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THE INTERBANK MARKET AFTER THE FINANCIAL TURMOIL: SQUEEZING LIQUIDITY IN A "LEMONS MARKET" OR ASKING LIQUIDITY "ON TAP"

by Antonio De Socio*

Abstract

After August 2007 the plumbing system that supplied banks with wholesale funding, the interbank market, failed because toxic assets obstructed the pipes. Banks were forced to squeeze liquidity in a "lemons market" or to ask for liquidity "on tap" from central banks. This paper disentangles the two components of the three-month Euribor-Eonia swap spread, credit and liquidity risk and then evaluates the decomposition. The main finding is that credit risk increased before the key events of the crisis, while liquidity risk was mainly responsible for the subsequent increases in the Euribor spread and then reacted to the systemic responses of the central banks, especially in October 2008. Moreover, the level of the spread between May 2009 and February 2010 was influenced mainly by credit risk, suggesting that European banks were still in a "lemons market" and relied on liquidity "on tap".

JEL Classification: E43, E44, E58, G21.
Keywords: interbank markets, credit risk, liquidity risk, financial crisis, Euribor spread.

Contents

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1. Introduction[♣]

The main purpose of the paper is to analyse developments in the euro interbank market after the financial market crisis beginning in August 2007. The turmoil heavily affected the interbank market, an important source of short-term liquidity for the banking system.[1] A simple picture can render the effects of the crisis, showing the fundamental importance of this plumbing system: the appearance of toxic assets obstructed the pipes because it was impossible to be sure whether the counterparty was a "lemon" or not. Banks were forced to squeeze liquidity in a "lemons market" or to turn to the only source that could provide it "on tap", the central banks.[2]

A widely used measure of the dysfunctions on the interbank market is the spread between unsecured and secured rates, which jumped to historically high levels after August 2007. Before the crisis, the main component was the counterparty risk of the borrower of an unsecured loan. After the turmoil, credit risk augmented because of uncertainty about the financial situation of counterparties due to poor disclosure about losses on structured products; moreover, increased risk aversion contributed to a re-pricing of credit risk. Since August 2007 another determinant of the spread has become important: liquidity risk for the banks increased[3] because market liquidity diminished or even disappeared as a result of asset fire sales and the difficulty or impossibility of calculating some asset prices.

The disruptions on the interbank market have a considerable effect on the whole economy because the price determined in this market affects borrowing conditions for firms and households and could interfere in the normal transmission of monetary policy. Indeed, between August 2007 and May 2009 the spread between unsecured and secured lending for euro, dollar and sterling was over 50 basis points and well above 100 basis points during the six months after Lehman's collapse. Compared with a spread that was as low as 10 basis points before the crisis, the problems on the interbank markets implied a higher cost of financing, which has been cushioned by record-low policy interest rates.[4]

Within the broad background summarized above, the paper has two empirical aims. The first is to disentangle the credit and the liquidity component in the euro interbank market; the results of the decomposition are relevant because central banks can affect only the latter, while credit risk depends on the characteristics of the participants in the market. The second aim is to test the accuracy of this decomposition by linking the two risks to actual financial variables. This assessment is a contribution to the existing literature and is paramount because the two components are obtained through subsequent approximations.

The first objective of the paper is to analyse the three-month Euribor-Eonia swap spread (a measure of the unsecured-secured spread; also called Euribor spread in the paper), which has been disentangled into two main components. The first relates to the credit risk of the banks in the Euribor panel, used as a proxy of counterparty risk in the interbank market; the second relates to liquidity risk, which represents the cost charged by a lender to insure against a liquidity shock during the period in which the loan is outstanding. The credit risk component is derived from CDSs of the banks included in the Euribor panel using a methodology similar to the Bank of England (2007). The liquidity risk is obtained as the difference between

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[1] A synthetic overview of the crisis is presented in Appendix A. See also BIS (2008, 2009), Brunnermeier (2009), and Gorton (2010).

[2] It is important to underscore that central banks can affect interest rates and liquidity independently: injections of liquidity do not necessarily imply a reduction in the policy interest rates and vice versa (e. g. Borio and Disyatat, 2009).

[3] See the Basel Committee on Banking Supervision (2008) for a definition of funding liquidity risk and market liquidity risk.

[4] Before the collapse of Lehman Brothers, three-month sterling Libor was around 6 per cent, three-month Euribor around 5 per cent, and three-month dollar Libor around 3 per cent (it was around 5 per cent before the crisis: the FED had already cut interest rates in 2007); all decreased to less than 1 per cent in the following months.

the Euribor spread and the credit risk. After the decomposition, the link between the intervention of central banks and the dynamics of liquidity risk is described.

An important development with respect to previous literature is the time span under study, which ends in February 2010 and allows an apparently quieter period to be considered. The particular behaviour of the euro interbank market during these months is the reason for the paper's interest in this period. In fact, before the crisis, and even during the most critical moments of the turmoil, the spread for euro interbank loans was lower than the spread for sterling or dollar loans. However, the situation changed between May and July 2009. On the one hand, the spread for sterling and dollar loans continued to decrease, reaching levels similar to those prevailing before the turmoil. On the other hand, the euro spread remained stable at a level around five-fold that prevailing before the crisis and higher than the spread on the other two currencies. A possible explanation for this feature relates to the deeper problems still affecting European banks, which may be reflected in a higher counterparty risk on the euro interbank market.[5] The decomposition of the Euribor spread offers an important indication in this sense because it allows its prevailing component to be identified and gives a different picture for the second half of 2009.

The two research questions based on these dynamics are 1) why did the Euribor spread increase after August 2007 and b) why did it not return to the pre-crisis level in the second half of 2009?

The results of the decomposition suggest that credit risk increased before the most important events of the crisis but that liquidity risk was mainly responsible for the subsequent increases in the Euribor spread and then reacted to the systemic responses of the central banks, especially in October 2008. Moreover, the level of the spread between May 2009 and February 2010 was influenced mainly by credit risk, suggesting that European banks were still in a "lemons market" and relied on liquidity "on tap". These results are robust to different methods. In particular, a stochastic decomposition yields similar results to the deterministic one.

The second objective of the paper is to assess the decomposition by means of an innovative procedure that builds on two considerations. First, the decomposition of the Euribor spread relies on the credit risk measure being representative, which implies it should be as unrelated as possible to liquidity risk, especially during the crisis. Second, market liquidity should influence only the liquidity component of the spread, while risk aversion should be linked essentially to credit risk. The idea behind these two relations is that there exists a positive link between the credit risk of the counterparty in an unsecured transaction and the risk aversion of the lender, the effect of which is to increase this cost component of the loan. Liquidity risk depends instead on the possibility that an eventual liquidity shock cannot be solved on the interbank market and is related to market conditions.[6]

The empirical analysis moves from these two considerations. First, it focuses on the correlation between the Euribor spread, its liquidity and credit component, and measures of risk aversion or market liquidity. They include proxies used in the previous literature and others based on European variables, since the paper focuses on the euro interbank market. As a further robustness check, the correlations are evaluated using univariate time series analysis. The aim of the regressions is not to establish causal relationships, but only to verify the strength of the relations. The regressions are estimated also using GARCH models, owing to the presence of periods of different volatility in the time span under analysis. The use of this model is another improvement on some previous time series analyses. Finally, a derivation of two other measures of liquidity risk is used to assess the one derived as a residual from a deterministic decomposition.

The analyses show that there are only relationships between credit risk and measures of risk aversion, and between liquidity risk and proxies of market liquidity. Liquidity risk is related both to European and US market liquidity, while after the crisis credit risk becomes correlated with measures of risk aversion, both general and specific to Europe. These results somehow change after May 2009, when the

[5] IMF (2010) underscores the greater problems of the euro area due to sovereign risk. Further sources of concern are the financial sector's expected write-downs in 2010 and slow economic growth.

[6] In principle, there is also a relation between risk aversion and market liquidity because a lender can be so risk averse as to decide to exit from the interbank market, thus affecting market liquidity. However, the effects of the single participant should be marginal.

influence of US variables on the Euribor spread or liquidity risk is non-significant, even if credit risk still has a relation with general measures of risk aversion.

The paper is organized as follows. Section 2 surveys the recent literature about the effect of the crisis on the interbank market. The third section presents the dynamics of the rates on the interbank markets and of the variables used in the empirical analysis. The first objective of the paper (the Euribor spread decomposition) is dealt with in the fourth section. Section 5 evaluates the decomposition and Section 6 deals with some additional analyses to test the results. The main findings obtained from the decomposition, as well as those related to its assessment, are summarized in the seventh section, which also contains some concluding remarks.

2. The literature

Analyses of the effect of the turmoil on the interbank market have mainly focused on the spread between the unsecured and the secured rate.[7] This section considers also works about the repo or forex (FX) market, whose problems were also important for the funding of banks. Finally, it summarizes papers about linkages between financial markets.

Many analyses of the tensions on the interbank market have concentrated on the Libor spread, even if it has been observed that the information given by the banks on the panel could be partially biased (among others see Dolan 2008 and Mollenkamp and Whitehouse 2008). There are two possible main reasons for this: 1) each bank is asked the price at which it expects to obtain a loan; 2) the panel is smaller than that of Euribor.

Bank of England (2007) proposed a first decomposition of the Libor spread. The spread relates to overnight index swap (OIS), used as a proxy of the risk-free rate; since policy rate expectations are included both in Libor and OIS, they do not influence the spread. The decomposition relies on credit default swaps (CDSs) of banks in the Libor panel to estimate the credit risk component. As a consequence, the residual of the spread is associated with frictions in the interbank market and liquidity premia. The breakdown of the twelve-month Libor-OIS spread suggests that liquidity risk played a bigger role during August and September 2007, while credit risk represented a larger part of the spread in the fall of 2007, especially in November. Michaud and Upper (2008) find evidence that credit risk is more important for long-term behaviour and point to liquidity factors to explain daily behaviour. They also point out the importance of year-end effects. The results of Taylor and Williams (2009) imply that increased counterparty risk is at the root of the initial enlargement of the spread. Another result of their econometric analysis is that the introduction of the new term auction facility (TAF) was not useful to reduce the spread.[8] Brunetti, Di Filippo and Harris (2009) obtain a similar result. Other studies (e. g. Christensen, Lopez and Rudebusch 2009) analyse the effect of central bank liquidity facilities and find these interventions helped to lower the Libor spread.

The analysis of the effect of the crisis on the interbank market in the euro zone mainly relies on Euribor data instead of the euro Libor rate.

The ECB (2008a) works out a decomposition for the one-month and the one-year spread between Euribor and Eonia swap rates and concludes that concerns about credit risk had a significant and persistent impact on the money markets, while the importance of liquidity risk varied throughout the turbulence. Angelini, Nobili and Picillo (2009) use micro data on Italian interbank transactions collected from e-MID and analyse the determinant of the single bank interest spread on Eurepo before and after August 2007. They find that borrowers' characteristics (rating, size, capital ratio) turn out to be important after the turmoil and that conditions for large borrowers become relatively more favourable. Eisenschmidt and Tapking (2009) present

[7] A description of the main indices used in the literature and in the paper is presented in Appendix B.

[8] They also underline the noise coming out of the comparison between Libor and repo (which can be used as an alternative to the Libor-OIS spread), possibly due to collateral delivery.

some evidence about the role of liquidity risk in the spread between one-year Euribor and Eurepo during the crisis. They also provide a theoretical explanation related to the funding liquidity risk of lenders in the unsecured markets. Nobili (2010) decomposes the one-year Euribor-OIS spread into a liquidity and a credit component and evaluates the effectiveness of ECB interventions. He finds that the role of liquidity risk decreases thanks to the interventions of the central banks, while credit risk becomes the main component of the spread from the winter of 2008.[9]

Other works concentrate on the effect of the crisis on the repo markets, the alternative to OIS as a form of secured lending.

Gorton and Metrik (2009) analyse the connections between securitization, financing through the repo market and the role of haircuts on the collateral used in these funding operations. They report a correlation between changes in the Libor-OIS spread and changes in credit spreads, repo rates, or repo haircuts on non-subprime AAA securitized assets, but no correlation between these three measures and the subprime housing market. They conclude that the uncertainty about the counterparty risk in repo transactions led to fears that liquidity would dry up for (high quality) collateral, causing an increase in the repo haircuts. Hördahl and King (2008) describe the main developments in the repo markets during the turmoil and try to explain the differences between the US, euro area and UK. The effects on the repo-OIS spread were different. The crisis caused the largest disruptions in the US market, while conditions in the euro area were less tense, possibly thanks to a broader range of collateral and counterparties accepted by the ECB and a greater availability of government collateral. The increase in demand for US treasury bonds (especially from investment banks, which financed their assets mainly in the repo market) reduced the General Collateral Repo rate with respect to OIS, partly because of the scarcity of treasury bonds after September 2008. In the euro area and the UK the increased demand for cash is at the root of the rise in repo rates, which was higher than in OIS. Moreover, the heterogeneity of the collateral could explain the increase in Eurepo rates: a sign of this process is the increased spread between bonds of marginal or riskier countries and German bonds.

