

The EONIA Spread Before and During the Crisis of 2007 to 2009: The Role of Liquidity and Credit Risk

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Abstract

This paper provides an empirical assessment of the factors affecting the spread between the euro area overnight interest rate (EONIA) and the main policy rate of the European Central Bank (ECB). Up until the period when Lehman Brothers collapsed in mid-September 2008, the spread was small and positive. After this point, the liquidity surplus that developed from the fixed rate full allotment tendering arrangement in refinancing operations drove the widening of EONIA spread (trading below the ECB policy rate), although other factors also played a significant role. This paper explains the drivers of spread across alternative non-crisis/crisis regimes. In addition, the paper examines how the EONIA spread reacts to shocks imposed on a range of liquidity and credit risk factors in alternative crisis/non-crisis regimes. The results have implications for factors that should be monitored closely across both regimes, and also the implications that this may have for steering an unsecured overnight rate in crisis times.

Keywords: *EONIA Spread, Liquidity Risk, Credit Risk.*

JEL classification: *C32, E52, E58*

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1. Introduction

The interbank money market is the primary channel for the implementation of monetary policy for a number of central banks, including for example the European Central Bank (ECB) and the Federal Reserve. Steering overnight interest rates is crucial for these central banks as this provides an anchor for the term structure of interest rates. In the case of the euro area, the Euro Overnight Index Average (EONIA) is a weighted average of all overnight lending transactions between most active credit institutions in the euro area's money market. Effective steering of the overnight rate by the ECB would therefore imply a low spread between the ECB policy rate and the EONIA rate, whereby the overnight rate anchors the term structure of interest rates.

Since the intensification of the October 2008, a very large negative spread became evident, however. This was due to the large surplus of liquidity that became evident following the breakdown of interbank market activity and the non-standard monetary policy measures implemented by the ECB in response to the crisis. In non-crisis times, excess volatility is not prevalent in the EONIA as it tracks closely the main ECB policy rate, so that the EONIA spread is relatively low (i.e. less than five basis points).² In crisis times, however, this is not necessarily the case, and in the recent crisis, there has been a clear rise in both the level and volatility of the EONIA spread. Clearly, under such circumstances where volatility is higher, so too is uncertainty associated with the spread. During the recent crisis of 2007 to 2009, as liquidity dried up, a large policy spread was observed, particularly after the collapse of Lehman Brothers in mid-September 2008.

Liquidity-easing measures implemented by the ECB to restore interbank market activity have come at the expense of a very wide policy spread of around 65 basis points, with EONIA trading substantially below the minimum bid rate in open market operations. Initially, there were concerns that this may create some problems as regards providing the market with a clear signal on the monetary policy stance. In extreme circumstances, it can mean that the central bank becomes unable to steer the overnight interest rate, causing a loss of credibility as the central bank effectively loses control of the first stage in the monetary policy transmission mechanism.³ With this in mind, the ECB narrowed the standing facilities corridor. The aim here was to maintain signalling power in the policy rate in the face of a declining overnight rate. Lower trading volumes, however, led to a re-widening of the corridor. In any case, since the MRO rate no longer reflected the demand and supply for liquidity when fixed rate full allotment (FRFA) was introduced in October 2008, it could be argued that it is no longer an appropriate rate with which to judge the monetary policy stance.

The purpose of this paper is to assess the factors that have driven the EONIA spread (i.e. the difference in the overnight interest rate and the main policy rate of the ECB across three sub-periods: the non-crisis phase, the less intense phase of the crisis, the crisis after the collapse of

² A small positive spread can be justified on the grounds that the marginal rate of the main refinancing operations is usually greater than the minimum bid rate. In addition, the EONIA rate can be greater than the MRO rate as collateral costs differ between the central bank and the market (see Linzert and Schmidt, 2008). Moreover, in non-crisis times, there is evidence to suggest that liquidity variables may only be relevant during the last week of the maintenance period. For example, see Moschitz (2004), Ejerskov et al (2003) and Würtz (2003).

³ Of course, it can also mean that the signalling role of the EONIA rate may be impeded in an environment with an excessive surplus of liquidity.

Lehman Brothers. To this end, two empirical approaches are employed. The first approach is based on an OLS framework that regresses the EONIA spread on liquidity risk, credit risk, interest rate expectations, and the liquidity balance of the Eurosystem, as well as a number of dummy variables to capture specific events. The second empirical approach uses impulse responses derived from a five-variate vector autoregressive model to assess how the EONIA spread reacts to a shock imposed on the a range of liquidity and credit risk measures.

The layout of the paper is the following. Section 2 provides an overview of the context to the widening of the EONIA spread, Section 3 provides a review of previous studies, Section 4 outlines the data used and econometric methodology employed. Section 5 presents the empirical results. Section 6 summarises the main findings and draws some policy conclusions.

2. The Widening of the EONIA Spread

As can be seen from Figure 1, the EONIA spread has increased substantially since the intensification of the crisis in mid-September 2008, and there were initial fears that this would impede the signalling of the monetary policy stance. This is particularly the case since the emergence of a substantial liquidity surplus in the Eurosystem, where the EONIA rate appears to have tracked more closely the ECB’s deposit facility rate.

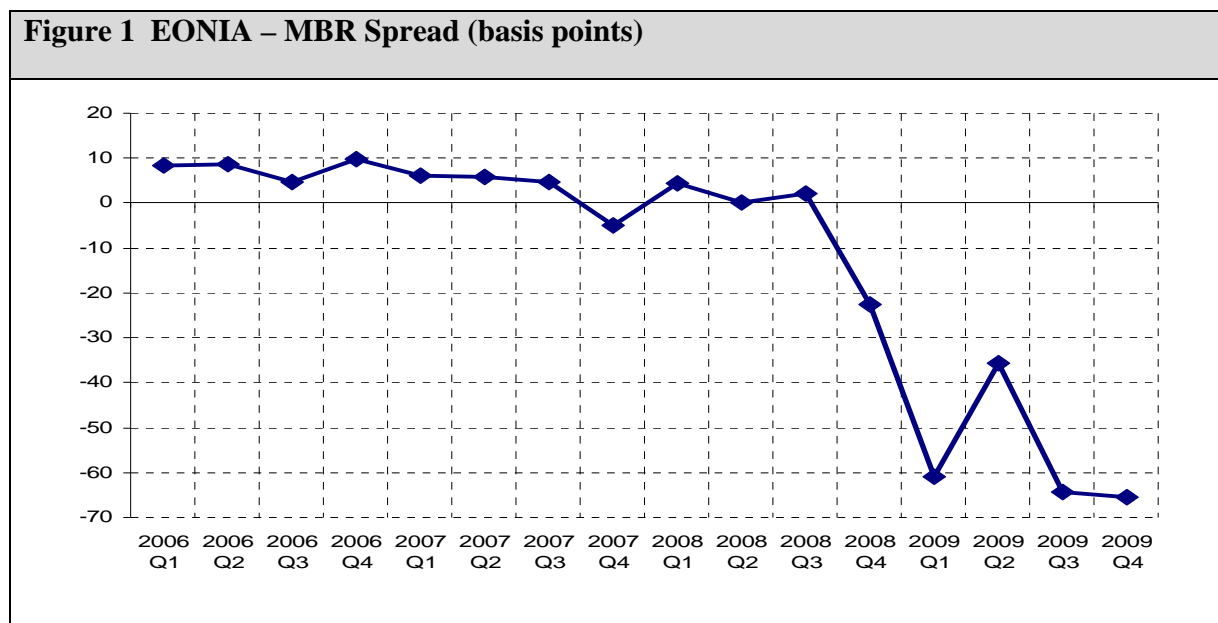


Figure 1 indicates that prior to Q4 2007, EONIA traded above the minimum bid rate, whereby the spread was positive and less than 10 basis points. The initial stage of the crisis before the collapse of Lehman Brothers in August 2007, and the associated exceptional injection of liquidity by the ECB (via a fine-tuning operation of around €95 billion), led to a temporary drop in the spread from positive to negative in Q4 2007. The spread level still remained below 10 basis points, however, and reverted to a positive level by the first quarter of 2008. In this context, it is useful to consider how the implementation of monetary policy took place prior to August 2007. Before then, the provision of liquidity by the ECB was done in a way which enabled the

banking sector to smoothly fulfil their reserve requirements over the course of a maintenance period. However, in the period from August 2007, this arrangement changed somewhat so that a more than proportionate amount of liquidity was supplied at the start of a maintenance period and less at the end. Over the course of the maintenance period, however, the net liquidity balance would be zero, so that the aggregate amount of liquidity supplied was the same both before the onset of the crisis in August 2007 and beforehand. This was known as liquidity ‘frontloading’. Given that this approach seemed to address market concerns (as the interbank market continued to function), the EONIA rate remained closed to the main policy rate of the ECB.

Following the collapse of Lehman Brothers in mid-September 2008, a very large and negative EONIA spread became apparent. By the end of 2009, the spread has averaged about 65 basis points. Figure 2, below, provides further context in terms of the movement of the EONIA rate relative to the 3-month Euribor rate and the standing facilities of the ECB.

