.08.<sup>8</sup>

By virtue of (8), the error correction term in (4) takes the form:

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

---

<sup>8</sup> The other two correlations are -0.83 (between  $E1$  and  $E2$ ) and -0.43 (between  $E2$  and  $E3$ ).

$\alpha_{21}$  in (9) is to be determined. Since error correction is established for  $cr$ ,  $\alpha_{21} \neq 0$ . Now a large and positive  $El_{t-1}$  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  $\alpha_{21}$ .

#### < Table 6: The effect of QE on liquidity and credit spreads (VECM)>

The estimated VECMs are reported in Table 7. 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, the Bank of England and other 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.<sup>9</sup> 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).<sup>10</sup>

From the empirical evidence of various studies (e.g., McAndrews *et al.*, 2008; Wu, 2008; Hesse and Frank, 2009) and the fact that financial markets are highly inter-linked, it is likely that these international factors

---

<sup>9</sup> Readers are recommended to see <http://www.bankofengland.co.uk/markets/Pages/sterlingoperations/timeline/timeline.aspx> for a time line on the Bank’s operations.

<sup>10</sup> For an overview of liquidity provision by the Bank of England, the Federal Reserve, the Bank of Japan and the ECB, see Fawley, B W and C J Neely (2013).

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, for such an attempt would require a far more complex model with considerable more information. *It should be noted that the relevant information on some of the various liquidity schemes is difficult to obtain and when the information is available, the observations involved are of varying frequency and period.* This section therefore carries out the relatively simple and yet informative pairwise single-equation analysis described in Section 4 to shed light on the role of international factors in reducing the UK liquidity and credit spreads. Therefore, 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 3: Interbank spreads and option implied volatilities**

Figure 3 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. For example, European banks with an established presence in the United States could borrow against appropriate collateral from the facilities the Federal Reserve makes available to depository institutions. 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. As can be seen from Figure 3, our variables of interest correlate highly with each other. For instance, the correlations between interest rate spreads during the QE period can be as high as 0.95 whereas those of option implied volatilities are even higher, the highest of which is 0.97! As is well known, any regression analysis that involves a large number of highly correlated variables will not only have difficulties in interpreting the signs of estimated coefficients but also risks co-linearity. For this reason, we restrict our ECM analysis to only pairwise and the associated *t*-statistics of the single-equation tests are provided in Table 7 below.

**< Table 7: 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, based on pairwise single-equation ECM tests, we can infer that liquidity provisions by other central banks did contribute to reduction in UK interbank spreads.

Table 7 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

In this paper, we examined the behaviour of the three-month sterling LIBOR-OIS (*ib*) spread over the course of the crisis. Following other investigators, we decomposed the spread into so-called liquidity risk and credit risk premia using three-month Repo-OIS (*lr*) and the Libor-Repo (*cr*) spreads, respectively, though it should be kept in mind that the two risk premia are closely related to each other. However, in contrast to the existing literature, we replaced the conventional central bank intervention dummy variables by the more informative ratio of accumulated money spent on buying gilts to banks' total assets, *qe*. Furthermore, the change in the spreads' time series properties as the crisis unfolds has been accounted for and error correction models were used for long-term inferences (see also McAndrews *et al.*, 2008).

The major results of the study are as follows. For the analysis of the interrelationship and determination of liquidity and credit spreads during the crisis, it is crucial to split the crisis period into central bank intervention and non-intervention periods. Our results show that the relationship between credit and liquidity premia depends on *qe*. 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, while there is no direct effect from *qe* on the credit spread. However, the narrowing of the liquidity spread (Granger) 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.

In particular, earlier studies (for instance, Bank of England, 2007) employ CDS as a measure of credit risk. Our results show that CDS is interchangeable with  $cr$  in the early period of the crisis. However, during QE,  $cr$  and CDS do not share the same stochastic trend and CDS plays no role in the determination of the  $ib$  spread. The insignificance of CDS during QE may be explained by its longer term to maturity. As the results show,  $qe$  narrows the liquidity spread, which in turn reduces credit premia as measured by  $cr$ . This effect does not occur in the long term maturity of the CDS.

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 used interest rate spreads in US and euro areas as well as option implied volatilities as proxies for the various UK and international liquidity schemes. 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.