Some papers underscore the importance of the links between the turmoil in the interbank market and the FX market. The tensions originated in the US and quickly affected many European institutions, which had to finance long-term investments in dollars without the possibility of rolling over short-term dollar borrowing in the interbank market (BIS 2008; McGuire and von Peter 2009a and 2009b).[10]

Baba, Packer and Nagano (2008) propose an analysis of the spillovers between the two markets during the turmoil. The presence of demand for dollars resulted in market deviations from covered interest parity (CIP), which is linked to the tensions in the interbank market. Baba and Packer (2009a) develop an empirical analysis of the CIP violation on the FX market between euro and dollar before the failure of Lehman Brothers. Two main hypotheses are tested: the importance of the perception of the relative counterparty risk between US and European financial institutions and the role of the ECB's dollar term funding auctions. They report that measures of relative counterparty risk and broad spread on the interbank markets explain CIP deviation during the turmoil and that ECB auctions reduced volatility. Baba and Packer (2009b) extend the time span of the analysis to include the deviation from the CIP between dollar and pound or Swiss franc and find stronger effects of the intervention of central banks after Lehman.

Another strand of literature evaluates the effect of the crisis using a systemic approach, seeking the linkages between financial markets (IMF 2008a and 2008b).

Frank, González-Hermosillo and Hesse (2008) use a Dynamic Conditional Correlation GARCH approach to model the transmission across the different segments of the US financial markets from the beginning of 2006 to the end of 2007. They report an amplification in the correlation between market and funding liquidity risk and an increase in the importance of bank solvency after July 2007. The IMF (2008b) uses a SVAR model to decompose the different components of the Libor spread. The variables included are a

[9] The results are obtained using two approaches: a) derivation of credit risk from one-year CDSs of the banks in the Euribor panel using a stochastic probability of default (liquidity risk is derived as a residual); b) derivation of a liquidity component using a methodology similar to Christensen, Lopez and Rudebusch (2009), augmented by a risk-free rate identified with the Eurepo.

[10] The importance of this issue is shown by the decision of the FED, in December 2007, to establish dollar swap lines with fourteen other central banks. For a synthesis of the subsequent decisions and some empirical analysis, see Goldberg, Kennedy and Miu (2010).

joint probability of distress of a group of systemically important banks as a measure of credit risk and five other variables added to disentangle liquidity and volatility risk. The findings underline the influence of credit risk on the volatility of the dollar spread and the role of the FX market in the euro and sterling spread.

The paper combines various parts of the former literature to reach its two objectives. It relies on similar methods to those presented at the beginning of this section to reach its first aim: disentangling the credit and liquidity risk of the Euribor spread. The second aim is to assess the decomposition, taking into account the analysis of the repo and the FX market and the analysis of the linkages between financial markets. In particular, some of the variables used in previous works are added as a control of those introduced in the paper. All of them are presented in the following section.

3. Data and variables

The data source of all the variables used in the paper is Bloomberg.[11] The time span ranges from January 2, 2004 to February 26, 2010 and the total observations amount to 1606 days. This time horizon allows the main events of the turmoil to be included and also excludes the effects of the most critical months of 2010 owing to the sovereign debt problems in Europe. These marked the start of another phase of the crisis and prevented the implementation of the "exit strategy", the buzz word in the second half of 2009.

The beginning of the crisis is set in August 6, 2007, the day on which the Euribor-Eonia swap spread reached a value well above the 99th percentile of its distribution before the crisis and also the first day of the week in which BNP froze redemptions for three investment funds related to subprime products.[12] Another important cut-off date is September 15, 2008, when Lehman Brothers collapsed. Hence the dataset includes 936 observations before the crisis and 670 after it began; 380 of these days follow the failure of Lehman Brothers.

3.1 Euro, dollar and sterling interbank markets

The main variable of interest is the spread between three-month Euribor and Eonia swap (*eurspread*).[13].

These interest rates are selected to take into account some issues raised in the literature that is summarized in Section 2. Euribor has been chosen because of the distortions potentially affecting Libor, while the Eonia swap is used to avoid the possible effects of collateral heterogeneity on the Eurepo rate. The paper focuses on the three-month duration because interest payments on loans, mortgages and bonds are usually indexed to the three-month Euribor rate; hence the analysis focuses on an interest rate with a stronger effect on the real economy. In these respects the paper also differs from other similar works, which focus on the Libor spread or Euribor-Eurepo spread or which analyse one-month or one-year spreads.

The dynamics of the Euribor spread during the crisis are shown in Section 4.1, together with its decomposition in a credit risk and a liquidity risk component. In this section a more general comparison is made with two other interbank markets. Figure 1 illustrates the dynamics of the three-month unsecured-secured spread for euro, dollar and sterling loans.

The analysis of the three time series is useful to recognize an important change that occurred after the deeper phase of the crisis. The Euribor spread averaged less than 6 basis points before the turmoil, below the analogous spread in dollar and sterling (9 and 11 basis points respectively). The spread in the euro interbank market remained lower even after the beginning of the crisis and in the months following the collapse of Lehman Brothers. However, by the end of May 2009 the dollar spread became smaller and at the end of July the sterling spread, too, became lower than the Euribor spread. In the last months of the time span examined the other two spreads reached levels similar to those prevailing before the crisis, while the

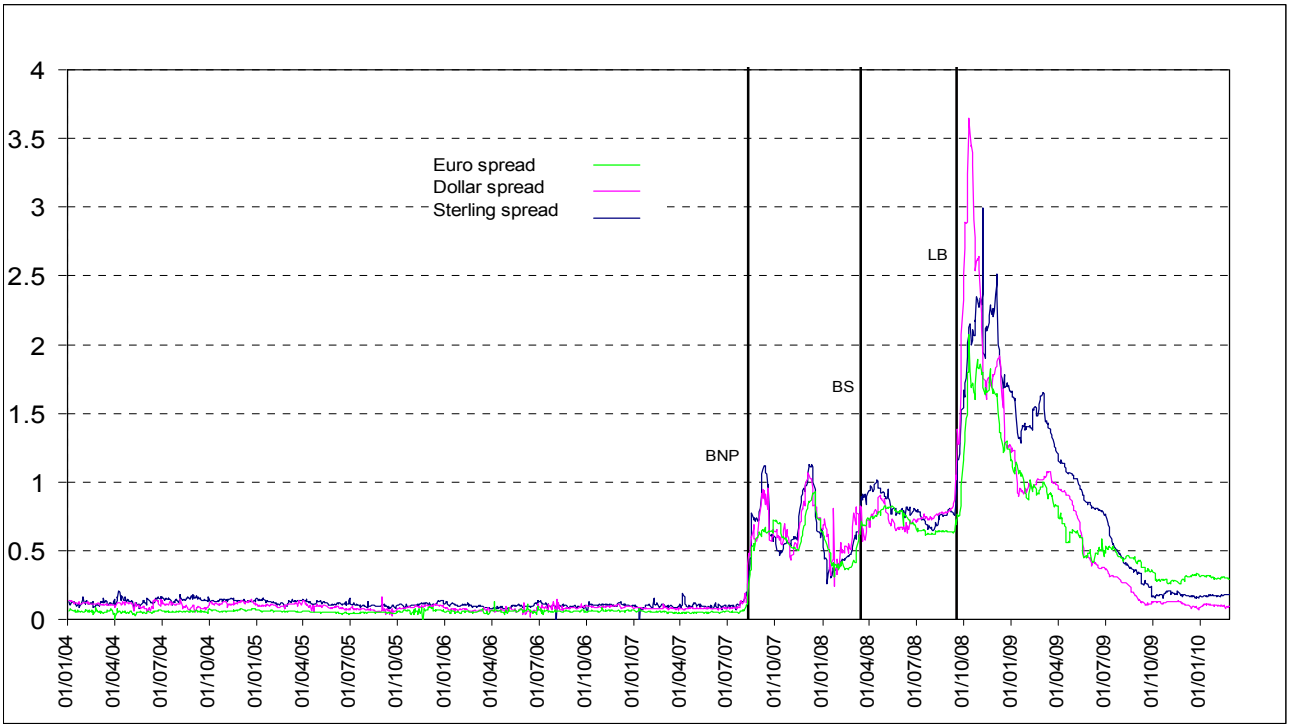
[11] The graph and some descriptive statistics of the variables are reported in Appendix C.

[12] The event took place on August 9, 2007, the day usually taken as the starting point of the turmoil.

[13] The qualitative results are similar when one-month or six-month periods are considered. As noted also by the ECB (2008a), shorter maturities are more influenced by liquidity risk, while credit risk has a stronger role in longer maturities.

Euribor spread was still 4-5 times higher. Its features during the turmoil are reflected in the increase in its average value (12 times; 8 times for the dollar spread) and standard deviation (36 times; 30 times for the dollar spread).

Figure 1. Tensions on the interbank markets: three-month unsecured-secured spreads



Note: BNP is August 9, 2007; BS is March 14, 2008; LB is September 15, 2008. Secured rate is OIS.

To summarize, two research questions follow from Figure 1:

1) why did the Euribor spread increase after August 2007?

2) why did it remain well above its pre-crisis level after May 2009?

The answers to these two related questions are provided by the role of credit risk and liquidity risk during the different phases of the crisis; the results presented in Section 4 offer a possible explanation of the dynamics of the Euribor spread.

3.2 Risk aversion and market liquidity measures

Credit risk is related to the possibility that the borrower will not repay the loan. An important but specific determinant is the (perceived) condition of the debtor. A more general influence is played by the risk aversion of the lender and, more broadly, of the financial markets.

Five variables are used as proxies of risk aversion. Three of them are related to the European market; one of these is derived from banks' CDSs.

The first variable is the one traditionally used: the Chicago Board of Options Exchange Volatility Index (*VIX*), a measure of the implied volatility priced into S&P 500 equity index options. Its mean was around 14 before the crisis and doubled after it, reaching 80 after the collapse of Lehman Brothers.

Another measure of risk aversion for the turmoil period is the exchange rate between the Swiss franc and the Australian dollar (*auch*). It reflects the role of the former as a "safe haven" currency in carry trade transactions, which resulted in a strong appreciation of the franc during the deeper phase of the crisis (see also Kohler 2010).

The third measure tries to proxy the risk aversion induced in the euro-area interbank market by the increased uncertainty about the soundness of the counterparties. The variable is the coefficient of variation of

credit spreads of Euribor panel banks (*Coef. Var.*), calculated in the following section.[14] The underlying idea is that greater heterogeneity among the banks in the panel increases uncertainty about the counterparties and is then correlated with risk aversion. It is important to underline that *Coef. Var.* gives different results with respect to VIX: the dispersion was very low around the period of Bear Sterns failure, it increased in September 2008 and reached historically high values in March and July 2009. This finding pointed to a need for more careful assessment of the interbank market counterparty, leading to increased risk aversion.[15]

Two other proxies of risk aversion are derived from government bonds of European countries. The first is the ten-year spread between Italian and German bonds (*itge10*). The rationale for this measure is that German government debt is a safe haven among European countries, while Italy has one of the biggest and most liquid government bond markets, around 50 per cent of which is owned abroad. A widening of the spread between these two important bonds in the European market can be seen as a signal of a flight to quality. The spread increased before the main events of the crisis (August 2007, Bear Sterns, Lehman), but reached record level around the beginning of 2009. The paper also considers the spread between Greek and German bonds (*grge10*) because it has been the highest historically and could be very sensitive to changes in market aversion to risk. It also allows the inclusion of the uncertainty stemming from the sovereign risk in Greece, which started to be an element of deep concern in the last months of 2009. It should be underlined that these two measures are related to risk aversion, but they depend also on the different (perceived) credit risk of the countries and on their debt liquidity. These two elements could represent a problem for the Greek spread as a measure of risk aversion, while the liquidity of Italian bonds and the relative reliability of its credit rating should allow them to be overcome for the Italian spread.

Liquidity risk measures the difficulty a bank might have selling its assets at a reasonable price if it needed funds when only the markets for some assets (typically AAA government bonds) are liquid. The paper considers five measures of market liquidity.

The first is an innovative proxy of the liquidity in the euro-area interbank market: the spread between three-month Eurepo and Eonia swap rates (*repo_eonia*). Since both are prices for secured transactions, the difference should be very small, and in fact before the turmoil it was close to zero. After the crisis its mean increased to 2 basis points and the spread reached a peak of more than 10 basis points in the weeks after the collapse of Lehman Brothers. The rationale behind this behaviour is the heterogeneity of the collateral used in Eurepo transactions (euro-area government bonds), which increased the liquidity risk of this alternative secured market (see Hördahl and King 2008).

The paper also considers measures of US market liquidity, which have been extensively used in the literature (e. g. Frank, González-Hermosillo and Hesse 2008; IMF 2008b) because dollar-denominated assets were the main source of the turmoil. It should be noted that these measures are included in the paper to take account of the problems in the respective markets, but they also incorporate a credit risk component.[16] In particular these variables are:

a) the three-month dollar Libor-OIS spread (*usspread*), which takes into account the tensions on the dollar interbank market;

b) the three-month Ted spread (*ted*), which is the difference between dollar Libor and treasury bills, to take into account the preference for US government bonds with respect to lending on the interbank market;

c) the three-month spread of asset-backed commercial paper on treasury bills (*abcp*), which proxies the stress on banks' liquidity coming from the refinancing of Special Purpose Vehicles (SPV).