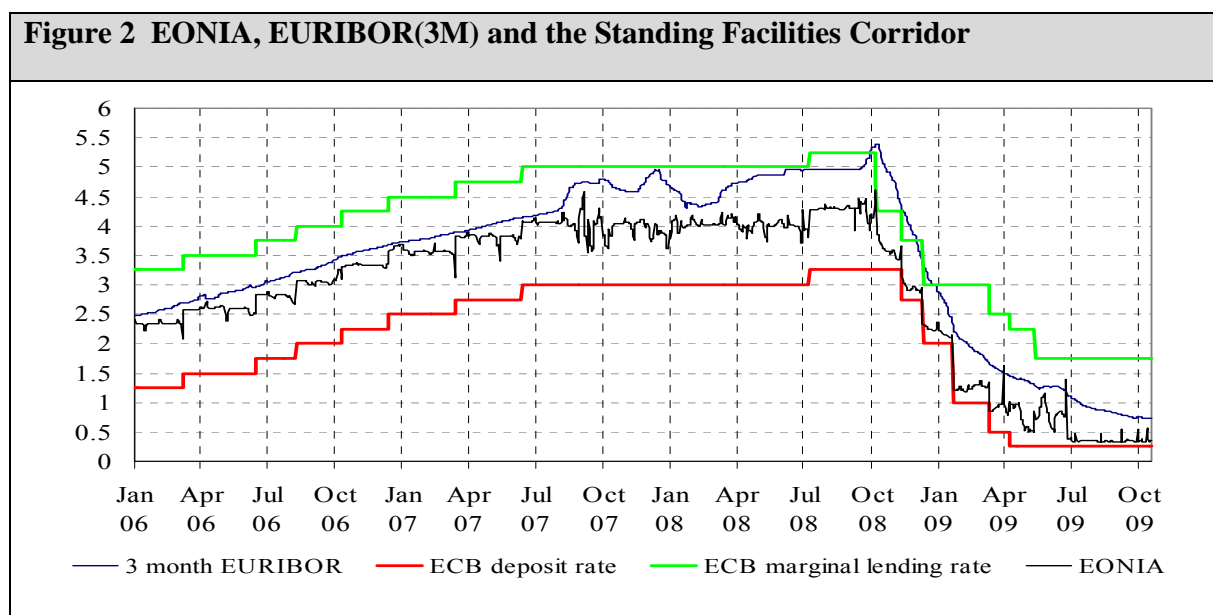


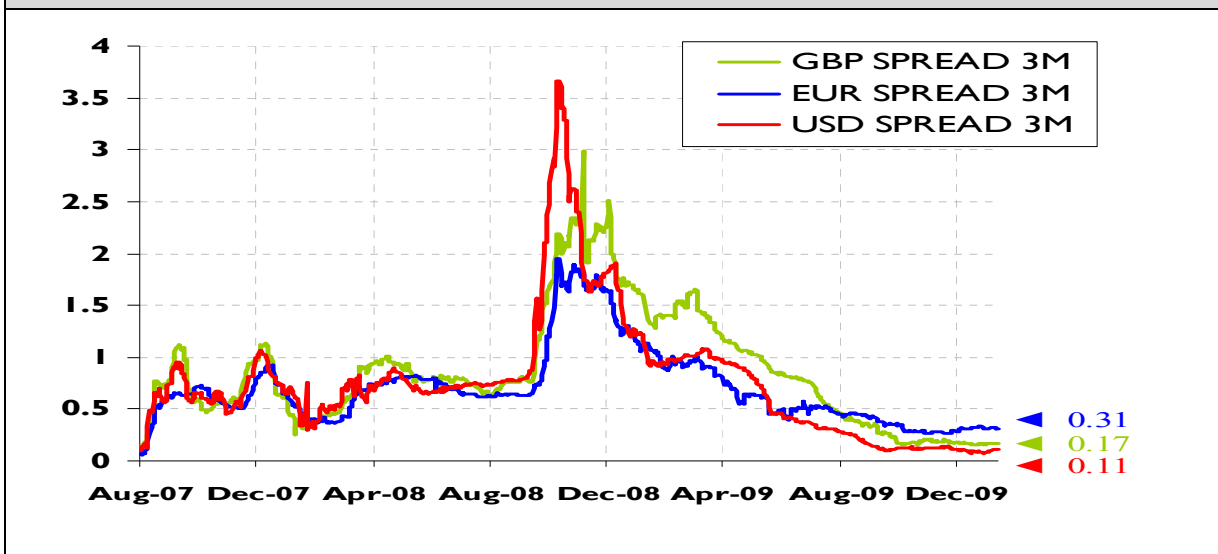
Figure 2 indicates that in the period prior to August 2007, the EONIA rate operated very close to the mid-point of the deposit facility rate and the marginal lending rate (as did the 3-month unsecured EURIBOR rate). In this way, the monetary policy signalling embodied in the EONIA up to this time was as the ECB intended. While greater volatility seemed to be evident in Q4 2007 (due to initial market uncertainty), it is also clear that EONIA continued to trade at the mid-point of the ECB’s standing facilities. However, when the financial crisis erupted following the Lehman collapse, it is clear that EONIA no longer traded at the mid-point of the standing facilities. Rather, it tracked more closely the deposit facility rate. Of course, during the period since October 2008, the ECB engaged in a range both conventional and unconventional monetary policy measures in response to the crisis. On the conventional side, between October 2008 and the end of 2009, the ECB cut the policy rate by 325 basis points – from 4.25% to 1%. As well as this, the ECB implemented a number of non-standard measures. Firstly, unlimited liquidity at a fixed rate was made available through a tender arrangement known as “fixed rate tenders with full allotment”. This measure became effective on 15 October for MROs, on 30 October 2008 for LTROs and on 13 October for the US dollar operations. This support enabled banks to maintain their crucial role in financing the real economy. Secondly, there was an

expansion in the list of collateral eligible for open market operations. This provided an opportunity for banks to refinance assets that had become less liquid in the wake of the market turmoil. Thirdly, the maturity period for refinancing operations was lengthened (in the first stage, by up to six months, and then for up to one year). At the same time, the frequency and the number of longer term refinancing operations increased. This measure made banks less vulnerable to short-term shocks and attenuated the maturity mismatch on banks' balance sheet. The first one-year LTRO was carried out in June 2009 at the rate of 1% (equal to the MRO rate at the time) and met a very high demand (€442 billion) with 1121 counterparties participating. The second and third one-year operations attracted less demand than that first, suggesting some shift toward normalisation in the market. Fourthly, the ECB engaged in the provision of liquidity in foreign currencies, particularly in US dollars via swaps with the Federal Reserve. This facility helped to address the currency mismatch in the balance sheets of banks and the malfunctioning of the internal swap market. Finally, to restore activity in the covered bond market, the ECB engaged in the outright purchasing of covered bonds. This measure commenced in July 2009.

The response by the ECB to the intensification of the crisis effectively (temporarily) ended the liquidity rationing system that was in place under variable rate auctions. The breakdown of the interbank market also meant that banks were uncertain whether any liquidity shortfalls would be counter-balanced on the market. Subsequent over-bidding by banks for liquidity under the MRO and LTROs caused the spread between the marginal rate and the minimum bid rate to widen considerably. The credit-easing measures of the ECB, described earlier, addressed the liquidity funding uncertainty faced by the banking sector. In particular, the provision of liquidity at full allotment with a fixed rate was instrumental in achieving this. As well as this, as can be seen from Figure 2, the standing facilities corridor was narrowed from October 2008. Prior to this date, a 200 basis point corridor existed, 100 basis points either side of the minimum bid rate. Thus, overnight deposits would incur a penalty of 100 basis points below the policy rate, while overnight lending would incur a penalty of 100 basis points above the policy rate. This narrowing of the corridor was carried out in order to alleviate the extent to which the MRO rate would lose signalling power as overnight rates declined.

By narrowing the corridor in October 2008, the extent of these penalties was reduced by half. Notably, the narrowing of the corridor increased the attractiveness of the deposit facility for excess reserves compared to the market. Even if greater returns may have been achievable on the market, banks were willing to pay a risk premium in return for the security offered through depositing overnight at the central bank. The increased usage of the deposit facility also led to a decline in EONIA trading volume and an EONIA rate below the MRO was consistently in place since the switch to fixed rate tendering in the refinancing operations. Following tentative signs of market recovery, as shown in Figure 3, and a willingness by the ECB to minimise crowding out interbank market activity, the standing facilities corridor was widened once again at the end of December 2008 to 200 basis points. This was also related to a fall in activity in the overnight market during the period of the narrow corridor.

Figure 3 Euribor-OIS Spreads



As a result of the widening of the corridor, EONIA volume increased somewhat. However, in combination with the wider corridor, the fixed rate tendering arrangement and associated liquidity surplus led to a rise in the spread between the EONIA rate and the minimum bid rate in the MRO. As can be seen from Figure 1, when the corridor was narrow in the fourth quarter of 2008, the EONIA spread was about 27 basis points. This increased to about 62 basis points in the first quarter of 2009 when the corridor was twice as wide. Given that this spread was negative, this implied that banks that were active on the money market could attain refinancing at a cost much lower (i.e. over 60 basis points lower) than banks relying on Eurosystem refinancing. The relationship between the EONIA spread and the liquidity surplus is provided in Figure 4 below.

Figure 4 Relationship between the EONIA spread and the Liquidity Surplus

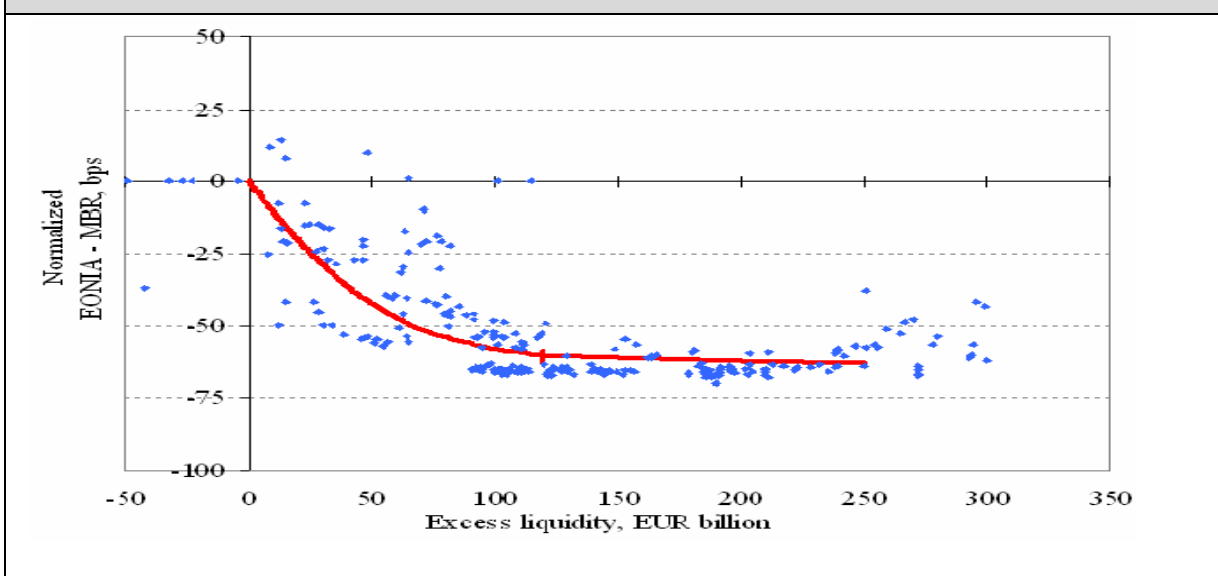


Figure 4 is based on the relationship between the EONIA spread and the liquidity surplus over the period January 2009 to January 2010. The EONIA spread has been appropriately normalised to reflect the change to the standing facilities corridor during this period (normalised to an overall corridor width of 150 basis points). It is clear that a liquidity surplus of about €120 billion is consistent with a stable EONIA spread of about -60 basis points.⁴