## REFERENCES

- Angelini, P, A Nobili and C Picillo (2011) 'The Interbank Market after August 2007: What Has Changed, and Why?' *Journal of Money, Credit and Banking*, 43, 923 – 958.
- Ashcraft, A, J McAndrews and D Skeie (2011) 'Precautionary Reserves and the Interbank Market', *Journal of Money, Credit and Banking*, 43, 311 – 348.
- Baker, M and J Wurgler (2007) 'Investor Sentiment in the stock market', *Journal of Economic Perspectives*, 21, 129 – 151
- Bank of England (2007) 'An indicative decomposition of Libor spreads', *Bank of England Quarterly Bulletin*, Q4, 498-99
- Banerjee, A, J J Dolado and R Mestre (1998) 'Error-Correction Mechanism Tests for Cointegration in a Single-Equation Framework', *Journal of Time Series Analysis*, 19, 267-283.
- Berrospide, J. 2012. 'Liquidity Hoarding and the Financial Crisis: An Empirical Evaluation', *The Federal Reserve Board*. April.
- BIS (1999) Implications of repo markets for central banks, <http://www.bis.org/publ/cgfs10.pdf>
- Breeton, F., Chadha, J.S. and Waters, A. 2012. 'The Financial Market Impact of UK Quantitative Easing', School of Economics Discussion Papers. University of Kent. KDPE 1211. June.
- Bridges, J. and Thomas, R. 2012. 'The Impact of QE on the UK Economy – Some Supportive Monetarist Arithmetic', Bank of England Working Paper No. 442. January.
- Brunetti, C, M Di Filippo and J Harris (2009) 'Effects of central bank interventions on the interbank market during the sub-prime crisis' (June), [http://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=1428662](http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1428662)
- Buraschi, A and D Menini (2002) 'Liquidity risk and specialness', *Journal of Financial Economics*, 64, 243-284.

Butt, N, R Churm, M McMahon, A Morotz and J Schwanz (2014) 'QE and the bank lending channel in the United Kingdom', *Bank of England Working Paper* No. 511.

Christensen, J.H.E., Lopez, J.A. and Rudebusch, G.D. 2009. 'Do Central Bank Liquidity Facilities Affect Interbank Lending Rates?' *The Federal Reserve Bank of San Francisco*. June.

Covtitz, D and C Downing (2007) 'Liquidity or Credit Risk? The Determinants of Very Short-Term Corporate Yield Spreads', *Journal of Finance*, 62, 2303 – 2328.

ECB (2008) *Financial Stability Review*, June

Engle, R and C Granger (1987) 'Cointegration and Error Correction: Representation, Estimation and Testing', *Econometrica*, 55, 251-276.

Fawley, B W and C J Neely (2013) Four Stories of quantitative Easing, *Federal Reserve Bank of St Louis Review*, January/February, 95 (1), 51-88.

Fisher, P (2012) Liquidity support from the Bank of England: the discount window facility, *Speech given at the National Asset-Liability Management global conference*, London, March 2012

Gagnon, J, M Raskin, J Remache and B Sack (2010) 'Large scale asset purchases by the Federal Reserve: Did they work?', *Federal Reserve of New York Staff Report* No. 441.

Goldberg, L S, C Kennedy and J Miu (2011) Central bank dollar swap lines and overseas dollar funding costs, *FRBNY Economic Policy Review*, May, 3-20

Hesse, H and N Frank (2009) 'The effectiveness of central bank interventions during the first phase of the subprime crisis', *IMF Working Papers* No. 09/206

Heider, F, M Hoerova and C Holthausen (2009) 'Liquidity Hoarding and Interbank Market Spreads: The Role of Counterparty Risk', *ECB Working Paper Series* No. 1126.

Hoerdahl, P and M R King (2008) 'Development in repo markets during the financial turmoil', *BIS Quarterly Review*, December, 37-53



IMF (2008) 'Global financial stability report: containing systemic risks and restoring financial soundness', World Economic and Financial Surveys, October

John, S, M Roberts and O Weeken (2012) The Bank of England's special liquidity scheme, *Research and Analysis Quarterly Bulletin*, Q1, 57-66

Joyce, M, A Lasasosa, I Stevens and M Tong (2010) 'The financial market impact of quantitative easing', *Bank of England Working Paper* No. 393.

Joyce, M and M Spaltro (2014) 'Quantitative easing and bank lending: a panel data approach', *Bank of England Working Paper* No. 504.

Kapetanios, G., Mumtaz, H., Stevens, I. and Theodoridis, K. 2012. 'Assessing the Economy-wide Effects of Quantitative Easing', *Bank of England Working Paper* No. 443. January.