These three measures show some common dynamics: great volatility in the period of the crisis before Lehman Brothers, after which they reached record high levels; from the second half of 2009 they were back to pre-crisis level. It is worth noting that the standard deviation of *usspread* increased nearly 30 times during the crisis, the highest value of all the variables considered.

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[14] It is the coefficient of variation of all banks' spreads, calculated for each bank as in formula (3).

[15] It should also be noted that increased dispersion could signal greater difficulty finding a "good" counterparty on the interbank market, thus affecting market liquidity.

[16] During the most critical phases of the crisis the variables should proxy mainly liquidity problems on these markets.

A fifth proxy of liquidity risk is derived from the FX market: the three-month deviation from covered interest parity for the euro/dollar exchange rate (*cip*), which measures the tensions caused to European banks by the need to find dollars for their controlled vehicles (e. g. McGuire and von Peter 2009a and 2009b). It is calculated as follows:

$$(1) \qquad cip = F_{3m} - S * \frac{(1 + \$libor_{3m})}{(1 + €libor_{3m})}$$

in which F_{3m} is the three-month forward rate, S is the spot rate, and $\$libor_{3m}$ ($€libor_{3m}$) is the interest rate for a three-month loan in dollars (euros). Before the crisis the possibility of arbitrage was basically zero, while during the turmoil the difference was on average 80 times larger.[17] At the beginning of 2010 the level was still well above the pre-crisis value.

To summarize, there are five proxies for both risk aversion and market liquidity, which will be used for the analyses presented in Sections 5 and 6. Some of them are used in previous works on the interbank market, while others are innovative and more related to the European context. The most important variables in this sense are the spread between Italian and German bonds and the coefficient of variation of the spreads of Euribor panel banks as proxies of risk aversion; and the Eurepo-Eonia swap spread as a measure of market liquidity. The other variables are included more to control the results obtained with these main ones.

4. Euribor-Eonia swap spread, liquidity risk and credit risk

The aim of this section is two-fold. First, it decomposes the Euribor spread into a credit and a liquidity risk component and evaluates their relative importance during the crisis. Second, it relates the interventions of the ECB and other central banks with the dynamics of liquidity risk.

4.1 Disentangling credit risk and liquidity risk

The first step in decomposing the Euribor spread is to derive its credit risk component from CDSs of the banks included in the Euribor panel. The methodology is similar to that of the Bank of England (2007); one difference with respect to this and previous works is the use of five-year CDSs, which is the most liquid maturity and best reflects credit risk. As stated by the ECB (2008b, page 2): "The 5 year CDS are selected since they represent the most liquid CDS instruments and should be applied regardless of the maturity of the debt instruments which are guaranteed".

The use of this methodology requires a series of caveats. Among them it is important to remember that a) the pricing model of a CDS implies a recovery rate in case of default of 40 per cent, which could differ from the actual one; b) the pricing of a CDS assumes risk-neutral probability, which could be a strong hypothesis, especially during the most critical phases of the turmoil; c) the CDS market could be affected by liquidity effects;[18] and d) the characteristics of the sellers of the protection could affect the prices (CDS spreads may go down if the probabilities of default of the protection sellers go up), although this problem should be reduced by the collateral usually required in such contracts. Even bearing in mind these potential weaknesses, CDSs seem to be an adequate instrument for detecting credit risk with sufficient approximation. The greatest problem concerns the liquidity of the market (c), which could cause an overestimation of credit risk; the characteristics of protection sellers (d) should instead move the price in the opposite direction. The analyses presented in the following sections support the hypothesis that the influence of liquidity is limited and that the measure of credit risk derived from CDSs is a good approximation.

In addition to these theoretical problems, there are also practical ones. Time series of CDSs for all 43 banks in the Euribor panel are not obtainable from Bloomberg, as there are data only for 36 of them. There

[17] During the crisis the exchange rate was 1.43 and the deviation from CIP 0.0012 (on average). This gives the possibility of a "risk-free" profit of slightly less then 0.1 per cent.

[18] Longstaff, Mithal, and Neis (2005) found that most of the spread is due to default risk.

are 25 banks for which CDSs are available for almost the whole period, and 28 for which the time series cover nearly all the days after the beginning of the crisis.[19] However, the presence of data for a majority of banks could be considered a potential advantage because it allows only the most traded CDSs to be taken into account and limits liquidity problems. A possible alternative would be to require quotations for some banks directly from market makers. However, this would introduce heterogeneity in the price providers.

The credit risk is calculated as follows. For each bank *i* and day *t*, the implicit probability of default ($PD_{i,t}$) in the next three months is derived using a simplified approach which relies on a flat CDS curve:

$$PD_{i,t} \approx 1 - e^{\left(\frac{-CDS_{i,t}d}{1-R}\right)} \tag{2}$$

in which $CDS_{i,t}$ is the CDS spread of bank *i* on day *t*, d=0.25 (since the time spell is a quarter) and *R* is the recovery rate in case of default, which is assumed to be 0.4.[20] The formula is the same as that derived in Hull (2006, page 483); there the average default intensity corresponds to the ratio *CDS/(1-R)*. The logic behind the formula is similar to that of the derivation of a three-month interest using a five-year interest rate, with continuous compounding in the hypothesis of a constant interest rate.

A simple arbitrage relation serves to derive the spread applied to an unsecured loan (calculated on the secured lending rate, in this case the Eonia swap) for bank *i*, which is equal to the expected loss:

$$Credit\_spread_{i,t} = PD_{i,t}(1-R) \tag{3}$$

The credit component of Euribor is represented by the mean of the spreads of all the *n* banks in the panel for which it is possible to calculate (3) on each single day.[21] The liquidity risk is then derived as a residual component.

$$Credit\_risk_t = \frac{\sum_{i=1}^{n} Credit\_spread_{i,t}}{n} \tag{4a}$$

$$Liquidity\_risk_t = Euribor\_spread_t - Credit\_risk_t \tag{4b}$$

The rationale behind the decomposition is that an unsecured loan exposes the lender to two risks: 1) the insolvency of the borrower (credit risk), and 2) the possible need for liquidity during the period in which the loan is outstanding (liquidity risk).[22] A secured loan has a collateral or some mechanism of guarantee such that the lender is protected from both risks. If the interbank market is working perfectly, liquidity risk is zero and the spread between the unsecured and the secured rate is equivalent to credit risk; this difference should be equal to the cost of the insurance that a lender can obtain buying a CDS on a representative "prime bank" of the Euribor panel.[23] In this sense, the residual difference between the unsecured-secured spread and the credit risk component represents the liquidity risk: it is the cost a borrower in an unsecured lending has to pay to compensate the lender for bearing the risk of not being able to obtain a loan in case of a need for liquidity.

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[19] A detailed description of the Euribor panel and of banks' CDSs can be found in Appendix D.

[20] This value is commonly assumed. In any case, the calculation of the CDS spread is not very sensitive to the recovery rate (Hull 2006, page 513). The results of (3) are basically unchanged if the recovery rate is assumed to be 0.3.

[21] If only the 25 banks with complete data are used the results are nearly identical. After the crisis, the average for this sample is less than 1 basis point lower; the correlation on levels and first differences of the two series is close to 1.

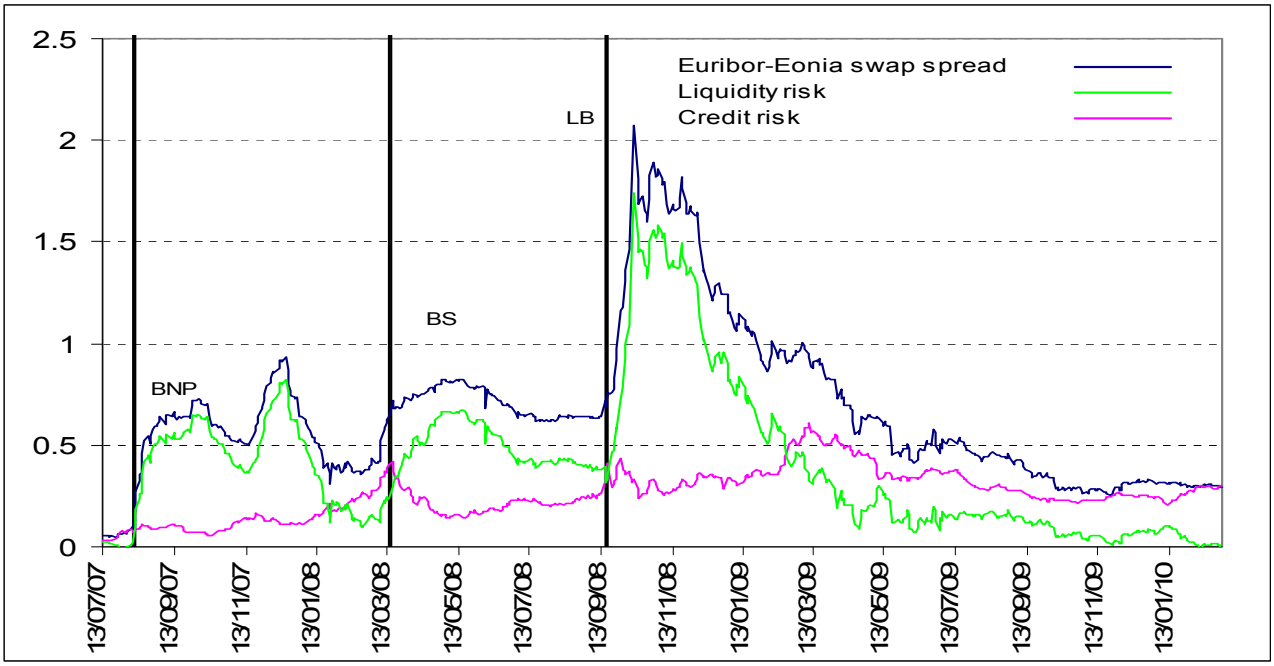
[22] A theoretical model of this decomposition is presented in Eisenschmidt and Tapking (2009).

[23] A more precise derivation should exclude the upper and lower quartile of the panel, as in the calculation of the Euribor. An approximation could be to use the median to derive credit risk in formula (4a), as in Section 6.

It is important to stress that the results of the analysis in Section 5 allow a stochastic decomposition to be derived as well and that the liquidity component is very similar.

The decomposition obtained for the crisis period is presented in Figure 2 and is used to evaluate the role of the two risks involved in an unsecured lending in the interbank market as opposed to a secured one.[24]

Figure 2. Euribor spread decomposition after the turmoil



Note: BNP is August 9, 2007; BS is March 14, 2008; LB is September 15, 2008.

At first glance it is straightforward to derive an important feature of the turmoil period: the change in the relative importance of the two components during the time span under analysis.[25] More in detail, it is possible to distinguish eight periods in which the relative importance of the two risks changed:

1) at the end of July 2007 *credit risk* augmented sharply and was the predominant component of the spread;

2) after the beginning of the crisis *liquidity risk* jumped and the spread reached more than 90 basis points in mid-December 2007, before coming down in the following month after the first coordinated intervention of central banks;

3) after mid-January 2008 the spread remained constant for nearly two months, due to falling liquidity risk and increasing *credit risk*, which reached a new peak around the time of Bear Sterns' collapse;

4) from mid-March 2008 *liquidity risk* increased and the Euribor spread arrived at around 80 basis points in May, before decreasing slightly during the summer;

5) a few days before the collapse of Lehman Brothers *credit risk* started to increase;

6) after Lehman *liquidity risk* sky rocketed and became the predominant component of the Euribor spread until February 2009;

7) *credit risk* increased until mid-March 2009, when the central banks introduced stronger unconventional policy measures (e.g. purchases of long-term bonds from the FED in the US; quantitative easing in the UK; further special longer-term refinancing operations from the ECB) and data on the favourable performance of the financial sector were released (they also fuelled a rally in equity markets);

8) after March 2009, both the components became smaller and at the end of July 2009 the spread returned to the lowest level since the beginning of the crisis. However, the reduction was the result of a strong decrease in *liquidity risk*.

[24] The complete time series is reported in Appendix C.

[25] The decomposition applied to the period before the crisis indicates that credit risk (3.1 basis points on average) was greater than liquidity risk (2.6 basis points on average), whose importance increased from 2006.

This historical overview shows that credit risk is a measure of tensions that has anticipated the main events (beginning of the turmoil, Bear Sterns, Lehman Brothers). It also suggests that credit risk was perceived to be high before the introduction of unconventional policies and the release of improved financial sector results in March 2009. Liquidity risk was the most important driver of the Euribor spread and it has been affected by the main events of the crisis and then by the systemic response of central banks around the world, especially in October 2008.

The situation during the first months of 2010 was the outcome of the huge effort by central banks around the world to inject liquidity and to insure assets, which reduced liquidity risk to the lowest level since the beginning of the turmoil. But credit risk remained well above its pre-crisis level, a signal that the counterparty risk in the euro interbank market was still high.