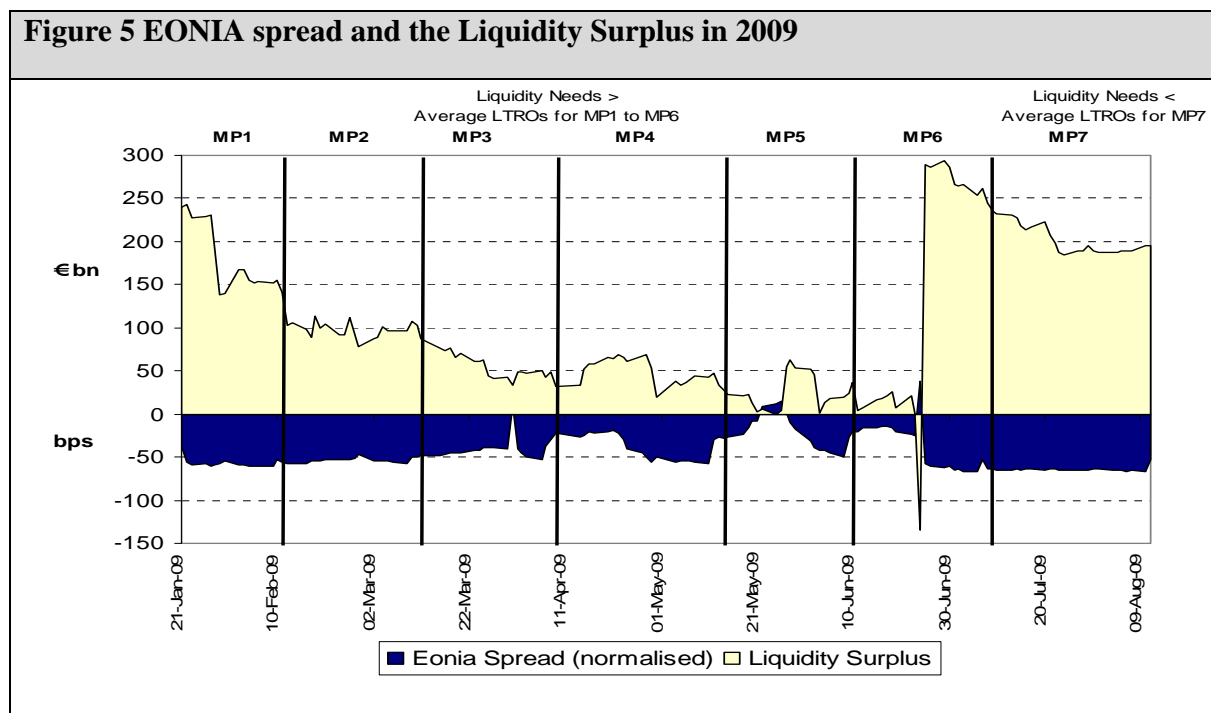


Figure 5 outlines the relationship between the EONIA spread and the liquidity surplus in the first seven maintenance periods of 2009, covering the period before and after the settlement of the first 12-month LTRO in the amount of €442 billion. From the chart, it can be seen that the spread is largely non-responsive to the liquidity surplus when the surplus is above about €100 billion, in line with the assessment made earlier in Figure 4.

An important issue to consider in the context of the substantial EONIA spread is the consequences for the signalling of the monetary policy stance. As can be seen from Figure 1, prior to the crisis the EONIA spread was positive and below 10 basis points, implying that it was marginally more costly to refinance on the market. Using monetary policy operations, the short-term market rates were steered towards the mid-point of the standing facilities (i.e. the minimum bid rate). Given that short-term rates are the first stage in the monetary policy transmission mechanism, it is important to ensure that the signalling of the stance is as transparent as possible. This occurs in non-crisis times via the so-called ‘separation principle’. This holds that the monetary policy stance is firstly determined by consideration of price stability concerns. The implementation of the stance then takes place via liquidity operations, which aim to steer the EONIA rate close to the main policy rate. Such a system tends to operate smoothly in conditions

⁴ This curve is based on updating the original model of S. Manganelli, a logistic regression of the form: $Eonia_spread_t = \beta_0 + \beta_1(1 + e^{\beta_2 \cdot liq_surplus_t})^{-1} + \varepsilon_t$. As well as updating the original model, this version also adds a constraint to restrict the EONIA spread to zero when the liquidity surplus is zero.

where the market is functioning properly. In a financial crisis scenario, the signalling of the monetary policy stance is much more complex. In the context of the Eurosystem, the non-standard liquidity-providing measures introduced in October 2008 resulted in a disconnect between the EONIA and the main policy rate, and a breakdown in the separation principle. Effectively, all of the banking sector's liquidity needs were met by Eurosystem refinancing, resulting in overnight market rates being considerably lower than the main policy rate of the ECB. It is clear that under this scenario, the main policy rate is not in line with the EONIA rate, and the excess liquidity has caused the EONIA rate to move more in line with the deposit facility rate. As the crisis subsides and the non-standard measures implemented by the ECB are phased out, the separation principle should resume as the main policy rate resumes its signalling role. During the crisis, there was a need to trade-off a possible blurring of the stance with restoring a fully functioning interbank market.

3. Other Previous Studies

In terms of the most recent research on explaining the EONIA spread, Linzert and Schmidt (2008) sought to explain the widening of the spread over the period March 2004 to August 2006, specifically in relation to the change in the operational framework in March 2004. These authors firstly set out a practical rationale for why it is feasible that a small positive spread may exist between the EONIA and the policy rate. This is aided by decomposing the EONIA spread into two components: the spread between the policy rate and the marginal rate (i.e. the lowest rate at which liquidity allotment still occurs); and the spread between the marginal rate and the EONIA rate. The change in the operational framework is also an important consideration. For example, there is evidence to suggest that interest rate expectations had a strong role to play in driving the EONIA rate under the old framework, whereas this was expected to have a much more muted effect under the new framework (see Bindseil et al, 2002). This was due to the fact that under the new framework, the new policy rate would only become effective at the beginning of a new maintenance period after the meeting of the ECB Governing Council.⁵ Nautz and Offermanns (2007) make the point that the minimum bid rate of the ECB should set a lower-bound for interest rates, so that the adjustment of the EONIA to the policy rate should be stronger where the EONIA is low relative to the minimum bid rate.⁶ This, in turn, suggests that there may be an asymmetric response in the EONIA spread may to interest rate expectations. Such a scenario was identified for the euro area by Würtz (2003). In addition, in an application to the US, Sarno and Thornton (2003) indicate that expectations of rate rises have relatively stronger effects on overnight rates.

Linzert and Schmidt (2008) note that a positive spread can exist in the EONIA and the policy rate since the marginal rate of the MRO's is normally higher than the policy rate. In addition, the authors rationalise a spread in the EONIA (*vis-à-vis* the marginal rate) being possible given that open market operations are subject to collateral requirements, while the EONIA is calculated from unsecured transactions. Thus, a risk premium is incorporated into the spread. The empirical exercise undertaken by Linzert and Schmidt (2008) is based on OLS, whereby the EONIA

⁵ As a result, this was intended to mitigate against the distortive effect of interest rate expectations on the bidding by banks in MRO and the overnight rate dynamics.

⁶ In a related theme, Ayuso and Repullo (2003) note that a central bank's asymmetric loss function may lead to a non-symmetric EONIA adjustment (in terms of, for example, a greater degree of risk aversion for an interest rate below target than above target).

spread is regressed on a range of variables. These include: liquidity policy (the difference between actual and benchmark allotment), the bid-to-cover ratio (ratio between the total bid volume and the amount covered), within period rate expectations (spread between one-week swap rates and the policy rate), interest rate uncertainty (conditional volatility of the change in one-week swap rates), the liquidity deficit. Of note, it was found that liquidity policy significantly and positively affects the EONIA spread, as does the bid-to-cover ratio, and the liquidity deficit. The paper was written in the context of a widening EONIA spread since March 2004. The results indicate that a rise in the liquidity deficit has a particularly strong effect in increasing the EONIA spread. A similar, albeit less strong, effect is found with banks' uncertainty over liquidity conditions, whereby greater uncertainty increases the spread.

Hassler and Nautz (2008) examine the persistence of the EONIA spread in an attempt to measure the controllability that the central bank has in maintaining a low spread. Like many other academic papers on the EONIA spread, this paper was written in the context of a rising spread following the change in the ECB's operational framework in March 2004. These authors use fractional integration techniques and interpret the order of the fractional integration of the spread as a measure of ability to control the overnight rate.⁷ With an interest in explaining why the EONIA spread appears to be non-responsive to liquidity injections by the ECB, they find that this may be due to a rise in persistence. Overall, the finding is the spread is stationary prior to March 2004. After this period, it is fractionally integrated to the order of about 0.2. Thus, while they believe that the EONIA is still under control (with the order of integration being less than 0.5), the interpretation is that the extent of controllability may not be strong. This is of particular interest in the current paper, of course, where indeed controllability of the EONIA appears to be worsened considerably.

Nautz and Offermanns (2007) examine how the EONIA rate adjusts to term interest spread, and how the policy rate of the ECB is affected by interest rate expectations and the monetary policy operational framework of the ECB. They find a strong role played by the tender arrangement. Specifically, the introduction of variable rate tenders with a minimum bid rate in June 2000 did not lead to a loss of control over the EONIA, and in fact, the link between EONIA and the policy rate appears to be even stronger when a positive spread is rising. A previous study by Würtz (2003) uses an E-GARCH model to model the volatility of the EONIA spread.⁸ The equation used for the policy spread is non-linear to reflect the fact that the EONIA rate is bounded by the standing facilities of the ECB. Here it is found that expectations on changes in the policy rates and the end of the maintenance period effects are the main drivers of the EONIA spread. Gaspar et al (2008) present a model that examines the determinants of equilibrium in the market for daily funds. Using the EONIA panel database over the period 1999 to 2005, the model indicates that there is a rise in both the time series volatility and cross-section dispersion of the lending rates applied by commercial banks towards the end of the reserve maintenance period.

Nautz and Offermanns (2008) examine volatility transmission in the European money market, specifically assessing the transmission of EONIA volatility to longer term money market rates. Their analysis focuses on the period from March 2004 to August 2006. They find that the new framework has reduced the volatility in all money market rates. Interestingly they explain the

⁷ These authors note that previous studies on the volatility of the EONIA spread have found it to be generated via an I(0) data generating process (e.g. see Perez Quiros and Rodriguez Mendizabal, 2006) and Nautz and Offermanns, 2007). They view this approach as being overly restrictive, however, where a series is either I(1) or I(0).

