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Abstract

This paper investigates the relationship between credit risk and liquidity components in the interbank spread and how this relationship unfolded during the recent financial crisis. We find that prior to the central bank's Bank of England's intervention counterpart risk was a major factor in the widening of the spread and also caused a rise in liquidity risk. However, this relationship was reversed after central bank started quantitative easing (QE). Using the accumulated value of asset purchases as a proxy for central bank's liquidity provisions, we provide evidence that the QE operations were successful in reducing liquidity premia and ultimately, indirectly, credit risk.

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

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1. Introduction

The main purpose of this paper is to analyse the developments in the UK interbank market after the beginning of the financial crisis in August 2007. The financial turmoil heavily affected this market which posed a considerable threat to the stability of the financial system, to banks' liquidity management and to the monetary transmission mechanism. Furthermore, the disruption of the interbank market has considerable effects on the economy since interbank rates affect a wide range of lending rates for households and firms. As a result research has been intense in this area. There is still controversy about the contribution of various risk premia in the interbank spread and their interrelationship during the unfolding of the crisis. Results of the effect of central bank liquidity provisions on the Libor spread depend on the chosen model and the country that is studied. Furthermore, early studies analysed the decomposition and determinants of the Libor spread. More recently, concerns have been raised about the reliability of Libor fixing. In the following paragraphs we briefly summarise the literature that addresses these problems and set the paper into context.

The Bank of England (2007) proposed a decomposition of the Libor spread into credit risk and non-credit risk premia. The Libor spread refers to the difference between Libor rate and the rate on overnight index swaps (OIS), which is used as a proxy for the risk-free rate. Its decomposition relies on using premia of credit default swaps (CDS) of the banks in the Libor panel as an estimate for credit premia in Libor. The residual of the decomposition is then attributed to frictions in the interbank market and to liquidity risk. The Bank found that in the early months of the crisis (August and September 2007), liquidity risk dominated the spread, but credit risk represented a larger part of the spread after November 2007. Michaud and Upper (2008) made a similar decomposition of the Libor spread, but used the spread between secured and unsecured loans in addition to CDS as a measure of credit risk. Furthermore, they proxy market liquidity by the number of trades, trading volume, bid/ask spreads and the price impacts of trades. They concluded that at higher frequencies liquidity has played a more important role while credit risk factors were traceable at lower frequencies. Taylor and Williams (2008, 2009) found that counterparty risk was the main driver of the widening of the Libor spread. They were sympathetic to the argument that liquidity had been reduced in the money markets by the rise in counterparty risk, but they could not find any convincing evidence of liquidity risk when they compared the Libor market with the market for certificates of deposit (CDs). Consequently, various efforts to find significant reductions of the Libor spread by the new term auction facility (TAF) proved futile. Research that explored the effectiveness of extra liquidity provision by central banks to reduce the liquidity premium in the interbank market has provided controversial results. Brunetti *et al* (2009) used reported trades and quotes of the e-MID regulated interbank market and, similar to Taylor and Williams, found that central bank interventions create greater volatility rather than enhance liquidity. While in a recent study Angelini *et al* (2011) found supporting evidence for Taylor and Williams, several articles reached different conclusions concerning the effectiveness of liquidity injections by central banks; see, e.g., McAndrew *et al* (2008), Wu (2008), Christensen *et al* (2009), Hesse and Frank (2009) and Nobili (2009) found that central bank intervention reduced liquidity risk on money market rates.

We now know that these investigations, featuring the Libor spread, were taking place when the meaning of the Libor spread itself should have been open to question as the result of alleged misreporting. In fact, active discussions on how well Libor captured funding costs during the crisis began with the publication of the *Wall Street Journal* article in April 2008.[1] Research on this issue concentrated on comparing Libor survey responses with other borrowing rates, notably bank bids at the Federal Reserve Term Auction facility and term borrowing from Fedwire payments. Kuo *et al* (2012) found that Libor survey responses broadly track TAF and Fedwire data between 2007 and 2009, but also that Libor lay below them at certain times. They discuss a range of factors that may account for the discrepancy and they conclude that while misreporting by Libor panel banks would cause Libor to deviate from other funding rates, their result does not indicate that Libor misreporting occurred. Taylor and Williams (2008) used alternative measures to the Libor spread (CDs, term fed funds and Eurodollar rates) and their main findings on the Libor spread were unchanged. In an earlier paper, Abrantes-Metz *et al* (2011) find that the statistical second-digit distribution of Libor fixing deviates from the distribution implied by Benford's law, while Abrantes-Metz *et al* (2012) did not find systematic evidence of Libor misreporting based on a comparison of Libor quotes matched to CDS spreads. Schwarz (2010) finds no evidence of misreporting on euro Libor in the early crisis based on e-MID data and Gyntelberg and Woolridge (2008) note that dollar Libor differed from Eurodollar rates during January 2008 but, they do not conclude that Libor was misreported. Based on this evidence, our paper continues the focus on the Libor spread.