Kuo, D, D Skeie and J Vickery (2012) 'A comparison of Libor to other measures of bank borrowing costs', [http://www.newyorkfed.org/research/economists/vickery/LiborKSV\\_staff\\_webpage.pdf](http://www.newyorkfed.org/research/economists/vickery/LiborKSV_staff_webpage.pdf)

McAndrews, J, A Sakar and Z Wang (2008) 'The effect of the term auction facility on the London Inter-Bank Offer rate' *Federal Reserve Bank of New York – Staff Reports*, No. 335

McGuire, P and G von Peter (2009) The US dollar shortage in global banking and the international policy response, *BIS Working Papers*, No. 291

Michaud, F and C Upper (2008) 'What drives interbank rates? Evidence from the Libor panel', *BIS Quarterly Review*, March, 47-58

Mollenkamp, C 'Bankers cast doubt on key rate amid crisis,' *Wall Street Journal*, 15 April 2008.

Nobili, S (2009) 'Liquidity Risk in Money Market Spreads', paper presented at the ECB Workshop on "Challenges to Monetary Policy Implementation beyond the Financial Market Turbulence," Frankfurt. [http://www.ecb.int/events/pdf/conferences/20091130\\_ecb\\_workshop/20091130\\_session6\\_nobili.pdf?7396ec03bd6c68b0d1e3aca1fb388c6ab](http://www.ecb.int/events/pdf/conferences/20091130_ecb_workshop/20091130_session6_nobili.pdf?7396ec03bd6c68b0d1e3aca1fb388c6ab) (accessed 5 November 2012).

Poskitt, R (2011) 'Do liquidity or credit effects explain the behaviour of the LIBOR-OIS spread?' *University of Auckland Working Paper*. <http://economics-finance.massey.ac.nz/documents/seminarseries/manawatu/LIBOR-OISspreadMassey25May2011.pdf> (accessed 5 November 2012)

Puddu, S. and A Wälchli (2012) 'TAF Effect on Liquidity Risk Exposures', *Frontiers of Finance 2012 - Conference at Warwick University*

Taylor, J B and J C Williams (2008) 'Further results on a black swan in the money market', Discussion Paper 07-046, Stanford Institute for Economic Policy Research

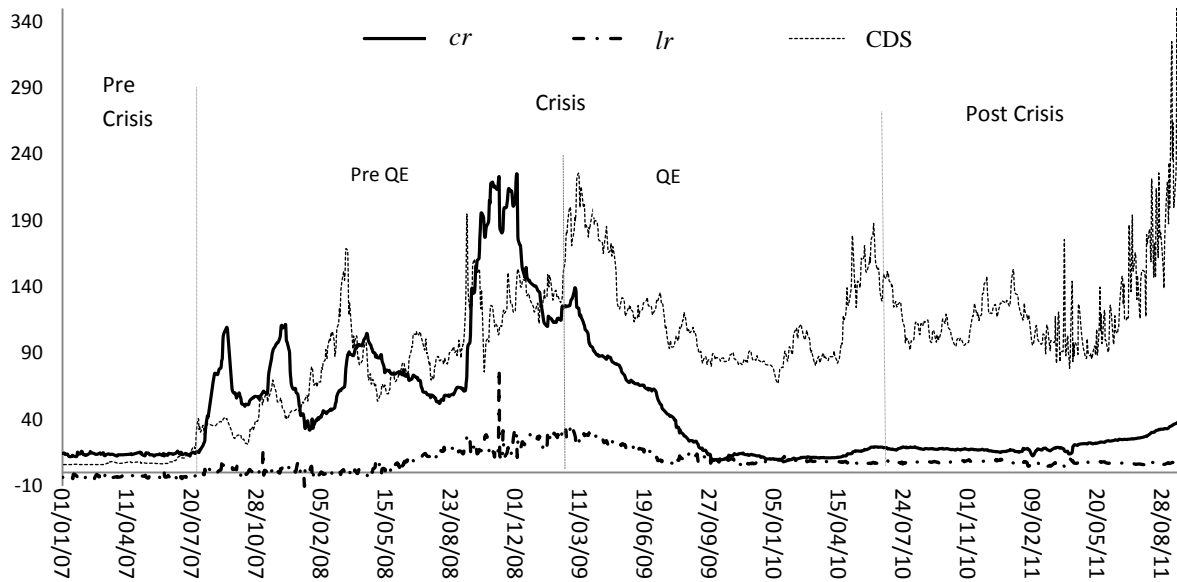
Taylor, J B and J C Williams (2009) 'A black Swan in the money market', *American Economic Journal: Macroeconomics*, 1, 58-83

Taylor, J B (2012) 'Monetary Policy Rules Work and Discretion Doesn't: A Tale of Two Eras', *Journal of Money, Credit and Banking*, 44, 1017 - 1032.