⁸ The use of the EGARCH model for assessing the volatility of overnight rates and the martingale hypothesis during the maintenance period was first carried out by Hamilton (1996) where the focus was on the Federal funds rate.

fluctuation in the EONIA rate as being due to not only the EONIA spread, but also the term spread (defined as the spread between the 3-month Euribor rate and the minimum bid rate). These authors find that this term spread, as an indicator of interest rate expectations, is an important determinant, even under the new framework. Hirsch et al (2007) examine the impact of aggregate liquidity supply on the EONIA spread over the period March 1999 to November 2006. The so-called 'end-of-period' liquidity effects (net recourse to the standing facilities on the last day of the maintenance period) and 'within-period' effects (deviations from the proportional reserve fulfilment path). The results of the empirical work undertaken suggest that liquidity effects do not appear to have an impact on the EONIA spread before the last MRO. By contrast, after the last MRO there appears to be strong liquidity effects on the spread. Since the ECB began to implement fine-tuning operations on the last day of the maintenance period, the end-of-period liquidity imbalance that is addressed due to this means that there is a strong impact on the spread for this day. Interestingly, the authors note that the fine-tuning operations after the last MRO have not completely eliminated the volatility in the spread. The authors note that this may be due to the presence of 'within period' liquidity effects.

Bartolini and Prati (2005) assess the volatility of overnight interest rates for a range of countries, including the euro area. These authors use an EGARCH model and focus on the results from the variance equation to identify the effect of monetary policy implementation across countries on interest rate volatility. In addition, Sarno and Thornton (2003) use an error-correction framework applied to the US. In this case, the overnight rate is assessed by estimating error-correction equations for the Federal funds rate and the 3-month Treasury bill rate. These authors find that the adjustment of the Federal funds rate to the Treasury bill rate is asymmetric, so that the effect is more pronounced when the Federal funds rate is below its equilibrium level. Similar effects in, respectively, a Japanese and European context have been found by Kuo and Enders (2004) and Clarida et al (2006).

An apparent gap in the literature relates to the particular factors that have affected the policy spread in the midst of the financial crisis of 2007 to 2009. The crisis caused this spread to rise substantially in the period after August 2007, and notably after the collapse of Lehman Brothers in September 2008. The interbank market in the euro area effectively broke down, as banks refused to lend with each other. Instead, they borrowed from the ECB and re-deposited with the ECB. This caused a change in the refinancing framework of the ECB, when in October 2008 it offered refinancing to banks at full allotment with a fixed rate for maturities up to 12 months. This expansion in liquidity provision was aimed at lowering borrowing costs as the central banks acted as intermediaries for interbank market activity. The result was a substantial liquidity surplus in the Eurosystem and an associated rise in the central bank's balance sheet by a factor of about two, but also an apparent distortion of the signalling of the monetary policy stance. For example, following the introduction of the fixed rate full allotment tendering procedure, the demand for liquidity was determined exogenously. As a result, the signalling power of the minimum bid rate became somewhat impaired, as it no longer reflected supply and demand for liquidity. With the substantial rise in the liquidity surplus, the signalling role of the stance appears to have been assumed by the deposit rate. This was deemed a pragmatic response during the crisis. Given the extent of the need for liquidity, the loss of the signalling power of the minimum bid rate was balanced against restoring the functioning of the money market. In terms of alternatives, the ECB could have of course reduced the minimum bid rate. This, however, would have been an even stronger signal of the monetary policy stance than the option that was implemented to effectively allow the deposit rate to steer the overnight rate. The fact remains,

however, that the signal of the monetary policy stance has been impaired both before and during the crisis. The following section describes the data and methodology.

4. Data and Methodology

The data is sourced from the ECB's Statistical Data Warehouse and Bloomberg. The EONIA spread is defined as the difference between the EONIA rate and the minimum bid rate in open market operations. The liquidity balance is defined as the difference between open market operations and the sum of autonomous factors and required reserves. Liquidity risk is defined as the 3-month EURIBOR-OIS spread, bank credit risk is given by the iTraxx Senior Financial Index, while market expectations of future monetary policy is represented by the 3-month forward rate spread with the EURIBOR.⁹ In order to isolate the effect of a liquidity surplus on the spread, the liquidity balance variable is interacted with various threshold levels of liquidity surplus.¹⁰ A daily frequency for the data is collected. In implementing the approach, the following sub-periods are of particular interest:

- Pre-crisis: 29 June 2006 to 6 August 2007
- Crisis Pre-Lehman Collapse: 7 August 2007 to 14 September 2008
- Crisis Post-Lehman Collapse: 15 September 2008 to 22 October 2009

These dates coincide with events and also to ensure an equal number of observations across each sub-period. The post-Lehman collapse period was very different period in the sense that all of the euro area's banking sector's refinancing needs were met by the Eurosystem, which caused the EONIA rate to drop below the policy rate after that (since the cost of refinancing for banks with access to the money market (EONIA) was much lower than the rate applied to banks that needed to go to the Eurosystem). The dysfunctional interbank market and fixed rate full allotment arrangement drove the spread lower during this phase. As a result, in considering the empirical results from this phase, it is important to bear this in mind.

As regards the methodology, the *first empirical approach* is based on an OLS framework that regresses the EONIA spread on liquidity risk, bank credit risk, interest rate expectations, and the liquidity balance of the Eurosystem. This model also controls for the effects of the last day of the maintenance period, as well as the crisis and FRFA periods using appropriate dummy variables. In addition, persistence in the spread is captured by regressing on a lagged dependent variable, and the liquidity balance variable is interacted with dummies to reflect threshold liquidity surplus levels.

⁹ The iTraxx Senior Financial Index is available only since 21 June 2004.

¹⁰ Specifications reported indicate the optimal models.

The basic specification of the OLS model would take the following form:

$$y_t = \alpha + \beta_1 x_{1,t} + \beta_2 x_{2,t} + \beta_3 x_{3,t} + \beta_4 x_{4,t} + \beta_5 y_{t-1} + \beta_6 d_1 + \varepsilon_t \quad (1)$$

where:

α is the intercept term

y_t is the EONIA spread

α is an intercept term

$x_{1,t}$ is the Money Market Liquidity Risk, represented by the 3-month EURIBOR-OIS spread

$x_{2,t}$ is the Bank Credit Risk, denoted by the iTraxx Senior Financials index

$x_{3,t}$ is the Eurosystem liquidity balance (i.e. OMOs minus AF minus RR), which is interacted with liquidity surplus levels

$x_{4,t}$ is the Interest rate expectations, denoted by the 3-month forward rate-EURIBOR spread

y_{t-1} is the lagged EONIA spread

d_1 is a dummy taking the value of one for the last day of the maintenance period

ε_t is the residual term

The *second empirical approach* uses a linear vector autoregressive model (VAR). This approach enables a determination to be made of the how the EONIA spread would react to a shock imposed on liquidity risk, bank credit risk, the liquidity balance, and interest rate expectations. This involves computing impulse responses from the VAR consisting of the same variables used in the OLS analysis. A lag order of n days would be selected based on analysis of information criteria from the VAR residuals. In selecting the lag, close attention would be paid to balance the issue of overparametrisation against underestimation of the lag order. The generalised form of the VAR is as follows:

$$[X]_t = c + \sum_{i=1}^p A_i [X]_{t-i} + d + \varepsilon_t \quad (2)$$

where X_t is a 5x1 vector comprising the variables used in equation (1) and ordered with the EONIA spread in the first position, c is a 5x1 vector of intercepts, A_i is a 5x5 matrix of autoregressive components, d is a 5x1 vector capturing the last day of the maintenance period, and ε_t is a 5x1 vector of random disturbances for each of the variables in X_t .

The main focus of this approach is on the adjustment of the EONIA spread to an unexpected temporary shock imposed on the money market liquidity, credit risk, the liquidity balance, and interest rate expectations. In computing the impulse response functions the missing identification of the contemporaneous relation between the EONIA spread and the other variables in X_t would be solved by using the traditional Cholesky decomposition of the residual variance-covariance matrix. The usefulness of this approach lies in the fact that it shows both the magnitude of the adjustment, as well as the length of time that would elapse for the adjustment in the spread to be completed. This complements the OLS analysis and is informative from a policy perspective in terms of providing an indication on the persistence and scale of liquidity and credit risk shocks on the EONIA spread.

As a starting point in the analysis, the EONIA spread variable is transformed to eliminate negative values that appear in the series. In order to do this, in the first instance, the absolute value of the most negative data point is added to each data point in the series. As a result, the minimum value in the series becomes zero. This series can be referred to as d . The series is then