Within this context, our paper aims to examine the cause of the widening of the interbank rate spread between secured and unsecured lending during the crisis period. We investigate the relationship between credit and liquidity risk and how this relationship unfolded over the crisis period by decomposing the interbank spread into its liquidity and credit risk components. Furthermore, the crisis period is split into pre-QE and QE periods, which allows us to examine the effect of the Bank of England's asset purchase programme on risk premia. Our results show that credit risk was a major factor in the pre-QE period (September 2007 – February 2009) and caused a rise in liquidity risk. This result is consistent with the notion that asymmetric information in the unsecured interbank market can increase the likelihood of liquidity hoarding by banks.[2] In the later part of the crisis, during the QE operations (February 2009 to June 2010), there is some evidence that this relationship is reversed. The purchase of gilts by the Bank of England reduced the liquidity spread significantly which in turn reduced credit risk. One possible interpretation is that liquidity

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[1] Mollenkamp, C 'Bankers cast doubt on key rate amid crisis,' *Wall Street Journal*, 15 April 2008.
[2] For a theoretical model and empirical evidence see Heider *et al* (2009) and Ashcraft *et al* (2011) respectively.

funding risk results in greater risk of default in banks. Hence, a reduction in liquidity permia as a result of the QE operations ultimately, but indirectly, reduces credit risk in the interbank market. Furthermore, we find bi-directional causality between QE intervention and liquidity risk and unidirectional causality from credit risk to Bank intervention.

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 its 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 it were to be used to determine counterparty risk in the Libor spread. Previous studies used dummy variables to capture the impact of central bank liquidity provisions during the crisis.[3] We use the ratio of the cumulated value of asset purchases by the Bank under its QE programme to banks' assets. The cumulated value not only provides a better measure for the extent of the QE operations, it also represents the increasing likelihood of meeting the liquidity needed in the interbank market. Finally, McAndrew *et al* (2008) pointed out that the more likely temporary effect of TAF can only be measured by an OLS regression model in first differences. Additionally they found a unit root in the Libor spread. We take up their findings and estimate an error correction model which distinguishes between level and difference effects.

The paper is structured as follows: Section 2 presents the model and methodology, section 3 shows descriptive statistics and correlations, section 4 reports and discusses the estimation results and finally, section 5 concludes.

2. *Model and methodology*

2.1 Decomposition of Libor-OIS

The main objective here is to investigate the role of credit risk and liquidity factors in causing the dramatic and persistent jump in the Libor-OIS spread during the recent financial crisis, and the effect of QE carried out by Bank of England in its attempt to lower the spread. We decompose the spread into its credit risk and liquidity component as follows:[4]

(1) (LIBOR-OIS) = (LIBOR-Repo) + (Repo-OIS)

We proxy the credit risk component 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, Nobili, and Picillo (2011).

[3] An exception is Poskitt () who introduces three new measures of liquidity conditions. Two of these measures are based on a time series of intraday quote data from the offshore market funding and the third is from the commercial paper market.

[4] This decomposition is however not unproblematic because these two risks are related. A bank that faces difficulties raising funds is also at greater risk of default and the inability to raise funds will be factored into the credit risk premium. Similarly, uncertainty over the creditworthiness of banks could lead some banks to withdraw from the interbank market, thereby increasing liquidity risk (Bank of England, 2007).

For the liquidity premium we use the Repo-OIS spread, which is the difference between a secured lending rate and the risk-free rate. This choice needs some justification, because it is not used as a liquidity premium in the literature on interbank lending spreads. Like any other financial market, the repo market is subject to a variety of risks, such as credit risk, liquidity risk and operational risk[5] (BIS, 1999). 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. However, 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). Therefore, the risk embedded in the repo spread may be regarded as mostly liquidity in nature.