Wu, T (2008) 'On the effectiveness of the Federal Reserve's New Liquidity Facilities', Working Paper, Federal Reserve Bank of Dallas

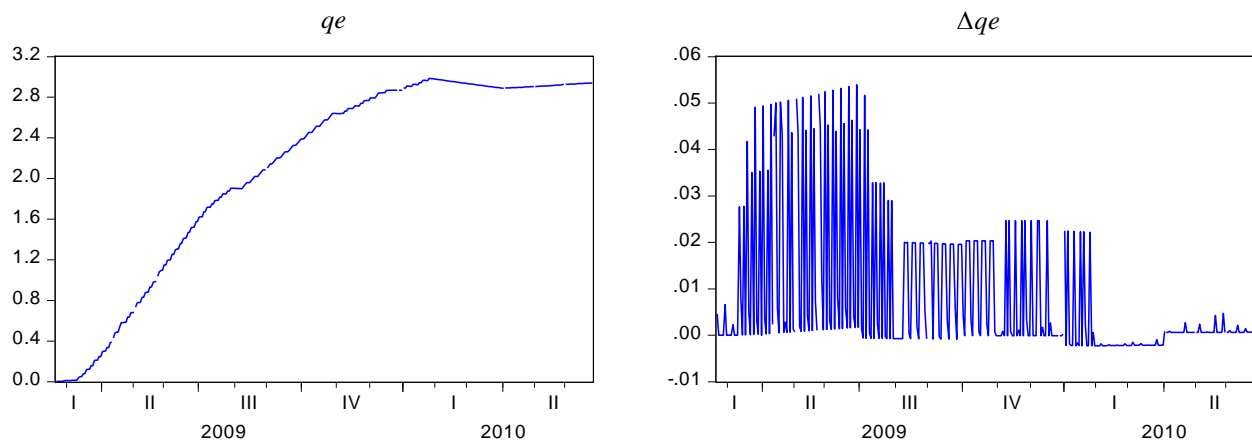
## Figures and Tables

**Figure 1: Credit and liquidity spreads and CDS**



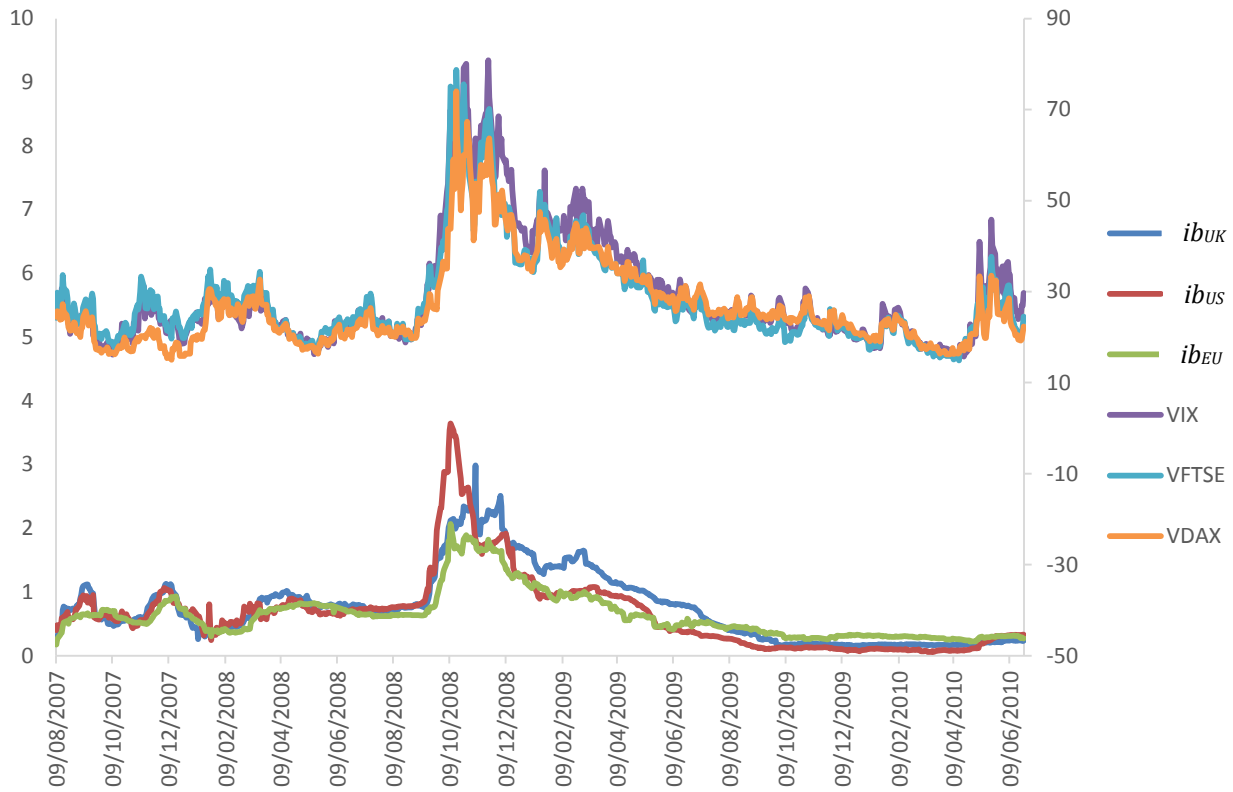
$cr$  stands for the three-month Libor-Repo spread,  $lr$  stands for the three-month Repo-OIS spread, and CDS denotes five-year credit default swap.