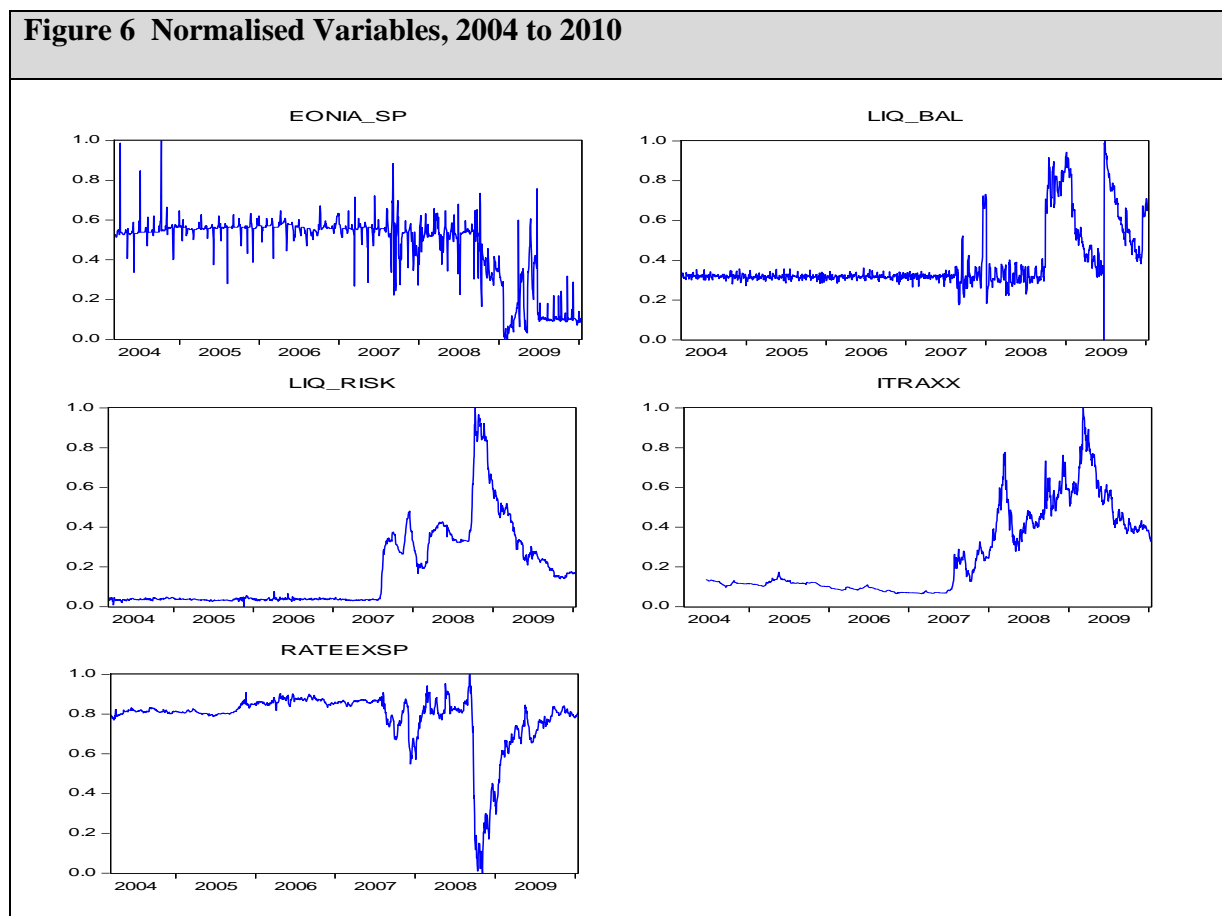
normalised. Assuming σ represents the normalised value for each data point, then d is normalised as follows:

$$\hat{o}_t = \frac{d_t - d_{\min}}{d_{\max} - d_{\min}} \quad (3)$$

As a result, the series now lies in the range [0, 1]. As a result, equation (3) can be simplified as follows:

$$\hat{o}_t = \frac{d_t}{d_{\max}} \quad (4)$$

A similar transformation process is carried out on the other variables in the dataset. The transformed series are plotted in **Figure 6** below.



Note: Please refer to the Appendix for a bivariate cross-plot of the EONIA spread with each of the explanatory variables.

5. Empirical Results

5.1 Results from OLS Regression

The following elements of the empirical analysis focus on comparing how drivers of the spread may have changed in non-crisis compared to crisis regimes. Using the same basic framework as outlined in equation (1), the following sub-periods are assessed:

- Model A: 29 June 2006 to 6 August 2007 (pre-crisis)
- Model B: 7 August 2007 to 14 September 2008 (crisis pre-Lehman collapse)
- Model C: 15 September 2008 to 22 October 2009 (crisis post-Lehman collapse)

While one must exercise a degree of caution in comparing the results across these models, the approach is followed that such comparisons are feasible given the same dependent variable and the same number of observations across each of models A, B and C. Table 1, below, details the pre-crisis scenario results.

Table 1 Model A: Factors driving the EONIA Spread, Pre-crisis				
<i>Explanatory Variable</i>	<i>Coefficient</i>	<i>Std. Error</i>	<i>t-Statistic</i>	<i>p-value</i>
Liquidity Balance	-0.200 *	0.105	-1.901	0.058
Liquidity Risk	0.857	0.590	1.452	0.148
Interest Rate Expectations	-0.133	0.170	-0.779	0.436
Bank credit risk	-0.075	0.084	-0.894	0.372
End of maintenance period dummy	-0.039 ***	0.010	-3.912	0.000
Lagged EONIA spread	0.302 ***	0.055	5.514	0.000
Intercept	0.544 ***	0.163	3.317	0.001

Notes: Model exhibits no signs of serial correlation and appears to fit reasonably well with an R^2 value of 0.47. ***, **, and * denote statistical significance at the 1%, 5% and 10% levels respectively. The t-statistics are based on Newey-West heteroskedasticity and autocorrelation-corrected standard errors. In addition, the null of non-stationarity for the variables was rejected using the Augmented Dickey-Fuller test, thereby allaying spurious regression concerns.

In the pre-crisis sample period, it is clear that the persistence in the spread is quite low, whereby a one unit rise in the spread at time $t-1$ increases the spread at time t by 0.30 units. As expected, the lack of liquidity risk and credit risk concerns during this period implies that these indicators are not significant. This is consistent with a well-functioning market. The liquidity balance is significant however. The following analysis refers to the determinants of the spread in the period of the crisis prior to the collapse of Lehman Brothers. Table 3 outlines the drivers of the EONIA spread in the initial phase of the crisis, prior to the collapse of Lehman Brother in mid-September 2008.

Table 2 Model B Factors driving the EONIA Spread, Start of Crisis Period				
<i>Explanatory Variable</i>	<i>Coefficient</i>	<i>Std. Error</i>	<i>t-Statistic</i>	<i>p-value</i>
Liquidity Balance	-0.161 ***	0.061	-2.659	0.008
Liquidity Risk	-0.087 **	0.041	-2.098	0.037
Interest Rate Expectations	0.019	0.059	0.314	0.754
Bank credit risk	0.021	0.032	0.655	0.513
End of maintenance period dummy	-0.001	0.039	-0.028	0.978
Lagged EONIA spread	0.521 ***	0.080	6.503	0.000
Intercept	0.308 ***	0.079	3.910	0.000

Notes: Model exhibits no signs of serial correlation and appears to fit reasonably well with an R^2 value of 0.87. ***, **, and * denote statistical significance at the 1%, 5% and 10% levels respectively. The t-statistics are based on Newey-West heteroskedasticity and autocorrelation-corrected standard errors. In addition, the null of non-stationarity for the variables was rejected using the Augmented Dickey-Fuller test, thereby allaying spurious regression concerns.

During the initial phase of the crisis, as in the case of the pre-crisis phase, it is clear that the main difference compared to the pre-crisis phase relates to the role played by liquidity risk. Even though the EONIA spread was relatively low during the less intense phase of the crisis, the EONIA traded below the policy rate in the last quarter of 2007, indicative of interbank market concerns. Persistence in the spread has risen by almost a factor of two in this period compared to the pre-crisis phase. Regarding interest rate expectations, it was an aim of the new operational framework (introduced in March 2004) to eliminate the effect of interest rate expectations on the EONIA rate, and given the lack of significance on this variable, it would seem that this aim was achieved. Table 3 describes factors driving the EONIA spread in the period following the collapse of Lehman Brothers.

Table 3 Model C Factors driving the EONIA Spread, Intense Crisis Period				
<i>Explanatory Variable</i>	<i>Coefficient</i>	<i>Std. Error</i>	<i>t-Statistic</i>	<i>p-value</i>
Liquidity Balance	-0.186 ***	0.029	-6.361	0.000
Liquidity Risk	-0.034	0.065	-0.523	0.602
Interest Rate Expectations	-0.087	0.066	-1.329	0.185
Bank credit risk	-0.068 *	0.039	-1.766	0.079
End of maintenance period dummy	0.112 ***	0.020	5.563	0.000
Lagged EONIA spread	0.774 ***	0.032	24.185	0.000
Liquidity Balance * Liquidity Surplus €60-120 billion	-0.065 ***	0.021	-3.073	0.002
Intercept	0.221 ***	0.068	3.269	0.001

Notes: Model exhibits no signs of serial correlation and appears to fit reasonably well with an R^2 value of 0.86. ***, **, and * denote statistical significance at the 1%, 5% and 10% levels respectively. The t-statistics are based on Newey-West heteroskedasticity and autocorrelation-corrected standard errors. In addition, the null of non-stationarity for the variables was rejected using the Augmented Dickey-Fuller test, thereby allaying spurious regression concerns.

In the intense phase of the crisis, it is notable that liquidity risk is no longer a significant variable, reflecting the unlimited provision of liquidity at a fixed rate by the ECB in refinancing operations. It is apparent, however, that credit risk concerns and possible fears of default have some impact upon the EONIA spread during this period. In considering these results, it is crucial to bear in mind that the overarching driver of the EONIA spread in this phase of the crisis was the ECB's fixed rate full allotment policy in refinancing operations, which caused the EONIA rate to trade significantly lower than the MRO rate. Persistence in the spread is the highest in this phase compared to other phases, with a coefficient of 0.774.