Liquidity risk affects the repo spread through the following channels. A typical repo trader is specialised and focused on a limited number of bonds in a particular segment of the yield curve. Therefore, traders may not be well diversified and their trading positions may be exposed to idiosyncratic liquidity shocks, giving rise to a liquidity risk premium in the repo spread. Furthermore, large market shocks demand portfolio re-allocation towards high-quality assets. The correlation between repo spreads of these bonds increases which reduces even more the possibility of diversifying risk away. Other types of liquidity risk may arise in the repo market. One type of liquidity risk may be related to re-financing difficulties and can arise from over-reliance on very short-term funding resources and an institution may find it difficult to roll over maturing repos. Another source of liquidity risk is associated with the liquidation of collateral, as for instance in the event of default of the counterparty. If markets become illiquid, for instance, due to market stress, the exposure may become under-collateralised if the collateral can only be sold at a discount. Repo rates reflect these liquidity premia. Empirical evidence is provided by Buraschi and Menini (2002), who show that the deviation from the expectations hypothesis is due to a time-varying risk premium which they relate to liquidity risk being still embedded in the repo spread.

2.2 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 and Libor-Repo and credit default swaps. Since a unit root is found to be present in the interbank spreads during the financial crisis, McAndrews, Sakar, and Wang (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) reduction 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 consider the following single equation dynamic error correction model (ECM)

[5] Operational risk is related to the transaction structure and legal procedures. Operational risk will be incorporated in the repo rate, but due to its institutional character, we can assume that it is constant over the time period we are considering here.

(2) $$\gamma(L)\Delta y_t = \alpha(L)\Delta x_t + \beta(y_{t-1} - \lambda x_{t-1}) + \varepsilon_t$$

where the term in brackets is the error correction term and β measures the speed of adjustment of disequilibrium errors. The variables are cointegrated when the β-coefficient is significant and negatively signed. Furthermore, we can infer long-run Granger causality on the basis of the significance of the speed of adjustment coefficient. If variables are cointegrated, there exists at least uni-directional Granger causality.

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.[6] The rationale for using accumulated money is as follows. First, 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 illiquidity in the money market.

For example, to study whether the quantitative easing (QE) conducted by the Bank of England is effective in lowering the liquidity premium in the Libor-OIS spread, the ECM equation may be

(3) $$\Delta(\text{Repo-OIS})_t = \alpha\,\Delta\text{Ratio}_t + \beta[(\text{Repo-OIS})_{t-1} - \lambda\text{Ratio}_{t-1}] + \varepsilon_t.$$

We would like to point out here that it is possible for QE to have an impact (it can be either short or long run) on the interbank spread and yet no cointegration between the two variables in (3) is observed. On the other hand, if the β-coefficient is significant and negatively signed, the variables are cointegrated and we can conclude that QE is successful in lowering risk premia for illiquidity.

3. Descriptive statistics and correlations

In this section, we present descriptive statistics and graphs which i) explain the motivation for the choice of the model and the estimation methodology and ii) show the importance of splitting the - crisis period into pre-intervention and QE period and iii) that QE intervention has changed the relationship between credit and liquidity risk premia. From this section onwards, LMO, LMR, RMO and CDS denote Libor-OIS, Libor-Repo, Repo-OIS and credit default swaps respectively.

[6] The banks' total asset value is only available quarterly and is thus linearly interpolated so that the ratio can be calculated on a daily basis. We also estimated using the absolute accumulated spending alone by the Bank on gilts. The results were unaffected and can be obtained from the authors on request.