Further support for the idea that European banks have deeper problems than US or UK banks can be derived indirectly from the difference between three-month Euribor and three-month euro Libor. These two rates were basically the same until July 2009, when the difference increased to around 2 basis points; the spread widened further to more than 4 basis points after September 2009. Since one of the differences between these two rates is the panel of banks quoting them, it could signal that the risk of an interbank loan in euros to a panel of (mainly) European banks is greater than to a panel of international banks.

The results of the decomposition are very important because they show that the central banks were successful in reducing liquidity risk (and raise a question about what could happen when exit strategies are implemented), but also that the banks were not yet considered as reliable as they had been before the crisis. To recall the image proposed at the beginning of the paper, it is likely that the Euribor spread is "low" because banks have the alternative to demand liquidity "on tap" from central banks and to avoid the (still high) counterparty risk associated with participating in a "lemons market". But if the interbank market is working better mainly thanks to the intervention of central banks, it means that the main problems of its participants have not yet been solved. These findings help to explain the particular dynamics of the Euribor spread observed in Figure1 since the second half of 2009.

4.2 Liquidity risk and the intervention of central banks

The liquidity risk is the cost a lender charges in an unsecured loan to insure against a liquidity shock; this price could be affected by the interventions of central banks because they are the alternative to which banks can turn if the interbank market is not functioning properly. The existence of a relation between the most important actions decided by the central banks during the crisis and the changes in liquidity risk is evident in Figure 2. In fact, there are some distinctive moments characterized by a strong increase in liquidity risk, followed by a sharp decrease: December 2007, October 2008, and May 2009. The ECB and other central banks intervened during these periods respectively with US dollar TAF, special measures following the collapse of Lehman Brothers, and further actions taken by the ECB in May 2009.[26].

Table 1 examines the relationship in greater detail. It reports a) the evolution of liquidity risk before the announcement of the interventions (the number of days in which the changes were positive and the cumulative change in the level); b) the level reached by liquidity risk (and the Euribor spread) on the day considered, which always corresponded to or was near a local maximum; and c) the number of days in which the change was negative and the cumulative difference in level in the following twenty or fifty days. The events taken into account are the announcements of the TAF, of the fixed rate operations with full allotment, and of the beginning of one-year longer-term refinancing operations. In this case the settlement day of the first auction is also considered, since it happened seven weeks later.[27]

Liquidity risk increased on nearly all the days preceding the announcements; during each time spell it nearly doubled, contributing to increase the Euribor spread. The effects of the actions of central banks are pretty clear. In the twenty days after the announcement of the TAF, the increase in liquidity risk was

[26] ECB operations are summarized at www.ecb.int/mopo/implement/omo/html/index.en.html.

[27] If settlement days instead of announcement days are considered in the two other cases, the results are basically unchanged.

counterbalanced. In 2008 it took more time to offset partially the consequences of Lehman Brothers' collapse: fifty days after the introduction of a new auction type, liquidity risk decreased by only 59 basis points.[28] In both cases it must be noted that liquidity risk continued to decrease in the following weeks as well. The intervention of the ECB in May 2009 happened in a context of lower liquidity risk and allowed another important result to be obtained: in the following twenty days liquidity risk decreased by 19 basis points, reaching the lowest level since the beginning of the crisis. The settlement of the first one-year auction further reduced liquidity risk, even if the effect was somehow smaller due to the fact that the level was already very low.

Table 1. The intervention of central banks and liquidity risk dynamics

		Before		**Day of ann/settl**		**20 days after**		**50 days after**	
		Positive change		*Level*		*Negative change*		*Negative change*	
		# days/ TOT	D.Liq TOT	Liq Risk	Euribor spread	# days	D.Liq TOT	# days	D.Liq TOT
	TAF								
Announcem	12 December 2007	18/20	39	81	92	18	-41	-	-
	Fixed rate&full allottment…								
Announcem	08 October 2008	16/20	75	146	180	9	8	30	-59
	… and 1 year								
Announcem	07 May 2009	7/10	14	28	64	12	-19	29	-11
Settlem	25 June 2009	11/20	9	38	56	11	-3	23	-3

Note: The local maxima of liquidity risk were respectively on December 12, 2007; October 10, 2008 (174 bps); May 8, 2009 (30 bps); and June 23, 2009 (38 bps).

All in all, these results offer a quantitative evaluation of the ability of the central banks to reduce tensions on the interbank market and thus the Euribor spread. The findings suggest that their role was really important at the end of 2007 and after the collapse of Lehman Brothers, while their ability to affect the total spread has diminished since 2009: liquidity risk reached its lowest level from the beginning of the crisis and further actions produced smaller effects. In fact, the outcome of the decomposition indicates that the problems on the euro interbank market since mid-2009 depend mainly on its participants, as demonstrated by a persistently elevated credit risk.

5. Assessing the decomposition

The decomposition is obtained from two time series: Euribor spread and credit risk, which is derived from banks' CDSs. Liquidity risk is then calculated as a residual. This procedure relies on the credit risk measure being representative, which means that it should be as separate as possible from liquidity risk, especially during the crisis. The close relationship between the intervention of central banks and changes in liquidity risk presented in Section 4.2 allows an indirect assessment of the decomposition: if the two components are correctly identified, credit risk should not be related the actions of central banks. In fact, there is no evidence of the systematic relationship presented in Table 1 for credit risk. The aim of this section is a more precise appraisal of the decomposition, which represents the second objective of the paper.

5.1 A first evaluation of the decomposition

A preliminary assessment of the decomposition can be derived from the simple correlation between the three time series during the two periods in which the time span is divided, presented in Table 2.

[28] Some of these results are similar to those obtained by Nobili (2010).

Table 2. Correlation between Euribor spread, liquidity risk and credit risk

Period	Obs	Euribor spread & Liquidity risk	Euribor spread & Credit risk	Liquidity risk & Credit Risk
			LEVEL	
Pre Crisis	936	0.76***	-0.07	-0.71***
Post Crisis	670	0.95***	0.23***	-0.07
			FIRST DIFFERENCE	
Pre Crisis	935	0.99***	0.04	-0.07
Post Crisis	670	0.94***	0.22***	-0.13***

Note: The beginning of the crisis is set on August 6, 2007. Three asterisks denote significance at the 1 per cent confidence level.

It is confirmed, as seen in Figure 2, that the level of the spread is strongly correlated with liquidity risk, especially after the beginning of the turmoil; the link between the Euribor spread and credit risk is very low. The relations between credit and liquidity risk are more important: as they sum to the Euribor spread, a negative correlation would be expected. Instead, the level of liquidity and credit risk are uncorrelated after the crisis (but they are negatively correlated before). First differences are uncorrelated also before the crisis.[29] These findings are a preliminary assessment of the decomposition: credit risk (and its changes) are not influenced by liquidity risk during the turmoil.

Table 3 presents the correlation, before and after the crisis, between the three spreads and the measures of risk aversion or market liquidity.

Table 3. Correlations: Euribor spread, liquidity risk, credit risk, and risk aversion/market liquidity

LEVEL	**Euribor spread**		**Liquidity risk**		**Credit risk**	
	Pre Crisis	*Post Crisis*	*Pre Crisis*	*Post Crisis*	*Pre Crisis*	*Post Crisis*
Risk aversion						
VIX	-0.05	0.81***	-0.41***	0.66***	0.58***	0.55***
auch	0.03	-0.64***	0.21***	-0.50***	-0.29***	-0.49***
Coef. Var.	-0.05	0.01	-0.05	-0.21***	0.02	0.72***
itge10	0.07	0.34***	0.33***	0.07	-0.44***	0.89***
grge10	0.09***	-0.06	0.33***	-0.26***	-0.42***	0.65***
Market liquidity						
repo_eonia	0.51***	0.43***	0.10***	0.25***	0.40***	0.61***
usspread	0.27***	0.91***	-0.10***	0.87***	0.44***	0.22***
ted	0.04	0.77***	0.24***	0.80***	-0.33***	-0.06
abcp	0.05	0.63***	0.19***	0.71***	-0.23***	-0.19***
cip	0.10***	0.56***	0.39***	0.48***	-0.48***	0.30***
FIRST DIFFERENCE	**Euribor spread**		**Liquidity risk**		**Credit risk**	
	Pre Crisis	*Post Crisis*	*Pre Crisis*	*Post Crisis*	*Pre Crisis*	*Post Crisis*
Risk aversion						
VIX	-0.03	0.34***	-0.03	0.25***	0.02	0.28***
auch	0.05	-0.26***	0.06	-0.20***	-0.03	-0.18***
Coef. Var.	0.05	-0.05	0.04	-0.07	0.08	0.07
itge10	-0.07	0.18***	-0.10***	0.06	0.24***	0.36***
grge10	-0.04	0.10	-0.06	0.02	0.14***	0.24***
Market liquidity						
repo_eonia	0.85***	0.66***	0.85***	0.62***	0.01	0.15***
usspread	0.11***	0.37***	0.11***	0.32***	0.02	0.15***
ted	0.03	0.28***	0.02	0.21***	0.08	0.20***
abcp	0.03	0.08	0.02	0.05	0.09***	0.09
cip	0.16***	0.19***	0.16***	0.13***	0.01	0.20***

Note: The beginning of the crisis is set on August 6, 2007. Three asterisks denote significance at the 1 per cent confidence level.

There are no strong relationships between the level of these variables and those of the three spreads under examination before the turmoil. After the crisis there is a strong positive correlation between the Euribor spread and the dollar Libor spread, VIX and Ted spread. The two series in which the Euribor spread is decomposed show different correlations: liquidity risk is related to the dollar Libor spread, Ted spread and ABCP spread, while credit risk is positively correlated with the spread between Italian and German government bonds and with the dispersion of banks' spreads.

[29] The values are similar if the Euribor-Eurepo spread is used. However, the correlation between credit and liquidity risk in this case is higher, both in level and first difference.

The linkages between first differences are in general weaker. A major exception is the strong relationship, both before and after the crisis, between the Euribor spread and its liquidity component with the Eurepo-Eonia spread. The relationships are somehow stronger after the turmoil. The Euribor spread is correlated also with the dollar spread, VIX and Ted spread. Liquidity risk is correlated also with the dollar spread, while the spread between Italian and German bonds is positively related to credit risk.

The results presented in this section confirm the reliability of the Euribor spread decomposition. After the turmoil, credit risk and liquidity risk are uncorrelated; from the correlation analysis it emerges that the variables used to measure risk aversion are linked mainly to credit risk, while market liquidity variables are related to liquidity risk. This component is characterized by stronger relations with the three measures of the US financial markets than with the effects of the turmoil on the FX market. It is important to stress that these results are also valid after the turmoil, when the correlations among all the variables are in general higher.

The findings obtained with these simple correlations support the idea that the proxies introduced in the paper to represent European variables are mostly related to credit risk (the spread between Italian and German bonds and the coefficient of variation in the banks' spreads in the Euribor panel) or liquidity risk (the Eurepo-Eonia spread).

5.2 Regression analysis of Euribor-Eonia swap spread, liquidity risk and credit risk

This section evaluates the relationships between the three time series under examination and the proxies of risk aversion or market liquidity. It represents a robustness check with respect to the simple correlations presented in Table 3. The empirical analysis does not aim to establish causal relationships, but only to verify the strength of the correlations found in the previous section if the variables are considered together and their time dimension is taken into account.

The methodology used is based on univariate time series analysis.[30]

It starts from a modified Dickey-Fuller test (the DF-GLS test proposed by Elliott, Rothenberg and Stock 1996) for the three time series to check if they are integrated. Also the KPSS test for stationarity proposed by Kwiatkowski, Phillips, Schmidt, Shin (1992) is applied as a further control. This test can be considered complementary to the DF-GLS because it has a null hypothesis of stationarity.[31] The tests are performed before and after the crisis; the two time spans are examined separately as it is evident from Figure 1 that their dynamics have changed radically.

For each of the three series under examination the tests are followed by an OLS regression with Newey-West standard errors. The dependent variable is the level of the series if it is stationary and its first difference otherwise; the regressors are lags of the dependent variable selected to obtain whitened residuals using Schwartz information criterion (SIC). A second regression considers as explicative variables only risk aversion and market liquidity proxies, including their lags. In this second step all the ten variables are tested to find out which are correlated with the spread under analysis. A final regression includes both the lags of the spread under examination and the proxies of risk aversion and market liquidity to verify whether the correlation still exists if lags of the dependent variable are included.

The three regressions are then estimated for each spread also using GARCH (1,1). This robustness check is important because there is evidence of time-varying volatility clustering during the time span under analysis. Hence the GARCH regression which includes lags of dependent variables and of the various proxies is the preferred one.

The post-crisis period also includes two dummy variables, labelled *lehman* and *post_lehman*, which respectively take value one in the month after Lehman's collapse (from September 15 to October 10, 2008) and in the following period (from October 13, 2008), when the central banks and governments reacted strongly to the consequences of that event. The first dummy is used to test whether there are any effects

[30] The integration tests for the time series and the regressions are presented in Appendix E.

[31] I thank Giuseppe Ilardi and Paolo Piselli for this suggestion.

caused by market disruptions in the weeks after Lehman, while the second dummy controls whether there are any differences before Lehman collapse and a month after it.

To summarize, the estimated regressions are the following.