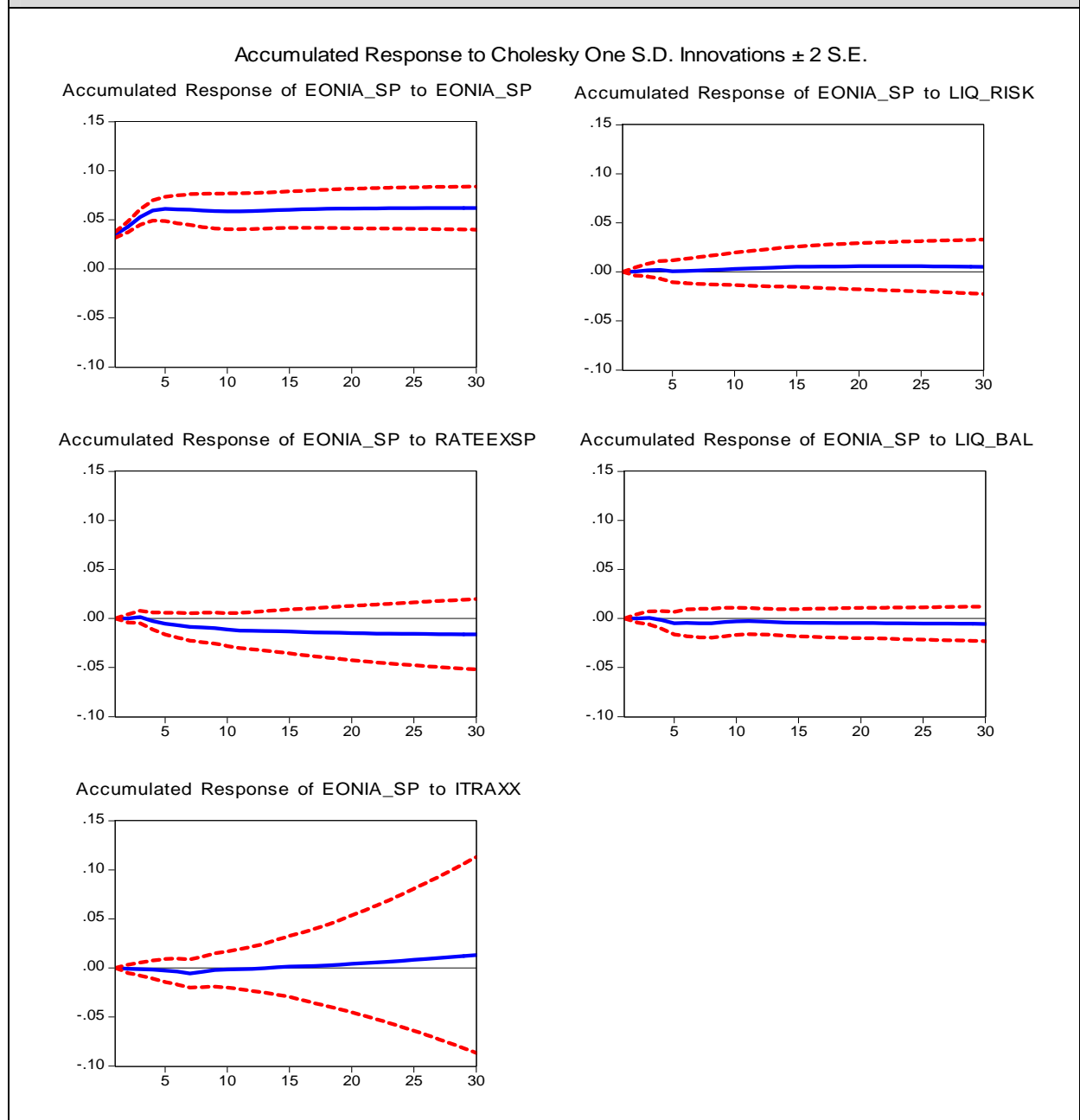
Across both Models B and C, it is also notable that the signs on the liquidity and credit risk variables are negative. This can be explained by the fact that interbank market activity that was prevalent during the crisis took place almost exclusively at the short end of the money market. For example, when liquidity risk is present, banks prefer to borrow in the overnight money market as opposed to the term money market. Similarly, when credit risk is present, banks to lend in the overnight market. As a result, a negative relationship exists between liquidity and credit risk and the overnight interest rate spread.

5.2 Results from Impulse Response Function Analysis

The second empirical approach involves estimating a five-variate vector autoregression and then computing impulse responses to assess how the EONIA spread responds to an unexpected temporary shock imposed on the explanatory variables. A uniform lag order of 5 days is applied given the wide range of optimal lag orders derived from different information criteria and the residual properties and since it is considered that overparametrization is a larger problem than underestimation of the lag order.

The main difference compared with the regression method, which examines the average impact of various explanatory variables on the EONIA spread, is the focus on the adjustment of the EONIA spread to an unexpected temporary shock in the level of the explanatory variables. In computing the impulse response functions the missing identification of the contemporaneous relation between the spread and other variables is solved by using the traditional Cholesky decomposition of the residual variance-covariance matrix. The impulse responses across the pre-crisis, the less intense phase of the crisis, and the crisis post-Lehman collapse are shown in Figures 7 to 9 below.

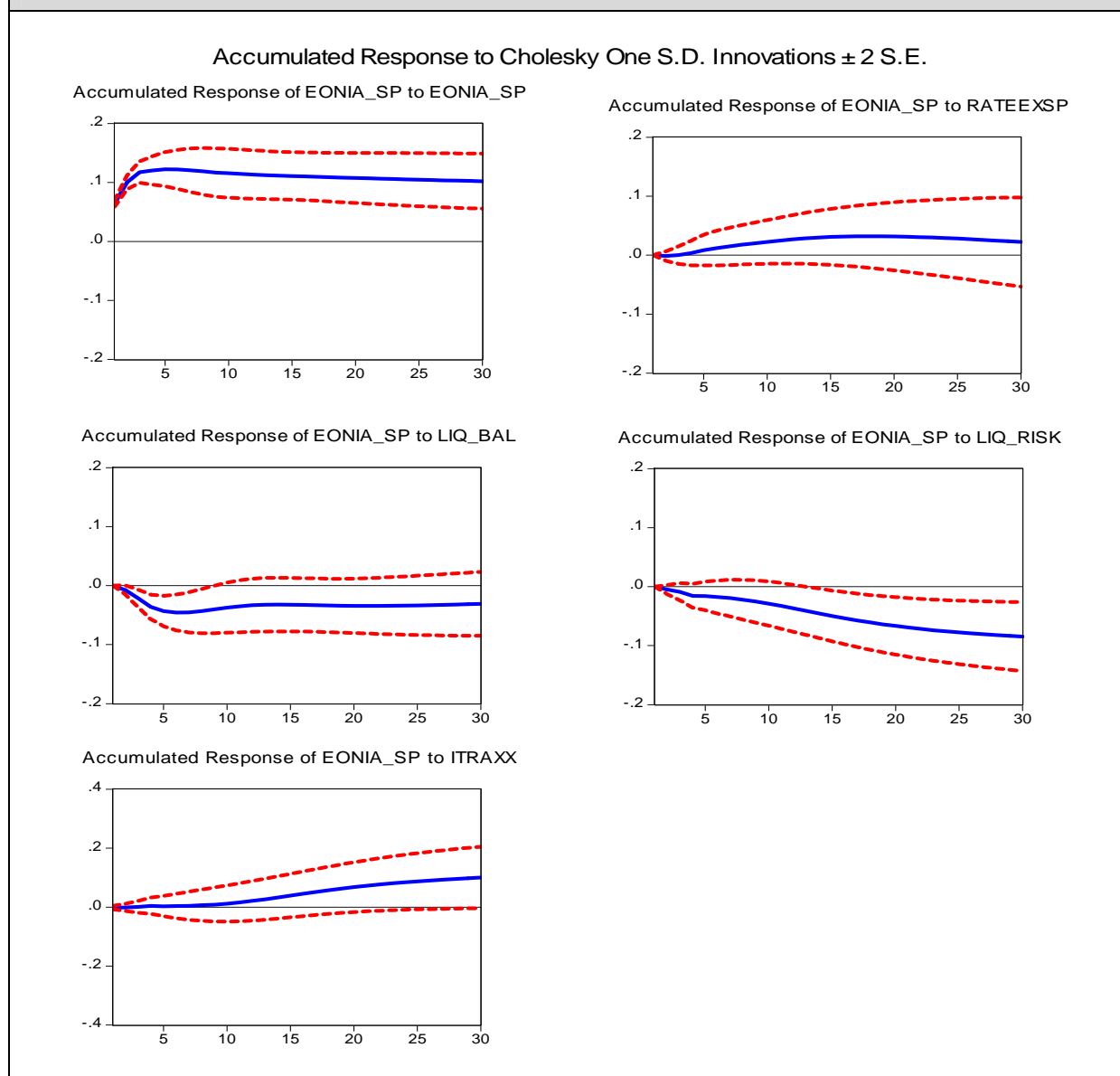
Figure 7 Adjustment of EONIA Spread to Shocks on Explanatory Variables: Pre-crisis



(Note: Percentage shares of the accumulated responses of the EONIA spread to cumulative shocks across each explanatory variable according to Equation 2).

Figure 7 shows that the EONIA spread in the pre-crisis period is only very marginally affected by unexpected temporary shocks imposed on the liquidity balance, liquidity risk, interest rate expectations, and bank credit risk. The adjustment is only significant, however, in the case of the liquidity balance. For example, the EONIA spread adjusts for less than 1% in response to a liquidity balance shock, and full adjustment in the reaction of the EONIA spread to the shock is completed in about 5 days. The low magnitude of the impact of shocks on the EONIA spread in the pre-crisis period is difficult to interpret in terms of deriving a clear policy implication. It can be stated that in normal times, a one standard deviation shock to the liquidity balance has only a marginal effect on the EONIA spread. Thus, in non-crisis times, the response of the EONIA spread appears relatively muted, in line with expectations for this type of regime.

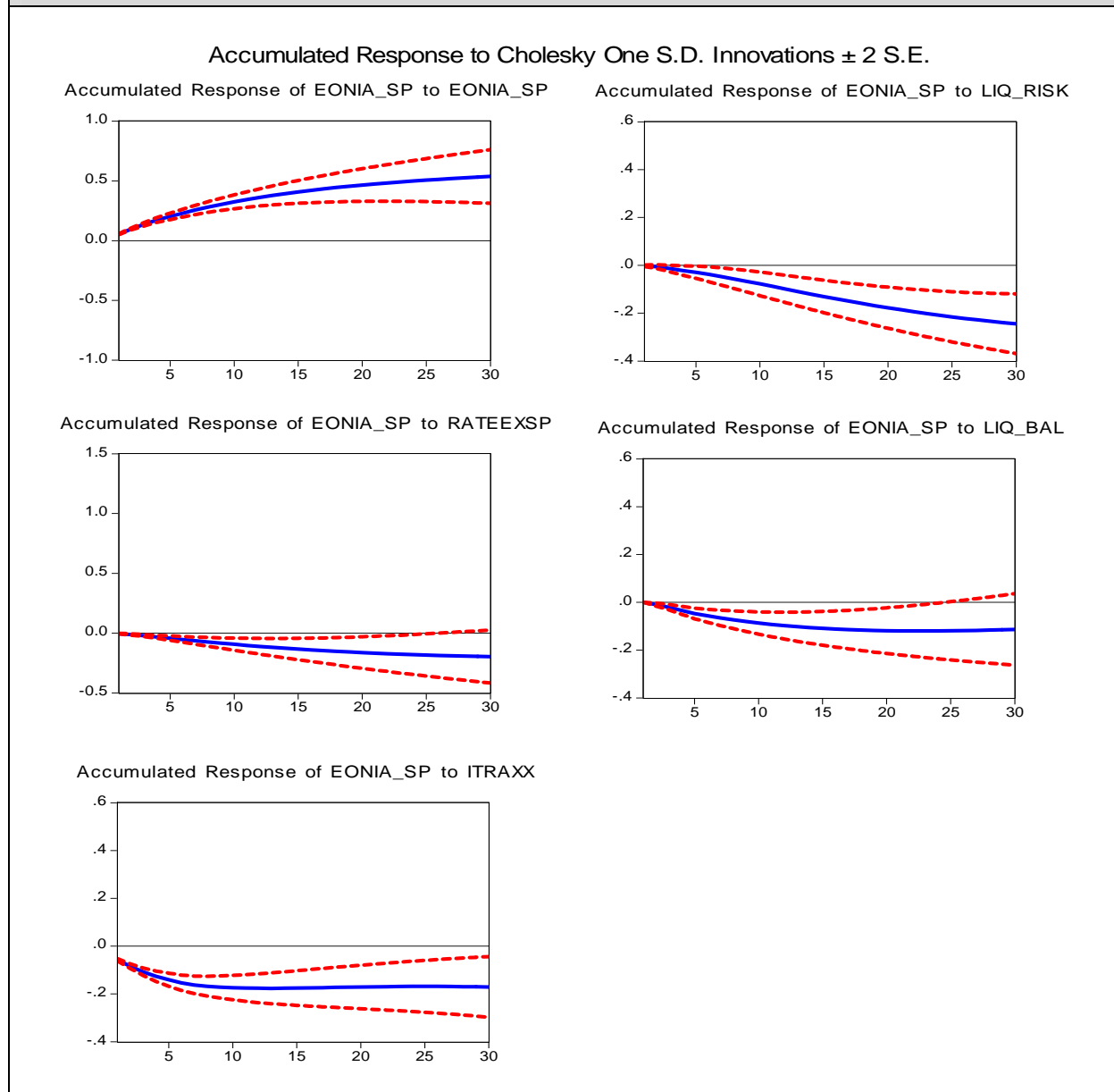
Figure 8 Adjustment of EONIA Spread to Shocks on Explanatory Variables: Less Intense Phase of Crisis