**Figure 2:  $qe$  and its first differences**



$qe$  is the accumulated asset purchases divided by banks' total asset value. Its first difference is found to be trend stationary. Regressing  $\Delta qe$  on an intercept and a trend produces a heteroscedasticity and autocorrelation consistent t-statistic of -6.61 for the trend coefficient.

**Figure 3: Interbank spreads and option implied volatilities**



*ib<sub>UK</sub>*, *ib<sub>US</sub>* and *ib<sub>EU</sub>* 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)
<i>lr</i>	-1.28 [0.64]	-3.87 [0.00]	-1.56 [0.50]	-3.81 [0.00]	-0.70 [0.99]	-1.92 [0.32]
<i>cr</i>	-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]
<i>qe</i>						-3.63 [0.01]
<i>qe(t)</i>						-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	
<b>Panel A:</b>									
Level	<i>lr</i>	<i>cr</i>	<i>lr</i>	<i>cr</i>	<i>lr</i>	<i>cr</i>	CDS	<i>lr</i>	<i>cr</i>
<i>cr</i>	-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
<i>qe</i>					-0.93	-0.97	-0.71		
<b>Panel B:</b>									
Difference	$\Delta lr$	$\Delta cr$	$\Delta lr$	$\Delta cr$	$\Delta lr$	$\Delta cr$	$\Delta CDS$	$\Delta lr$	$\Delta cr$
$\Delta cr$	-0.35		0.10		-0.30			-0.09	
$\Delta CDS$	-0.01	0.04	0.05	0.06	-0.02	-0.03		0.03	-0.05
$\Delta qe$					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 the intervention of the BoE**

Variables	Panel A		Panel B	
	Eqn 1 $\Delta r$	Eqn 2 $\Delta cr$	Eqn 3 $\Delta r$	Eqn 4 $\Delta cr$
$lr_{t-1}$	-0.109 <sup>b</sup> [-3.30]	0.037 [0.98]	-0.152 <sup>b</sup> [-3.88]	-0.028 [-0.63]
$cr_{t-1}$	0.014 [2.18]	-0.015 [-2.01]	0.011 [1.60]	-0.017 [-2.24]
$CDS_{t-1}$			0.021 [2.02]	0.026 [2.32]
$\bar{R}^2$	0.25	0.06	0.25	0.08
Durbin-Watson	2.15	2.00	2.14	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. The superscript b 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: Liquidity and credit risk during the period of BoE's intervention**

Variables	Panel A		Panel B	
	Eqn 5 $\Delta r$	Eqn 6 $\Delta cr$	Eqn 7 $\Delta r$	Eqn 8 $\Delta cr$
$lr_{t-1}$	-0.039 [-1.52]	0.047 [2.50]	-0.034 [-1.33]	0.050 [2.59]
$cr_{t-1}$	0.002 [0.36]	-0.013 <sup>b</sup> [-3.46]	0.002 [-0.29]	-0.015 <sup>a</sup> [-3.47]
$CDS_{t-1}$			0.003 [1.13]	0.002 [0.82]
$\bar{R}^2$	0.11	0.38	0.12	0.37
Durbin-Watson	2.22	2.01	2.02	2.02