(A) $$Spread_t = \alpha + \sum_{i=1}^{n} \beta_i Spread_{t-i} + \varepsilon_t$$

(B) $$Spread_t = \alpha + \sum_{j=0}^{m} \beta_j PROXY_{t-j} + \varepsilon_t$$

(C) $$Spread_t = \alpha + \sum_{i=1}^{n} \beta_i Spread_{t-i} + \beta_j PROXY_t + \varepsilon_t$$

in which:

Spread corresponds to the Euribor spread (*eurspread*), liquidity risk (*liq*) or credit risk (*cred*). If it is not integrated *Spread* is the level of the variable; otherwise it is the first difference;[32]

PROXY is a vector including the variables used to measure risk aversion and market liquidity; and

α is a constant before the turmoil and a vector which includes *lehman* and *post_lehman* after the crisis.

In general, the main results obtained before are confirmed: measures of risk aversion are linked mainly to credit risk, while market liquidity variables are related to liquidity risk. The relations with European variables are stronger.

5.2.a Relations before the crisis

The regressions relating to the pre-crisis period for each of the three spreads are reported in Tables 4-6. The outcome of the integration tests shows that the Euribor spread is stationary and credit risk is integrated; there is a mixed result for liquidity risk, which seems fractionally integrated. The dependent variables are in level (Euribor spread and liquidity risk) and first difference (credit risk).[33] The other variables are all in differences, because they are I(1).

The regressions confirm that the Euribor spread (Table 4) and liquidity risk (Table 5) have similar time series characteristics and relationships with other variables. They are both correlated with the Eurepo-Eonia spread and the dollar Libor spread; the relationships are stronger for liquidity risk. However, the dollar spread is significant only when lags of the dependent variable are added to the regression. All the results are confirmed using a robust GARCH (1,1) estimation, which takes into account phases of higher and lower volatility. In this period the main factor of influence on the total spread and its liquidity component is an indicator of market liquidity in Europe; a role is also played by the dollar interbank market. Even if the mean (and median) value of these two variables is equal to zero, the fit of the model increases considerably when they are added to the lags of the dependent variables: a signal of their importance when they assume more extreme values.

Credit risk variation (Table 6) has a very low relation with its past values and a very low correlation only with measures of risk aversion: the dispersion of banks' spreads and the spread between Italian and German bonds. The robust GARCH (1,1) regression shows just a marginally significant relation between the first difference of the variable and its lags.

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[32] The possibility of ECM in this second case was considered and evaluated using Johansen tests. But there is no strong statistical evidence of cointegration between each of the three dependent variables and the most significant proxies.

[33] Since liquidity risk is partially integrated, regressions in first difference have also been tested. The results are basically unchanged.

The results of these univariate regressions confirm that before the turmoil the Euribor-Eonia swap and its liquidity component were only related to variables of market liquidity, while there is no strong relation between the credit risk component and risk aversion variables.

5.2.b Relations during the crisis

The sets of regressions for the period of the crisis are presented in Tables 7-9. Since the three series under examination are I(1), the regressions are estimated on their first differences. It is worth underlining this result: the crisis had such a great impact on *eurspread* and *liq* that they became non-stationary.

The Euribor spread is related to its value of the week before (Table 7). It has relations with many other variables and when they are added to its lags the fit of the model improves significantly. There are both market liquidity and risk aversion variables that influence *eurspread*: the dollar Libor spread, CIP, the Eurepo-Eonia spread, VIX, the coefficient of variation of banks' spreads and the spread between Italian and German bonds.[34]. The results are changed when a robust GARCH (1,1) model is used: the main variables which influence the Euribor spread are only VIX[35] and the Eurepo-Eonia spread. All in all, the most relevant variable correlated with *eurspread* is a measure of European market liquidity; a significant role is played by a proxy of general risk aversion. There is also a relevant effect provoked by Lehman's collapse in the following month (in addition to the effects measured by other variables): a daily increase in the level of the Euribor spread of 2.4 basis points, which sums up to around 50 basis points in mid-October 2008 (col. C).

Also the liquidity risk is linked with its five-day lagged value (Table 8). The results obtained for the Euribor-Eonia spread could suggest that the European interbank market is not influenced by the US situation after the crisis. However, this finding does not hold when only liquidity risk is considered: it has a relation with the Eurepo-Eonia spread and the dollar Libor spread. In this case too, they increase the fit of the model. There is also a marginally significant negative linkage with the dispersion of banks' spreads, though this relation disappears when a robust GARCH(1,1) model is used. The Lehman period does not seem to influence liquidity risk when the two measures of market liquidity are taken into account: their variation is enough to explain the changes in liquidity risk. In sum, liquidity risk is related to measures of European market liquidity and to the tensions in the dollar interbank market.

Credit risk shows a relation with the change of the day before (Table 9). Since credit risk is not influenced by the dummies related to Lehman's collapse, they are excluded from the regressions presented. The links with other variables are stronger and also the fit of the model is higher. R^2 is still low (around 0.25), but this result is influenced by the lower correlation between first differences. The unconditional correlations between the levels of the variables considered are much higher (see Table 3) and support the results of these relations. The relation is positive and significant with VIX and the spread between Italian and German bonds; a lower relation exists with the Greek-German bonds spread.[36] These findings are confirmed when a robust GARCH (1,1) is used. The results suggest that both measures of general and European risk aversion are related to credit risk on the euro interbank market, as could be expected in a market where funding is exchanged internationally.

The outcomes of these univariate regressions confirm that after the turmoil the Euribor-Eonia swap spread has been strongly related to the Eurepo-Eonia spread and VIX. The linkages with other variables representing liquidity problems in the dollar market (dollar Libor spread, CIP) or risk aversion in Europe (Italian-German bond spread, coefficient of variation of banks' spreads) are not very robust. Liquidity risk is linked only to market liquidity proxies (Eurepo-Eonia spread and dollar Libor spread), while credit risk is related only to risk aversion variables (VIX and spreads with German bonds).

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[34] The maximum correlation between the regressors is less than 0.4, so the results are not influenced by multicollinearity.

[35] The relation is negative because on average the change in *eurspread* has been positive, while that of VIX has been negative.

[36] The correlation between these two spreads is 0.5, so there is no multicollinearity between them.

5.3 The level of liquidity risk

The correct identification of credit and liquidity risk has been assessed mainly through the correlations between some financial variables and the two components of the Euribor spread. The decomposition in Section 4.1 is deterministic and the liquidity risk is derived as a residual: the hypothesis is that it does not include any "error component". The findings obtained so far allow us to be confident that liquidity risk is related to market liquidity only, but it is not possible to be sure whether its level includes anything else. A first answer to this concern can be found in the model on which the decomposition relies: credit risk covers the possibility that the borrower will not repay the loan; what remains should be only liquidity risk.

The results of the regressions presented in Section 5.2 offer a further possibility to evaluate the measure of liquidity risk and to be more confident that it does not include an "error component".[37] It uses the relation between *liq* and the variables related to market liquidity, in particular *repo_eonia*. Since the focus is on the period of turmoil (when the decomposition is also more reliable), only this time spell is considered.

There are two ways in which the regressions are used.

a) To derive the predicted value of the level of liquidity (*LIQ*) from a regression in first differences that includes only financial variables;[38] then the fit of *LIQ* with *liq* is evaluated. In this way is it possible to assess the role of an unexplained component.

b) To obtain the predicted value of the level of the Euribor spread (*EURS*) from a regression in first differences that includes the Euribor spread, credit risk and the Eurepo-Eonia swap spread (as a proxy of the liquidity component).[39] The difference between *EURS* and *cred* gives another measure of liquidity risk (*LIQ_EURS*), which is compared with *liq*. This method requires a further step to derive the liquidity risk with respect to the previous one because the regression output is the variation of the Euribor spread. The advantage is that the proxy is derived from a stochastic decomposition, thus offering an alternative measure to the deterministic one proposed in Section 4.1. The idea behind this attempt is that *repo_eonia* is a good proxy of liquidity risk, as emerged from the analyses in Section 5.2.

Since all the variables considered are integrated, it is possible to obtain only predicted values of first differences from the regressions.[40] Hence, these further tests also require a method of deriving the level of liquidity risk from the estimation of first differences: the predicted value of levels is calculated as the sum of the lagged actual level and its estimated change. In sum, the predicted values of the level of liquidity risk are as follows (capital letters indicate estimated variables; hatted coefficients are estimation results):

(a1) $$\Delta LIQ_t = \hat{\alpha} + \hat{lehman} + \sum_{i=0}^{2} \hat{\beta}_i * \Delta repo\_eonia_{t-i} + \hat{\beta}_3 * \Delta usspread_t$$

(a2) $$LIQ_t = liq_{t-1} + \Delta LIQ_t$$

(b1) $$\Delta EURS_t = \hat{\alpha} + \hat{lehman} + \hat{\beta} * \Delta eurs_{t-1} + \hat{\gamma} * \Delta cred_t + \hat{\delta} * \Delta repo\_eonia_t$$

(b2) $$EURS_t = eurs_{t-1} + \Delta EURS_t$$

(b3) $$LIQ\_EURS_t = EURS_t - cred_t$$

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[37] I thank Andrea Nobili for suggestions about this further control.

[38] Only the significant variables of the regression presented in Table 8, column B are included. Also a regression including lags of changes in liquidity risk (Table 8, column C) was considered: even if results are slightly better in terms of fit, it was not chosen as the favourite specification in order to limit the role played by *liq*.

[39] The regression is derived from Table 7, col. C, but it uses the actual value of the credit risk component instead of the risk aversion proxies. Even if these proxies are related to credit risk, they are not a good proxy of it (see the fit in Table 9), an important reason being that risk aversion is only a component of credit risk, which includes also the (perceived) situation of the debtor.

[40] This model was chosen because there is no strong statistical evidence of cointegration. The regressions from which the coefficients of (a1) and (b1) are derived have a good fit considering they are on first differences: adjusted R^2 is 0.55 and 0.68 respectively.

It is important to stress that both decompositions have an error component coming from the regressions, which is equal to the difference between the level of the liquidity risk (*liq*) and the measures estimated with the two methods described above. In fact:

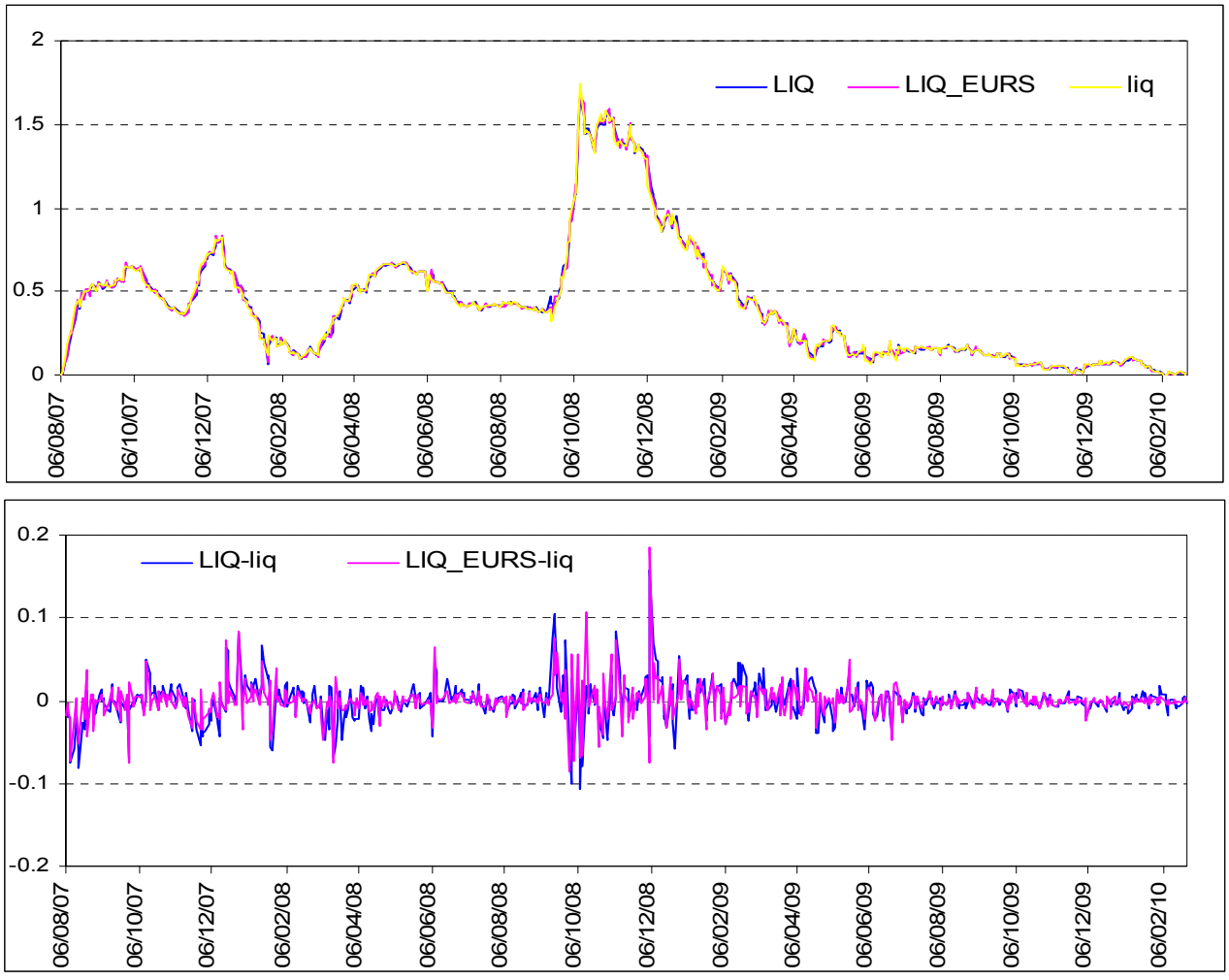
(a3) $$liq_t - LIQ_t = liq_t - (liq_{t-1} + \Delta LIQ_t) = \Delta liq_t - \Delta LIQ_t$$

(b4) $$liq_t - LIQ\_EURS_t = liq_t - (eurs_{t-1} + \Delta EURS_t - cred_t) = \Delta eurs_t - \Delta EURS_t$$

The results of both methods confirm that liquidity risk does not contain a relevant error component: the fit of the alternative series is nearly perfect (Figure 3, upper panel). A possible explanation for this finding relates to the properties of the time series considered. LIQ and *liq* have a common component, the lagged value of the liquidity risk (see a2). Since *liq* is integrated, its lagged value is relevant in forecasting the current level, so the fit depends also on the common part. Even if a similar reasoning can be applied to *eurs* in (b2), the comparison is between LIQ_EURS and *liq*, which is not used in this second method: the stochastic decomposition offers a further confirmation of the liquidity risk level as obtained from the deterministic one.