(Note: Percentage shares of the accumulated responses of the EONIA spread to cumulative shocks across each explanatory variable according to Equation 2).

During the initial phase of the crisis, prior to the collapse of Lehman Brothers in mid-September 2008, the response of the EONIA spread to unexpected temporary shocks is somewhat more pronounced than that of the pre-crisis period. For example, a 5% adjustment in the EONIA spread is evident following shocks imposed on the liquidity balance, with full adjustment in 10 days. Compared to the non-crisis phase, it is apparent that as a crisis develops, the EONIA spread becomes more sensitive to one standard deviation shocks on explanatory variables.

Figure 9 Adjustment of EONIA Spread to Shocks on Explanatory Variables: Crisis Post-Lehman Collapse



(Note: Percentage shares of the accumulated responses of the EONIA spread to cumulative shocks across each explanatory variable according to Equation 2).

During the phase of the crisis after the collapse of Lehman Brothers, there is a notably more pronounced magnitude in the response of the EONIA spread to shocks imposed on the

significant explanatory variables, e.g. credit risk. For example, the spread adjusts for about 20% in response to a credit risk shock, with full adjustment to the shock being completed after about 15 days. A liquidity balance shock leads to a 20% spread reaction with full adjustment in about 15 days. Compared to the less intense phase of the crisis, it is clear that the magnitude of the adjustment in the EONIA spread to various liquidity and credit risk shocks is about substantially greater in the post-Lehman phase.

6. Conclusions

An understanding of the factors that affect the EONIA spread in both crisis and non-crisis times is of key importance from a liquidity management perspective. This can help to provide information on which factors should be monitored in order to either reduce the magnitude of the spread or maintain its low level. Traditionally, overnight interest rates have been steered very close to the policy rate, so that the overnight rate anchors the term structure of interest rates. With a low spread between the overnight rate and the policy rate, the monetary policy stance is clearly signalled. When the spread becomes large, as has been the case during the crisis, the stance of monetary policy can become blurred. In an extreme case, it can imply that the central bank has lost credibility and lost control over the first stage of the monetary policy transmission. In the first quarter of 2010, the EONIA rate was some 65 basis points below the policy rate and about 10 basis points above the deposit facility rate. In non-crisis times, the signalling rate of the stance is provided by the minimum bid rate. This may not necessarily be the case in crisis times however. Following the collapse of Lehman Brothers, it became clear that the EONIA rate tracked more closely the deposit facility rate, owing to the liquidity surplus that existed at this time and the dysfunction in the interbank market.¹¹

This paper provides an overview of the drivers of the EONIA spread across non-crisis and crisis regimes. Persistence in the spread is low in the pre-crisis phase compared to the less intense phase of the crisis and the crisis after the collapse of Lehman Brothers. In the pre-crisis phase, the Eurosystem liquidity balance plays a significant role in affecting the spread. This is consistent across the less intense and intense phases of the crisis. Moreover, the coefficient sizes across all three regimes are similar, suggesting that the state of the regime in place (i.e. crisis or non-crisis) does change the influence of the liquidity balance on the spread. This, of course, is in contrast to liquidity and credit risk factors, which change considerably depending on the state of the regime. In particular, in the pre-crisis regime, liquidity and credit risk do not significantly affect the EONIA spread, and this is consistent with expectations in a well-functioning interbank market. In the phase of the crisis before the collapse of Lehman Brothers, both liquidity risk significantly affected the spread. Turning to the intense phase of the crisis, the unlimited supply of liquidity at a fixed rate in Eurosystem refinancing operations meant that liquidity risk was no longer significant in this phase. However credit risk is significant in this phase, as possible fear

¹¹ After the collapse of Lehman Brothers, at the end of September 2008, the 3-month unsecured EURIBOR rate was about 100 basis points above the minimum bid rate in open market operations. In addition, the breakdown of the interbank market at this time caused a substantial hoarding of liquidity by banks, whereby the circulation of money effectively halted as banks borrowed and re-deposited with the ECB. As a result of this, the ECB amended the operational framework for monetary policy implementation that was in place prior to 2004 by providing an unlimited quantity of liquidity at a fixed rate. The policy rate replaced the minimum bid rate. In addition, the standing facilities corridor was narrowed via a reduction in the marginal lending rate. This caused some decline in the EURIBOR rate, although not to the extent that would indicate a recovery in the interbank markets.

of default began to emerge. Interestingly, the (negative) signs on the liquidity and credit risk coefficients accord with expectations. This is related the fact that during both crisis phases, almost all of the activity that took place on money markets did so in the overnight market rather than the term market (i.e. in times of crisis and heightened uncertainty, banks prefer to borrow and lend overnight, thereby reducing risk exposure).

The scale of the response in the EONIA spread to shocks imposed on the explanatory variables is greater than in the pre-crisis phase. This is likely to be related to the development of market tensions and higher volatility, such that the impact of shocks will have a more substantial affect on the spread than in non-volatile market conditions. For example, in the pre-crisis phase, a liquidity balance shock causes a less than 1% reaction in the EONIA spread, with full adjustment complete in about 5 days. This compares to the less intense crisis phase, where a similar shock on the liquidity balance causes a 5% spread response with full adjustment in 10 days. For the post-Lehman phase, the duration for full adjustment is about 15 days but the shock causes a 20% response in the spread. A similar higher magnitude in the response of the spread to shocks is evident across other significant explanatory variables as the state of the regime moves from non-crisis to crisis.

In interpreting the post-Lehman results, it is important to bear in mind that the fixed-rate full allotment procedure in refinancing operations was instrumental in the widening of the spread during this period. As explained in Section 2, this meant that the minimum bid rate in open market operations no longer reflected demand and supply for liquidity. During this time, the EONIA rate tracked more closely the deposit facility rate. Overall, the results from the empirical work are largely as expected. It is evident that banks have some liquidity risk concerns in both crisis and non-crisis times. The main difference in crisis times relates to the role of credit risk and fears of default. Moreover, the EONIA spread appears to react progressively more substantially to shocks as the market environment moves from non-crisis through to the intense phase of the crisis.

The main policy implication from the research is that given the competence that the central bank has in counter-acting liquidity risk (which was eliminated effectively in the period of FRFA), it is clear that no such competence is apparent to address credit risk. This may stimulate some debate on the suitability of targeting the EONIA rate (an unsecured rate) in crisis times and that there may be some merit instead in targeted a secured overnight rate. In this way, the central bank would eliminate credit risk. Going forward, future research may explore the determinants of the spread between the EONIA rate and the deposit facility rate during the intense phase of the crisis. This may help to better approximate any distortions in the signalling of monetary policy given that during the post-Lehman phase of the crisis, the EONIA rate tracked the deposit facility rate rather than the MRO rate. In addition, given the influence of the liquidity balance on the spread across non-crisis and crisis regimes, it would be of interest to examine how the spread is affected by the individual components of the liquidity balance.

References

- Ayuso, J., and Repullo, R. (2003), "A Model of the Open Market Operations of the European Central Bank", *Economic Journal*, 113, pp. 883-902.
- Bartolini, L. and Prati, A. (2005), "Cross-Country Differences in Monetary Policy Execution and Money Market Rates' Volatility", *European Economic Review*, 50(2), pp. 349-376.
- Bindseil, U., Nyborg, K. and Strebulaev, I. (2002), "Bidding Performance in Repo Auctions: Evidence from the ECB Open Market Operations", ECB Working Paper No. 157.
- Breidt, F.J. and Carriquiry, A. L. (1996): "Improved quasi-maximum likelihood estimation for stochastic volatility models", in Jack C. Lee, W.O. and Zellner, A. (eds.), *Modelling and Prediction: Honouring Seymour Geisser*, pp. 228-47. New York: Springer-Verlag.
- Clarida, R.H., Sarno, L., Taylor, M.P. and Valente, G. (2006), "The Role of Asymmetries and Regime Shifts in the Term Structure of Interest Rates", *Journal of Business*, 79(3), pp. 1193-1224.
- Ejerskov, S., Moss, C.M. and Stracca, L. (2003), "How does the ECB Allot Liquidity in its Weekly Main Refinancing Operations? A Look at the Empirical Evidence", ECB Working Paper No. 244.
- Gaspar, V., Perez Quiros, G., and Rodriguez Mendizabal, H. (2008), "Interest Rate Dispersion and Volatility in the Market for Daily Funds", *European Economic Review*, 52, pp. 413-440.
- Hamilton, J. (1996), "The Daily Market for Federal Funds", *Journal of Political Economy*, 104, pp. 26-56.
- Harvey, A. C. (1989): *Forecasting, Structural Time Series Models and the Kalman Filter*, Cambridge University Press, Cambridge.
- Harvey, A.C., Ruiz, E. and Shephard, N. (1994): "Multivariate stochastic variance models", *Review of Economic Studies*, 61, 247-264.
- Hassler, U. and Nautz, D. (2008), "On the Persistence of the EONIA Spread", *Economics Letters*, 101 (3), pp. 184-187.
- Hirsch, A., Holthausen, C., Rieger, F., and Würtz, F. (2007), "Liquidity Effects in the Euro Area", mimeo.
- Kuo, S.H. and Enders, W. (2004), "The Term Structure of Japanese Interest Rates: The Equilibrium Spread with Asymmetric Dynamics", *Journal of the Japanese and International Economies*, 18, pp. 84-98.
- Linert, T. and Schmidt, S. (2008), "What Explains the Spread between the Euro Overnight Rate and the ECB's Policy Rate", ECB Working Paper No. 983.