Figure 1: Interbank and repo spreads and CDS

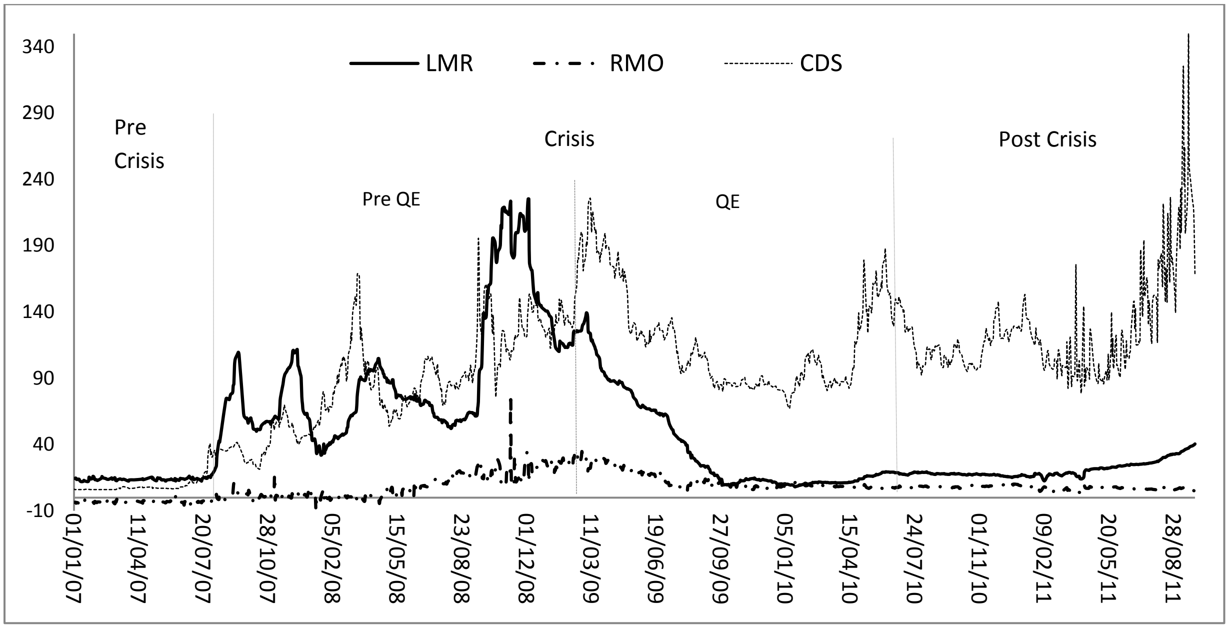

Figure 1 depicts how the time series properties of the credit risk (LMR) and liquidity risk (RMO) components of Libor-OIS spread (LMO) as well as CDS have changed over time. This suggests a possible presence of unit roots and structural change across different time periods, which is confirmed by the unit root test results over the different sample periods provided in Table 1 below. 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 property may be the result of the massive liquidity provision by the BoE. As our estimation results later on show, the size of the QE effect is large in the RMO component.

Table 1: Unit Root Statistic for Level of Spreads

	Whole period	Pre Crisis	Crisis	Post Crisis
RMO	-1.28 [0.64]	-3.87 [0.00]	-1.56 [0.50]	-3.81 [0.00]
LMR	-2.43 [0.13]	-3.10 [0.03]	-2.06 [0.26]	3.58 [1.00]
CDS	-0.75 [0.83]	-1.45 [0.56]	-2.35 [0.16]	-1.09 [0.72]
Ratio	-1.16 [0.69]		-0.62 [0.86]	

p-values are given in brackets.

Furthermore, Panel A in Table 2 shows how the relationship between the liquidity and credit risk components of the LMO evolved over time. In the pre-crisis period, there is some very small negative correlation between LMR and RMO and positive correlation between CDS and LMR. 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. During QE, the Bank reduced Repo relative to Libor so that as a result in the post QE period, the liquidity premium has fallen, but the credit risk premium remains and may be rising. The liquidity risk problem may be solved, but the credit risk worry is on the rise.

Table 2: Correlation between liquidity risk and credit risks

	Pre Crisis		Crisis Pre QE		Crisis QE			Post Crisis	
Panel A: Level	RMO	LMR	RMO	LMR	RMO	LMR	CDS	RMO	LMR
LMR	-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
Ratio					-0.93	-0.97	-0.71		
Panel B: Difference	dRMO	dLMR	dRMO	dLMR	dRMO	dLMR	dCDS	dRMO	dLMR
dLMR	-0.35		0.10		-0.30			-0.09	
dCDS	-0.01	0.04	0.05	0.06	-0.02	-0.03		0.03	-0.05
dRatio					0.00	-0.20	-0.09		

Panel B of Table 2 shows the correlation between the changes of credit and liquidity risk. In the pre-QE period, the correlation between changes in credit and liquidity risk premia is positive. During QE, this becomes significantly negative for DRMO and DLMR. While we saw that during QE both LMR and RMO are positively correlated, the negative sign of the correlation in the changes may be explained by the fall in the Repo rate in response to QE and one-day delayed fall in the Libor rate.