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. The superscripts a and b indicate significance of single-equation ECM test at 10% and 5% level respectively; 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 5: How the intervention of the BoE lowers liquidity and credit risks**

Variables	Panel A				Panel B			
	Eqn 9 $\Delta lr$	Eqn 10 $\Delta cr$	Eqn 11 $\Delta qe$	Eqn 12 $\Delta qe$	Eqn 13 $\Delta lr$	Eqn 14 $\Delta cr$	Eqn 15 $\Delta qe$	Eqn 16 $\Delta qe$
$lr_{t-1}$	-0.114 <sup>b</sup> [-3.88]		-0.0001 [-0.27]		-0.107 <sup>a</sup> [-3.73]		-0.0001 [-0.34]	
$cr_{t-1}$		-0.009 [-0.91]		-0.0006 [-5.01]		-0.009 [-0.93]		-0.0006 [-4.73]
$qe_{t-1}$	-0.958 [-3.10]	-0.324 [-0.70]	-0.0010 [0.28]	-0.0250 <sup>c</sup> [-4.39]	-0.981 [-1.97]	-0.389 [-0.76]	-0.0019 [-0.34]	-0.0228 <sup>a</sup> [-3.64]
Trend	0.002 [1.22]	0.003 [1.61]	-0.00009 [-4.06]	-0.00003 [-1.10]	0.003 [0.95]	0.004 [1.39]	-0.00007 [-2.01]	-0.00004 [-1.16]
$CDS_{t-1}$					-0.001 [-0.28]	-0.001 [-0.26]	-0.00003 [-0.51]	.00002 [0.40]
$\bar{R}^2$	0.06	0.16	0.23	0.25	0.06	0.16	0.23	0.27
D-W	2.02	2.02	2.01	2.00	2.02	2.03	2.01	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. The superscript a, b and c indicate significance of single-equation ECM test at 10%, 5% and 1% level respectively; see Banerjee *et al.* (1998, Table 2) for relevant critical values.

**Table 6: The effect of QE on liquidity and credit spreads (VECM)**

	Eqn 19 $\Delta lr$	Eqn 20 $\Delta cr$	Eqn 21 $\Delta qe$
$E1_{t-1}$	-0.094 <sup>c</sup> (-2.58)	0.080 <sup>b</sup> (2.17)	0.0002 (0.50)
$E3_{t-1}$	-0.763 (-1.16)	-0.042 (-0.14)	-0.016 <sup>c</sup> (-3.29)
Trend	0.000 (0.19)	0.002 (1.99)	-0.0000 (-2.99)
$\bar{R}^2$	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

HAC  $t$ -statistics are reported brackets. The residuals E1 and E3 are obtained respectively from the static OLS regression:  $lr = 0.166 - 8.635qe + 0.0215Trend + E1$  and  $qe = -2.096 - 0.0189cr + 0.00343Trend + E3$ . The lag length of the VECM is 2, with additional lags up to 6 and 11 for  $\Delta cr$  and  $\Delta qe$  in Eqn 20 and 21 respectively. The superscripts b and c indicate significance of  $t$ -test at 5% and 1% level respectively.

Table 7: Effects of international factors

		Dependent variable (y)									
		<i>cr</i>	<i>lr</i>	<i>cr<sub>US</sub></i>	<i>lr<sub>US</sub></i>	<i>cr<sub>EU</sub></i>	<i>lr<sub>EU</sub></i>	VIX	VFTSE	VDAX	<i>qe</i>
Long run forcing variable (x)	<i>cr</i>		-1.60	-1.03	-5.34**	-3.18	-4.50**	-3.71*	-4.00**	-4.38**	-7.50**
	<i>lr</i>	-3.68*		-0.22	-4.31**	-1.92	-4.73**	-3.66*	-3.91*	-3.95**	-4.45**
	<i>cr<sub>US</sub></i>	-2.62	-3.48*		-3.28*	-2.32	-3.22	-3.97**	-3.85*	-3.99**	-6.08**
	<i>lr<sub>US</sub></i>	-1.25	-3.26	-1.14		-1.91	-4.00**	-2.91	-3.19	-3.49*	-8.55**
	<i>cr<sub>EU</sub></i>	-0.13	-3.58*	-2.43	-7.82**		-2.29	-3.35*	-3.39*	-3.90*	-9.73**
	<i>lr<sub>EU</sub></i>	-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**
	<i>qe</i>	-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.