Moschitz, J. (2004), “The Determinants of the Overnight Interest Rate in the Euro Area”, ECB Working Paper No. 393.

Nautz, D. and Offermanns, C.J. (2007), “The Dynamic Relationship between the Euro Overnight Rate, the ECB’s Policy Rate and the Term Spread”, *International Journal of Finance and Economics*, 12, pp. 287-300.

Nautz, D. and Offermanns, C.J. (2008), “Volatility Transmission in the European Money Market”, *North American Journal of Economics and Finance*, 19, pp. 23-39.

Perez Quiros, G. and Rodriguez Mendizabal, H. (2006), “The Daily Market for Funds in Europe: What has Changed with EMU?”, *Journal of Money, Credit, and Banking*, 38(1), pp. 91-118.

Würtz, F. (2003), “A Comprehensive Model on the Euro Overnight Rate”, ECB Working Paper No. 207.

Appendix

Figure A1 EONIA Spread and iTraxx Index (Senior Financials)

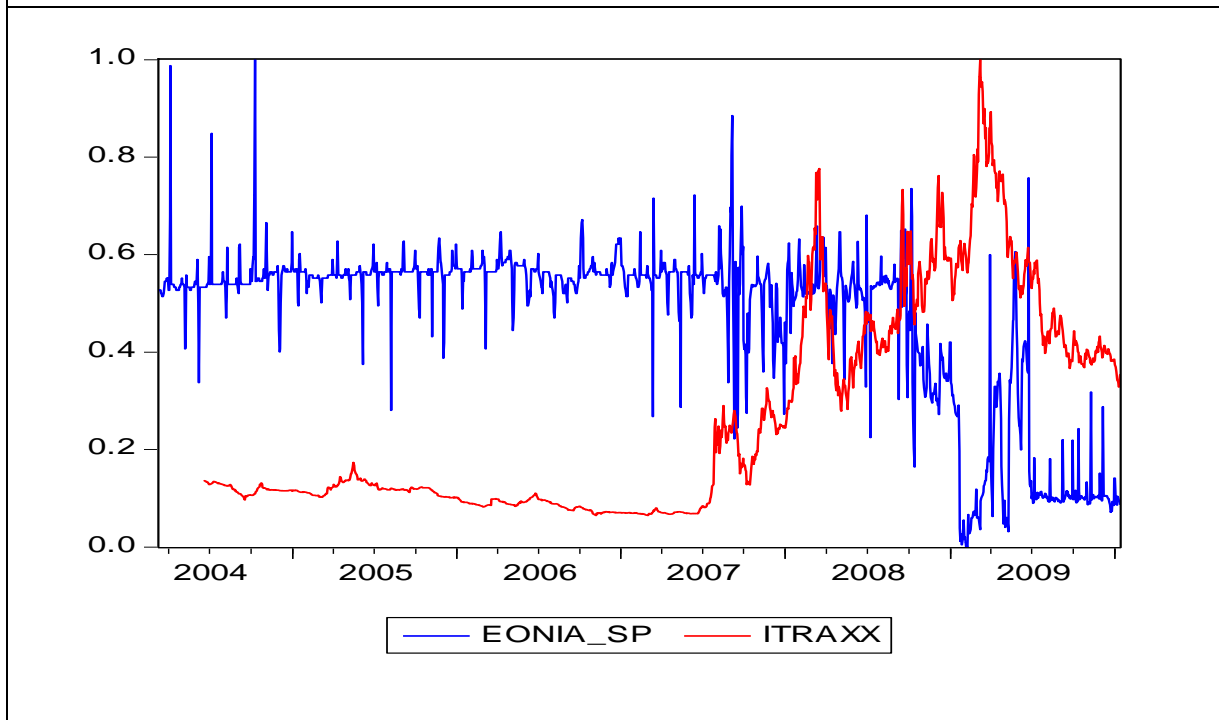


Figure A2 EONIA Spread and Liquidity Risk

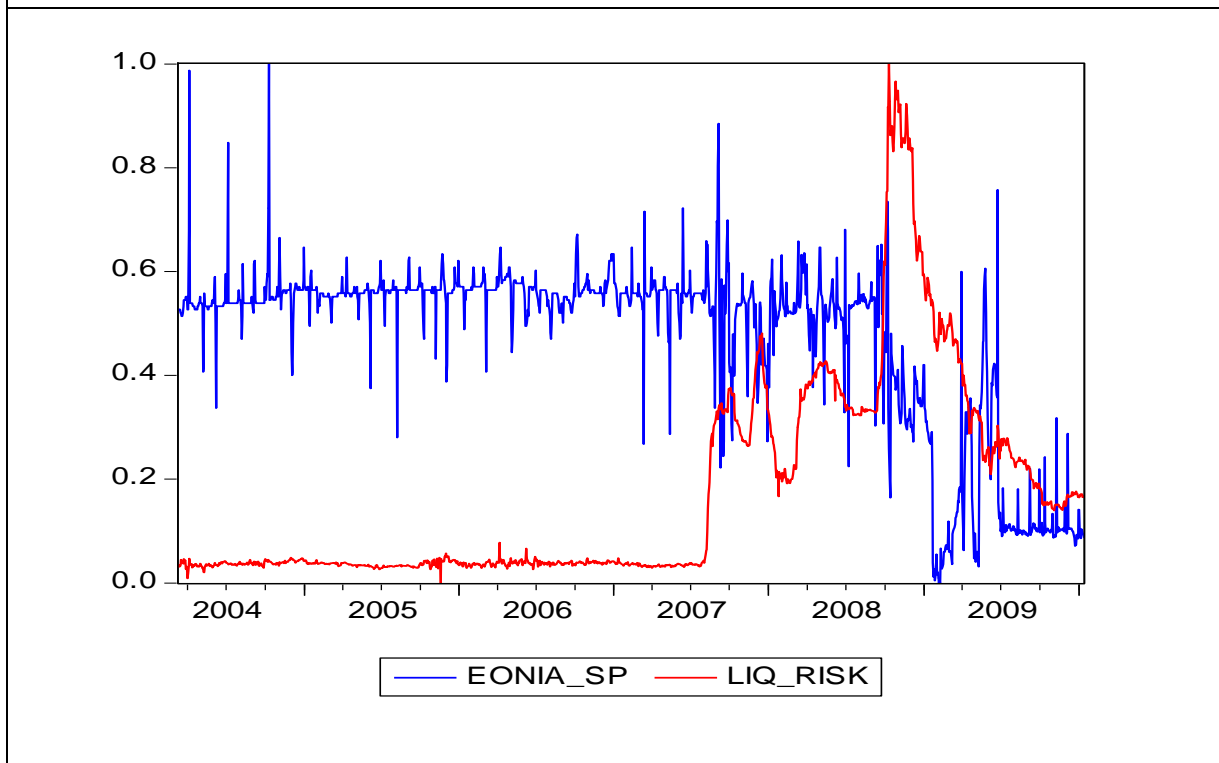


Figure A3 EONIA Spread and Liquidity Balance

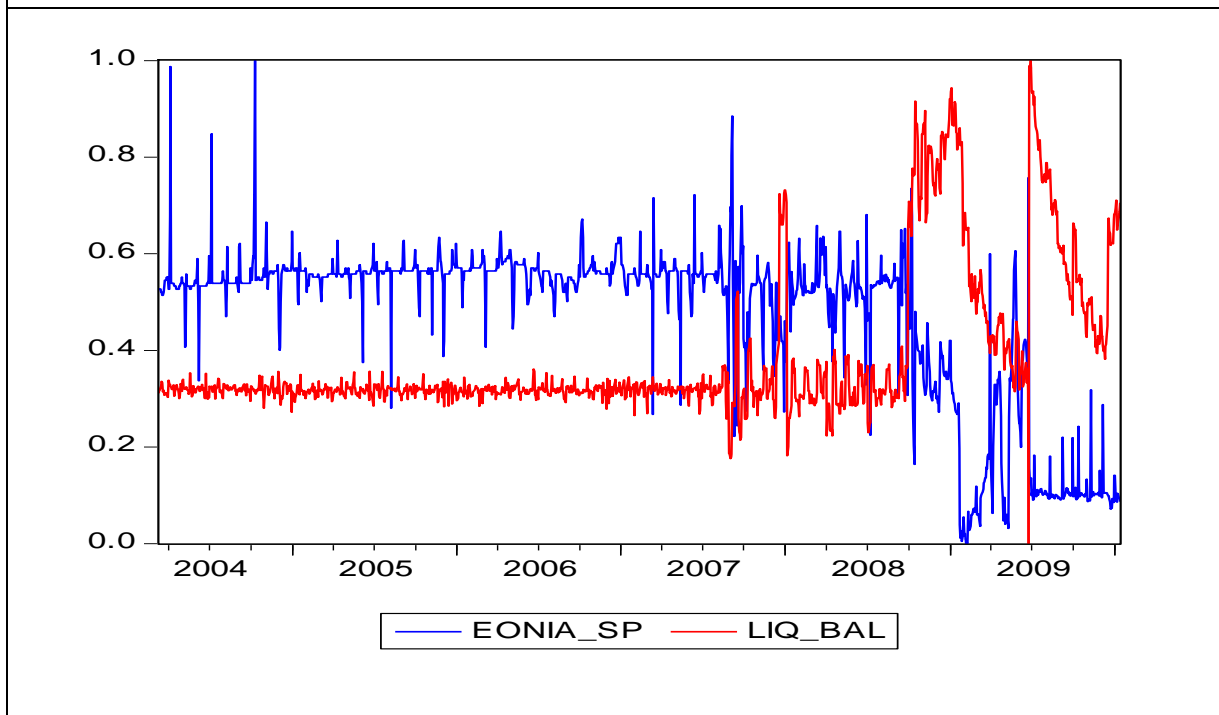


Figure A4 EONIA Spread and Interest Rate Expectations