The bottom panel of Figure 3 shows the difference between the liquidity risk measures, which also makes it possible to evaluate the role played by the error components of the two regressions, as shown in formulas (a3) and (b4). The difference is on average zero and it is lower (in absolute value) than 5 basis points in basically all the days considered, but in the most critical phase of the crisis. During the month after Lehman's collapse, the error was in many cases around 10 basis points, which is very small considering that liquidity risk was 10-15 times higher.

Figure 3. Liquidity risk: comparison of different methodologies of calculation



6. Robustness checks

The results presented in the previous section allow us to be more confident about the decomposition of the Euribor spread. As a further robustness check, this section considers a shorter and more recent time period, which complements the considerations made in Section 4.1 about the dynamics of the Euribor spread after mid-2009. It also shows further analyses using a different derivation of the credit risk component or a different proxy of risk aversion.

On May 7, 2009, the ECB decreased the monetary policy interest rate to 1 per cent and also introduced a series of measures: it prolonged the temporary expansion of the list of eligible assets; it decided to launch one-year longer term refinancing operation, which offered liquidity at the fixed rate of 1 per cent, satisfying all bids from the banks; it planned to buy euro-denominated covered bonds. As evidenced in Section 4.2, the introduction of all these measures affected the Euribor spread: in May it reached a level nearer to that prevailing before Lehman's collapse and it continued to decrease in the following months to the lowest value since the beginning of the crisis (Figures 1 and 2).

The empirical analysis proposed in the previous section has been repeated taking into account only this shorter period of time (starting from May 19, 2009), which has been the quietest during the financial turmoil. The analysis aims to verify whether the relations found for the whole crisis period still hold. The results for the three variables under examination are presented in Tables 10-12.

The Euribor spread (Table 10) continues to show a strong linkage with the Eurepo-Eonia swap spread only, while it has no relation with risk aversion variables. The relation with the dollar Libor is only marginally significant and disappears when lags of the dependent variable are included.

Liquidity risk (Table 11) is still strongly related to the Eurepo-Eonia swap spread. During this more recent period it is also significantly linked to the dispersion of Euribor panel banks' spreads. The positive relation could signal that the heterogeneity of the banks affected the market's liquidity: the need to distinguish between the counterparties could have reduced participation.

Credit risk (Table 12) has still significant relations only with risk aversion measures, in particular with the spread between Italian and German bonds. The table presents the results with two sets of regressors: the same as Table 9, whose coefficients remain similar (on the left), and the variables that in this shorter period have the most significant relations with credit risk (on the right). In this second case the exchange rate between the Swiss franc and the Australian dollar is used; its sign is negative because in the months under examination the franc depreciated (risk aversion decreased as did credit risk).[41]

The results of these regressions confirm those obtained for a longer period and further corroborate the decomposition of the Euribor spread. Moreover, they underline that the linkages with European variables are strongest after the second half of 2009. In fact, the Euribor spread and its liquidity component are not related to US variables, while credit risk still also has a link with general measures of risk aversion.

Credit risk (*cred*) is derived in Section 4.1 using the mean of the banks' spreads (formula 4a). A possible drawback of this calculation is the effect of outliers: the presence of riskier banks could bias the mean (especially during the crisis), even if the potential distortion is reduced by the number of banks. To take this problem into account the decomposition has been calculated also using the median of the spreads.

The resulting components of the new decomposition, called *cred_md* and *liq_md*, are basically unchanged before the crisis; after the crisis the credit risk component is slightly lower on average (3.5 basis points) and the liquidity component is correspondingly higher; the variance of the credit component is lower.[42] These are somehow expected results because the presence of riskier banks marginally increases the mean (and also the variance) during the turmoil. In both periods, the correlation between *liq* and *liq_md* is around 1, both in level and first differences, while the correlation between *cred* and *cred_md* is nearly 1 in level and around 0.9 in first differences. These findings suggest that the two components derived using the

[41] There is no significant presence of ARCH effects, hence the results with this model are not presented. The coefficients and their significance are nearly identical.

[42] The descriptive statistics are presented in Appendix C.

median of banks' CDSs are similar to those obtained with the mean. In fact, the correlation between *cred_md* and *liq_md* are nearly identical to those presented in Table 2. The results of the regression shown in Tables 5-6 and 8-9 are substantially unchanged for liquidity risk, while there are small differences in the coefficients for those relative to credit risk. The largest differences relate to *Coef. Var.*, which is significantly correlated with liquidity risk after the crisis (only when a GARCH model is used) and with credit risk in both periods.

All in all, the main findings of the analysis are unchanged using this different method of derivation of the credit risk component.

Another robustness check took into account the financial variables used in the assessment of the decomposition. The idea behind this attempt is that it might be possible to derive a "synthetic" proxy of risk aversion or market liquidity. It could be useful in particular for risk aversion, which includes many different variables in addition to VIX, the traditional measure.

The use of principal component analysis (PCA) allowed us to derive such a measure for risk aversion during the turmoil.[43] The first principal component (called *RA_synt*) represents 64 per cent of the total variance and is highly correlated with all five measures. It has been added to the regressions for liquidity and credit risk during the period of turmoil. The outcome of the regression analysis confirms that during the crisis liquidity risk is not linked to a measure of risk aversion (the coefficient of *RA_synt* is marginally significant only when other variables, in particular *repo_eonia*, are added to the regressions), while credit risk is strongly related to it.

7. Conclusions

The paper evaluates the effects of the financial turmoil on the interbank market, whose importance as a source of funding for banks was previously ignored because of its reliability. The market was similar to a plumbing system, whose importance is fully understood only when it breaks down.

The main object of the paper is the three-month Euribor-Eonia swap spread. The particular interest in the euro interbank market is motivated by the level of the spread after mid-2009: it decreased to the lowest point since the beginning of the turmoil while remaining nonetheless much higher than before the crisis. Dollar and sterling spreads were instead nearer to their pre-crisis average.

The paper disentangles the credit and the liquidity component of the Euribor spread, using CDSs of the banks in the Euribor panel to derive the former. The results of the breakdown show that the role of the two components changed during the crisis but that they had a similar behaviour around its main events. Credit risk increased before August 2007, Bear Sterns and Lehman; liquidity risk was mainly responsible for the subsequent increases in the Euribor spread and then reacted to the systemic responses of the central banks, especially in October 2008.

Another important finding is that credit risk mainly influenced the Euribor spread after the second half of 2009. Since the level of the Euribor spread was still higher than its average before the crisis, it signals an elevated counterparty risk in the euro interbank market. Moreover, the low liquidity risk is strongly influenced by the interventions of the central banks, which were thought to be temporary. The drawback of this situation is that European banks could become addicted to liquidity "on tap". It must be emphasized that these results are obtained considering a period that precedes the tensions created by sovereign problems in some European countries: in the second half of 2009 the two keywords were "exit strategy".

The paper also assesses the decomposition, proposing an innovative method based on proxies of risk aversion and market liquidity which include also some measures specific to the European context. The analyses show that there are only relationships between credit risk and measures of risk aversion, and between liquidity risk and proxies of market liquidity; the findings also hold during the turmoil, when there is a general increase in the correlation between the time series considered.

[43] The use of PCA has not allowed us to derive a similar result for the period before the crisis. Also it has not been possible to derive a synthetic measure for the five liquidity proxies, either before or after the crisis.

The results of the simple correlation and of the time series analysis confirm that the crisis had an impact on the relations between the Euribor spread, its two components and proxies of risk aversion or market liquidity. Before the crisis there is evidence of linkages between the Euribor-Eonia swap spread and its liquidity component only with variables of market liquidity. The time series analysis shows that the influence of the US market was important, even if the situation of European market liquidity seems to be the main force behind the dynamics of these two spreads. Instead, there is no strong relation between the credit risk component and risk aversion variables. After the crisis the linkages are in general stronger, as can be expected in a period of financial turbulence. The Euribor spread continues to be influenced by market liquidity in Europe, but risk aversion also becomes important. Tensions from the US market do not play a significant role. Liquidity risk is still related to both European and US market liquidity; there is no evidence of links to FX market disruptions. Credit risk becomes correlated with measures of risk aversion, both general and specific to Europe.

The three spreads considered have a higher correlation with European variables than with general proxies of risk aversion or US market liquidity. This result is even stronger when a more recent time spell is considered: during the quieter period of the turmoil (after May 2009), the influence of US variables on the Euribor spread or liquidity risk is non-significant, even if credit risk still has a relation with general measures of risk aversion. All in all, the outcome of the analysis suggests that liquidity on the euro interbank market could be influenced mainly by European variables, but credit risk is influenced also by the general attitude of financial market participants.

The relation between liquidity risk and the Eurepo-Eonia swap spread allows us to derive other measures of liquidity risk, which are similar to that obtained from the deterministic decomposition. It is important to stress that one of these proxies comes from a stochastic breakdown: this finding confirms that the residual of the deterministic decomposition can be used as a proper approximation of the liquidity risk level.

The findings of the paper suggest that it is important to look not only at the spread between unsecured and secured loans in the interbank market, which could signal that the worst is over after May 2009. It is also important to take into account indicators of the credit risk of the banks. The credit risk component has shown a remarkable capacity to anticipate some of the main events of the crisis and could be used as an early warning indicator of the problems faced by participants in the interbank market. In fact it also increased in mid-February 2009, reaching its highest level in March, when the central banks decided to introduce stronger unconventional policy measures (and positive earnings in the financial sector were announced, allowing financial markets to think that the worst of the crisis was over).

Briefly, the results obtained in the paper show that the interventions of the central banks were fundamental to avoid the collapse of the interbank markets. But the provision of liquidity "on tap" to banks cannot be a solution. The actions taken by the ECB since 2009 have produced a weaker effects on the Euribor spread because liquidity risk was very low. To reduce the spread it is more important to reduce the probability that the counterparty could be a "lemon", which requires greater disclosure about the situation of individual banks. Credit risk played a decisive role also later in 2010, which could signal that the results of the stress tests were not helpful. It is worth remembering that the dollar Libor decreased after the publication of the individual stress tests of US banks in May 2009, while the results of an aggregate stress test on European banks in October 2009 did not produce such an effect. Also the release of individual results in July 2010 did not produce significant effects on credit risk (or on the Euribor spread).

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Appendix

A – The main stages of the crisis

Starting in August 2007 the world financial market situation and macroeconomic scenario changed dramatically. The turmoil had its roots in US subprime mortgages, but it quickly moved to related financial assets (structured ABS, CDO, CLO) and share prices; it then extended to all the financial markets, even those unrelated to subprime products. The influence that the crisis had on the balance sheets of banks resulted in higher risk premia on the interbank market, where the spread between unsecured and secured lending increased to historically high levels. The tensions forced the central banks to intervene with an increase in refinancing operations, the broadening of accepted collaterals, the creation of dollar swap lines between the main central banks and the FED, and the reduction of interest rates.

The collapse of Lehman Brothers in September 2008 marked the start of a new phase of the crisis, with an intensification of the disruptions in the financial markets. The last months of 2008 included the intervention of governments to rescue banks and financial institutions, mainly through injections of capital (which started to be seen as insufficient in a context of increasing risks and current and future losses), expansion of retail deposit insurance, guarantees of wholesale liability, and asset purchases. Other economic policies to tackle the recession included large interest rate cuts (especially once the second-round inflation pressure from the oil price increase ended after the summer of 2008) and expansive fiscal policies.