4. Estimation Results

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

Table 3: Liquidity and credit risk before the intervention of the BoE

	Equation 1	Equation 2	Equation 3	Equation 4
Variables	d(RMO)	d(RMO)	d(LMR)	d(LMR)
RMO_{t-1}	-0.109 [-3.30]	-0.152 [-3.88]	0.037 [0.98]	-0.028 [-0.63]
LMR_{t-1}	0.014 [2.18]	0.011 [1.60]	-0.015 [-2.01]	-0.017 [-2.24]
CDS_{t-1}		0.021 [2.02]		0.026 [2.32]
$\bar{R}^2$	0.25	0.25	0.06	0.08
Durbin-Watson	2.15	2.14	2.00	2.00

Error correction terms for pre-QE period (8.9.2007 – 18.2.2009). All equations include an intercept and short-run dynamics up to lag length two. In squared brackets under the coefficients are t-values. The critical t-value for the cointegration test for the 1-variable (2-variable) model is -3.23 (-3.50) at the 5% significance level. None of the error correction models indicates first order serial correlation.

The first two equations in Table 1 show the error correction terms of the liquidity spread (RMO). In both cases, there is a positive and significant long-run relationship between liquidity and credit spreads.[7] The inclusion of the long-term credit risk measure in equation 2 takes up the role of the LMR spread, whose coefficient has become insignificant. In the pre-QE period, either credit risk measure is a good indicator of the credit risk premium. Equations 3 and 4 show the results of the error correction terms with change in LMR as the dependent variable. There is no cointegration and the R-square is low compared to the previous estimation results. These results support the claim made by Taylor and Williams (2009) and Angelini, Nobili and Picillo (2011) that the main driver of the rise in interbank spreads was the large 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 cause a widening of the liquidity risk premium in the long-run. Moreover, this causality is uni-directional only 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, has the massive liquidity provision by the Bank of England narrowed any of the spreads? And secondly, if QE were successful, how was the reduction in spreads been achieved? Finally, would the Granger causal relationship found in the previous section remains the same under QE?

Turning to the first question, equation 6 and 8 in Table 4 depict the results of the effects of the QE intervention on the liquidity and credit risk premia. The estimates of equation 6 clearly show that *Ratio* is the long-run forcing variable in the determination of the liquidity spread. In the long-run relationship between liquidity provision by the BoE and RMO, the interventions reduce the liquidity spread by 6.9 basis points for Gilt purchase equivalent to one percentage point of banks' asset value. The additional provision of liquidity does not change the credit risk premium directly

[7] The long-run relationships of equations 1 and 2 can be written as: (LMR) = 0.128(RMO) and (RMO) = 0.072(LMR) + 0.138 (CDS), respectively.

(equation 8). However, equation 7 shows that QE narrows indirectly the credit spread through a narrowing of the liquidity spread. Equation 6, in conjunction with equation 5, shows that a narrowing of the liquidity spread reduces the credit premium, but not vice versa. Interestingly, equation 9 and 10 suggest BoE reacts to changes in both liquidity and credit risk premia.

Table 4: Liquidity and credit risk during the period of the intervention of the BoE

	Eqn 5	Eqn 6	Eqn 7	Eqn 8	Eqn 9	Eqn 10
Variables	d(RMO)	d(RMO)	d(LMR)	d(LMR)	dRATIO	dRATIO
RMO_{t-1}	-0.039 [-1.52]	-0.103 [-3.68]	0.047 [2.50]		-0.001 [-1.80]	
LMR_{t-1}	0.002 [0.36]		-0.013 [-3.46]	-0.002 [-0.21]		-0.001 [-6.71]
$RATIO_{t-1}$		-0.709 [-3.22]		0.186 [0.54]	-0.010 [-4.06]	-0.032 [-7.84]
$\bar{R}^2$	0.11	0.06	0.38	0.16	0.16	0.25
D-W	2.22	2.02	2.01	2.02	2.02	2.00

Error correction terms for estimations during QE period (19.2.2009 – 24.6.2010). All equations include an intercept and short-run dynamics up to lag length two. In squared brackets under the coefficients are t-values. The critical t-value for the cointegration test is -3.23 at the 5% significance level. None of the error correction models indicates first order serial correlation.

Furthermore, we see that the roles of liquidity and credit risk spreads have changed. In contrast to the pre-QE period, the order of long-run Granger causation is now reversed: liquidity risk drives credit risk and not vice versa.

The results so far may be summarised as follows: The relationship between credit and liquidity risk changed during the QE period and this change was prompted by the massive liquidity provisions by the Bank. While pre-QE credit risk caused liquidity risk, this relationship is now reversed, without any feedback effects. Furthermore, QE has no direct effect on the credit spread, but it narrows the liquidity spread significantly in the long-run by 6.9 basis points and the latter, in turn, reduces LMR by 3.6 basis points. While credit risk does not respond to QE directly, QE is caused by both, liquidity and credit risk (Here some paper by BoE??).

The estimates of Table 5 underline the robustness of the previous inferences and additionally shed some light on the significance of the CDS as the credit risk component in the decomposition of the Libor-OIS spread. This is an important issue, since CDS is frequently used in the literature as a measure of credit risk. The results of equations 11 and 12 show similar to those in Table 4, that there is unidirectional causality from liquidity to credit risk. In the long-run, a narrowing of the liquidity spread reduces the credit spread by the same amount as in equation 7 in Table 4 and CDS does not play any significant role in the long-run. This result underlines the importance of RMO as the long-run forcing variable in the determination of the credit risk spread. Also here, the trigger of the fall in the liquidity spread is the interventions by the BoE (see equation 12) and CDS does not significantly determine the liquidity spread. Furthermore, there is no cointegration between LMR and CDS (see eqn 14), indicating that both variables are driven by different stochastic trends and cannot be exchanged against each other in the determination of the risk premia. This may also indicate that by decomposing the Libor-OIS spread into its credit risk component and approximating the latter with CDS may be inappropriate, particularly during the period with central bank intervention.

Table 5: Liquidity and credit risk during the period of the intervention of the BoE

	Eqn 11	Eqn 12	Eqn 13	Eqn 14	Eqn 15	Eqn 16
Variables	d(RMO)	d(RMO)	d(LMR)	d(LMR)	dRATIO	dRATIO
RMO_{t-1}	-0.034 [-1.33]	-0.104 [-3.68]	0.050 [2.59]		-0.0004 [-1.57]	
LMR_{t-1}	0.002 [-0.29]		-0.015 [-3.47]	-0.006 [-0.59]		-0.001 [-5.25]
$RATIO_{t-1}$		-0.631 [-2.72]		0.113 [0.31]	-0.013 [-4.93]	-0.031 [-7.11]
CDS_{t-1}	0.003 [1.13]	0.002 [0.83]	0.002 [0.82]	0.002 [0.92]	-0.0001 [-3.58]	-0.00002 [-3.58]
$\bar{R}^2$	0.12	0.06	0.37	0.15	0.19	0.25
D-W	2.02	2.02	2.02	2.02	2.00	2.00

Error correction terms for estimations during QE period (19.2.2009 – 24.6.2010). All equations include an intercept and short-run dynamics up to lag length two. In squared brackets under the coefficients are t-values. The critical t-value for the cointegration test for the 2-variable model is -3.50 at the 5% significance level. None of the error correction models indicates first order serial correlation.

Similar to Table 4, equations 15 and 16 show that central bank liquidity provision rise in the long-run with a narrowing of the liquidity and credit spreads.

5. Conclusion

The paper examines the behaviour of the LIBOR-OIS spread for three-month sterling over the course of the crisis. The spread is decomposed into credit and liquidity premia using three-month Repo-OIS and the Libor-Repo spreads, respectively. In contrast to the existing literature, we replace the conventional central bank intervention dummy variables by the more informative ratio of accumulated money spent on buying gilts to banks' total assets (see also Taylor, 2012). Furthermore, an error correction model accounts for the spreads' changed time series properties in the crisis compared to the pre-crisis period (see also McAndrew et al, 2008) and allows for long-term inference.

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; Taylor and Williams, 2009) employ CDS as a measure of credit risk. Our results show that CDS is interchangeable with LMR in the early period of the crisis. However, during QE, LMR and CDS do not share the same stochastic trend and CDS plays no role in the determination of the Libor-OIS 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 LMR. This effect cannot occur in the long term maturity of the CDS (also, Taylor, 2012).

Our results provide some indicative evidence that BoE intervention may have 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 lead 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.

Looking forward, authors recently have voiced concern about the massive liquidity provision by central banks. Angelini *et al.* (2011) point out that the rise in the spread was driven by risk aversion (i.e. by the *price* rather than the *quantity* of risk). Taylor (2012) is concerned about the loss of independence of the monetary policymaker and the consequences of the unwinding of the liquidity provisions.

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