The massive interventions produced their effects on the financial markets from March 2009, when optimism increased in response to signs that economic conditions were deteriorating less rapidly than before, even if the real economy remained depressed. During the summer of 2009 the combination of positive macroeconomic news and strong profits contributed to a rally in the stock markets and to the reduction of spreads in the bond markets. From the last months of 2009 attention started to focus on the possible effects of the exit strategy on economic growth. In the meantime, the effects of capital injections and positive earnings allowed banks to offset writedowns, even if their possible losses on credits remained an important source of uncertainty. The first months of 2010 were characterized, especially in Europe, by greater attention to sovereign risk because of increasing government debt and uncertainty about growth prospects.

B – Interbank market rates[44]

Libor (London Interbank Offered Rate) is the rate at which a bank perceives that it could be offered unsecured funds in the London interbank market. It is quoted in ten currencies and fifteen maturities as the average of the contributions by a panel of banks, ranging from eight to sixteen. It is calculated by the British Bankers' Association, discarding the top and bottom quartiles of the quotes.

Euribor is the rate at which each bank in the panel believes one prime bank is quoting to another prime bank for a deposit within the euro market. The panel consists of 43 banks and nearly all of them are European. It is calculated by eliminating the highest and lowest 15 per cent of all the quotes collected.

Overnight Index Swap (OIS) is an interest rate swap in which the floating leg of the swap is linked to an overnight interest rate. At maturity, the two parties exchange the difference between an agreed fixed interest rate and a variable interest rate, accrued through geometric averaging of the floating index rate on the agreed notional amount. In other words, the transaction means that the floating rate calculation replicates the accrual on an amount (principal plus interest) rolled at the index rate every business day over the term of the swap. If cash can be borrowed by the swap receiver on the same maturity as the swap and at the same rate and lent back every day in the market at the index rate, the cash payoff at maturity will exactly match the swap payout: the OIS acts as a perfect hedge for a cash instrument. Economically, receiving the fixed rate in an OIS is like lending cash. Paying the fixed rate in an OIS is like borrowing cash. Settlement occurs net on the earliest practical date. There is no exchange of principal. The index rate used is typically the rate for overnight transactions as published by the central banks.

[44] A detailed description of these rates can be found on www.euribor.org and www.bbalibor.com. For an explanation of OIS see www.acisuisse.ch/docs/dokumente/OIS_Note_CSFB_Zurich.pdf.

Eonia swap is an OIS on Eonia, which is a weighted average of all overnight unsecured lending transactions in the interbank market, initiated within the euro area by the banks of the panel. Eonia is calculated by the ECB.

Repos (repurchase agreements) are collateralized lending transactions. One party agrees to sell securities to another against a transfer of funds; the initial valuation includes market value and accrued interest. At the same time the two parties agree to repurchase the same or equivalent securities at a specific price in the future. When the transaction is terminated, the securities are sold again at a pre-agreed price, which add to the original sale price an interest rate (repo rate). The difference between the sale and repurchase price equates to a borrowing/lending interest rate for secured money.

Eurepo is the rate at which each bank of the panel believes that one prime bank is bidding another prime bank (and offering money) for a term repo in which a General Collateral (euro-area government bonds and bills) is exchanged.

While unsecured lending has a credit component, for a secured lending it is nearly absent. In fact, in an unsecured lending transaction the loan is subject to a counterparty risk for all its length. Instead, an OIS transaction reflects the risk of overnight failure, independently of the length of the loan. Moreover, credit exposure is only to net interest rate, not to the principal exchanged. Finally, OIS contracts are usually collateralized. The mechanism which ensures a repo transaction is based on the collateral given, whose changes in price and liquidity are the main risks of the transaction and influence the rates. In this sense repo rates are more sensitive than OIS swaps to market liquidity.

C – Data

The source of the data used in this paper is Bloomberg. The time span ranges from January 2, 2004 to February 26, 2010 and the total observations amount to 1606 days. With the exception of banks' CDSs, when a variable is missing in a certain day, its value is replaced by that of the previous day or two days before. The number of observations, the mean and the standard deviation of the variables, before and after the crisis, are reported in table A.

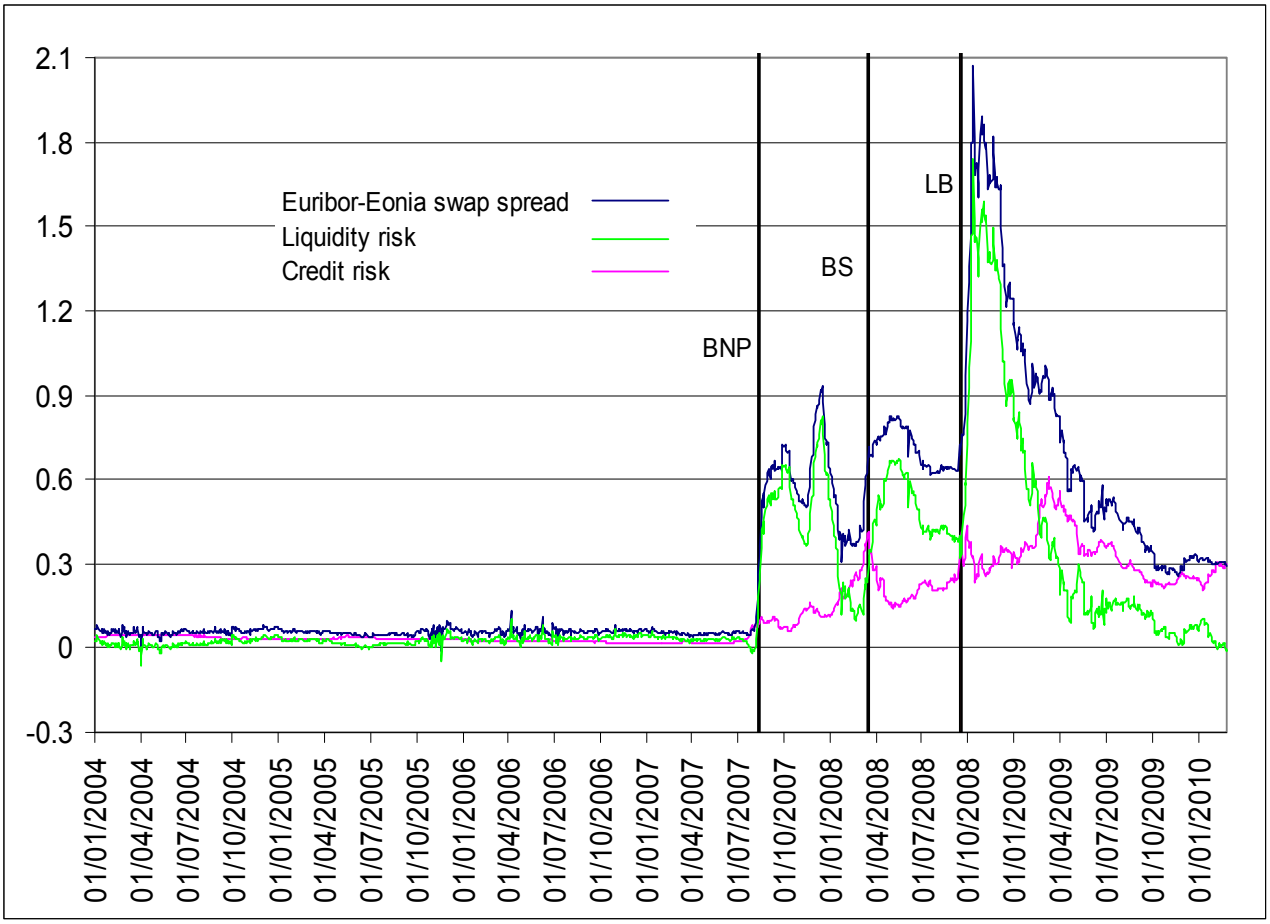
Table A. Main statistics

	Pre crisis			**Post crisis**		
	Obs	Mean	St. dev.	Obs	Mean	St. dev.
eurspread	936	0.0567	0.0101	670	0.6794	0.3671
liq	936	0.0257	0.0142	670	0.4175	0.3578
cred	936	0.0310	0.0093	670	0.2619	0.1121
liq_md	936	0.0292	0.0136	670	0.4563	0.3524
cred_md	936	0.0275	0.0086	670	0.2231	0.0801
VIX	936	13.7031	2.3983	670	29.9264	12.4001
auch	936	0.6141	0.0431	670	0.7683	0.1213
Coef. Var.	936	0.3320	0.0259	670	0.4099	0.1386
itge10	936	0.2228	0.0558	670	0.7692	0.3526
grge10	936	0.2515	0.0493	670	1.2819	0.8526
repo_eonia	936	-0.0084	0.0095	670	0.0197	0.0344
usspread	936	0.0905	0.0209	670	0.7304	0.6017
ted	936	0.3345	0.1099	668	1.0673	0.7729
abcp	936	0.2441	0.1025	668	1.0313	0.8843
cip	936	0.0000	0.0001	670	0.0012	0.0011

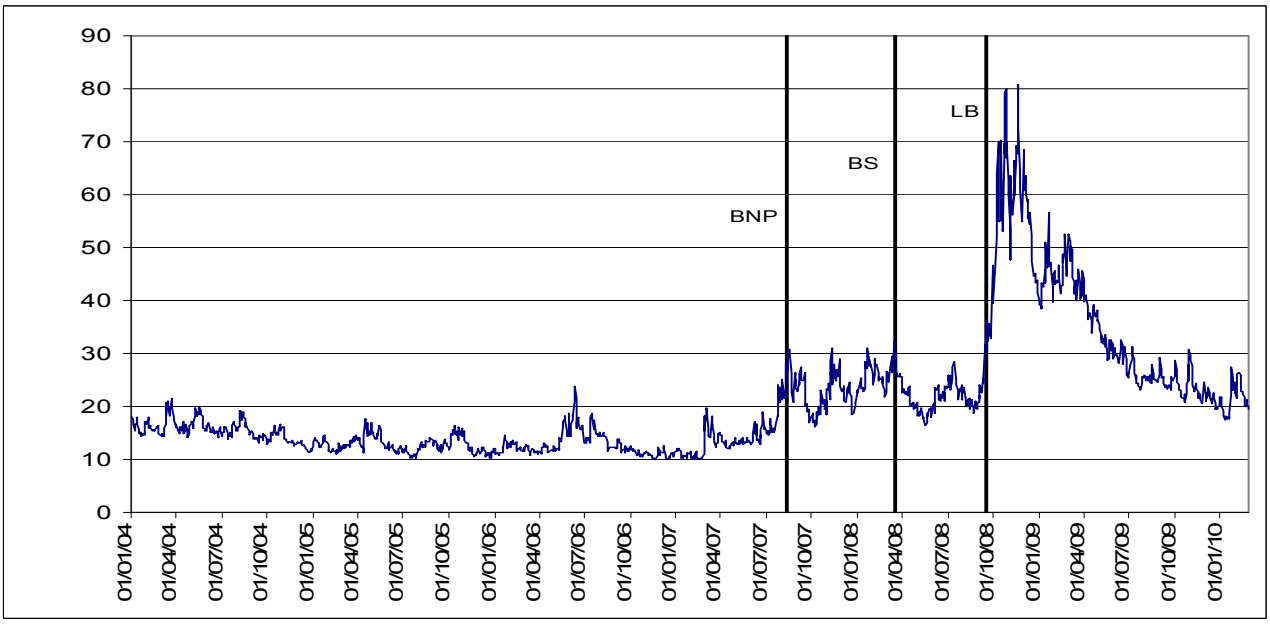
Note: The beginning of the crisis is set on August 6, 2007. Variables are in basis points, except for *VIX*, *auch*, *Coef. Var.* and *cip*.

The following graphs represent the Euribor-Eonia swap spread, decomposed into liquidity risk and credit risk and the ten variables used as proxies of risk aversion and market liquidity. In all of them BNP is August 9, 2007, BS is March 14, 2008 and LB is September 15, 2008.

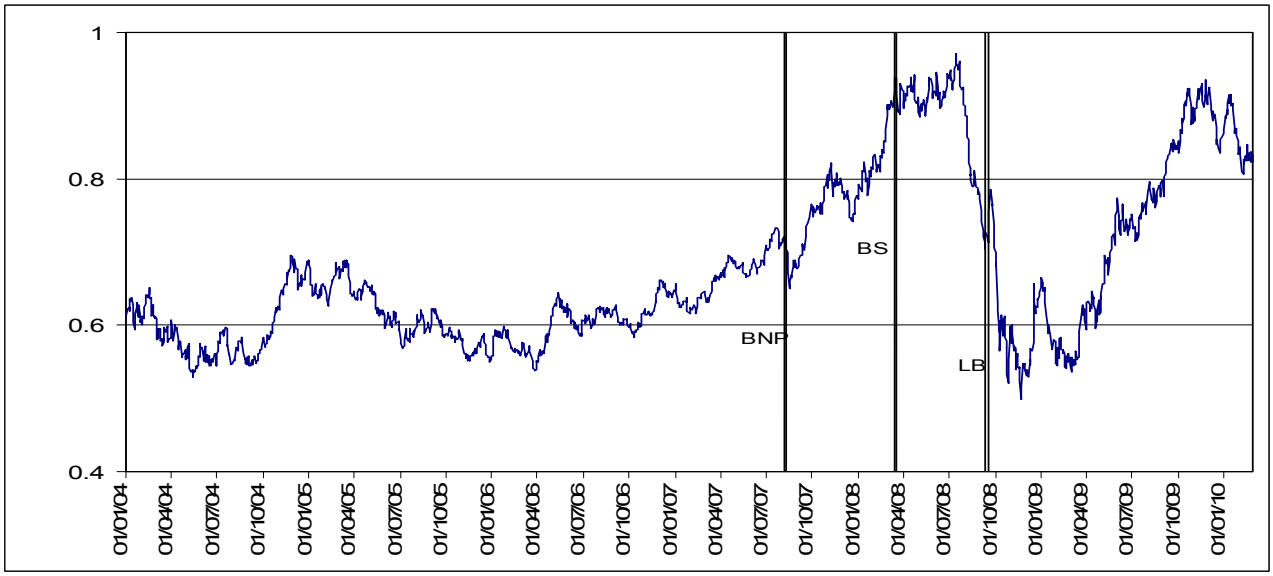
Three-month Euribor-Eonia swap spread (eurspread), liquidity risk (liq) and credit risk (cred)



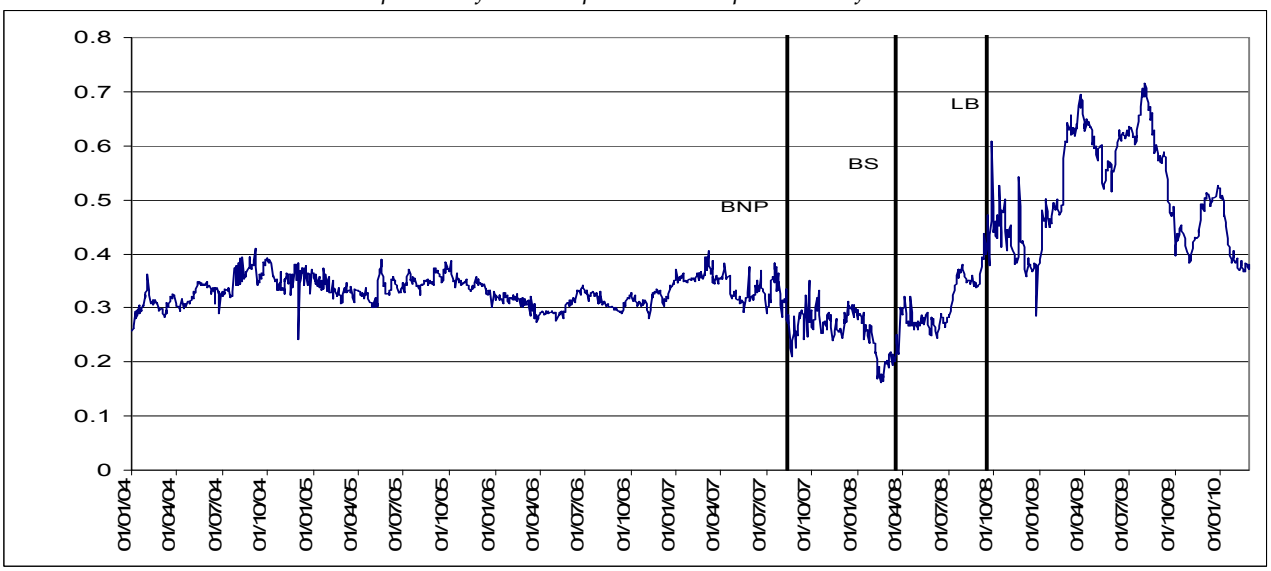
vix (VIX)



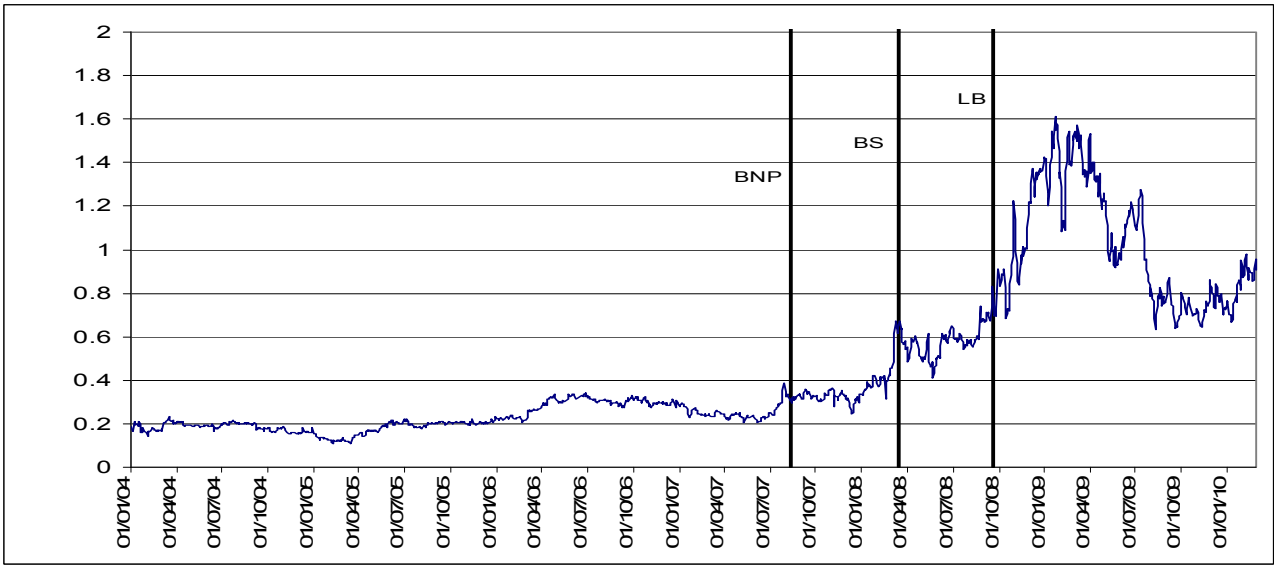
Swiss franc/Australian dollar exchange rate (auch)



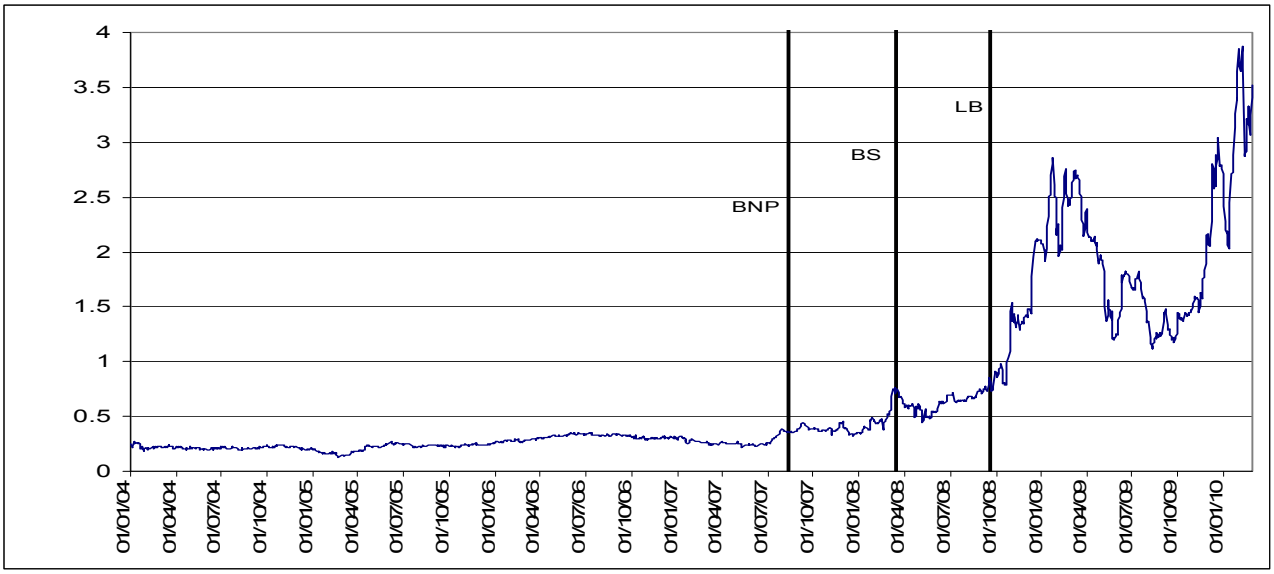
Dispersion of Euribor panel banks' spreads (Coef. Var.)



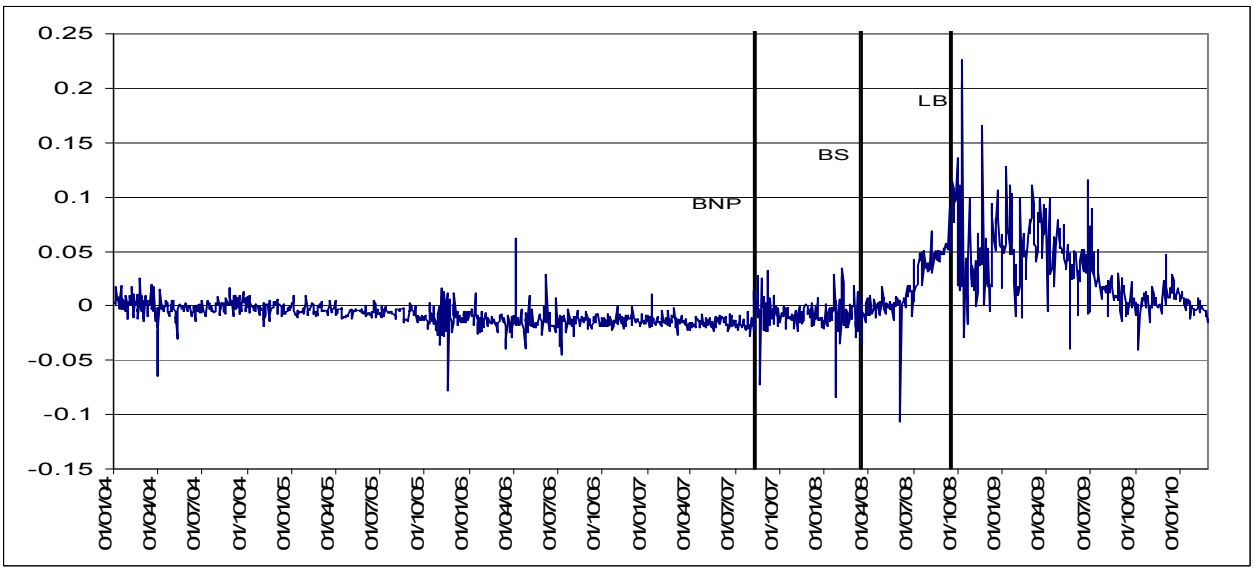
Spread between ten-year Italian and German bonds (itge10)



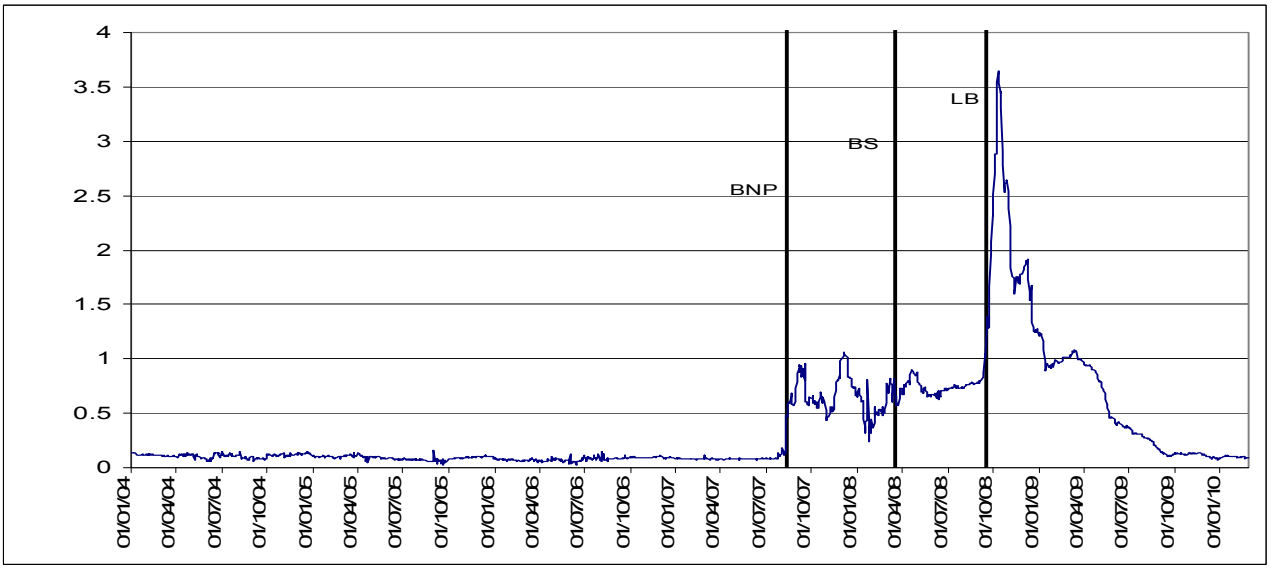
Spread between ten-year Greek and German bonds (grge10)



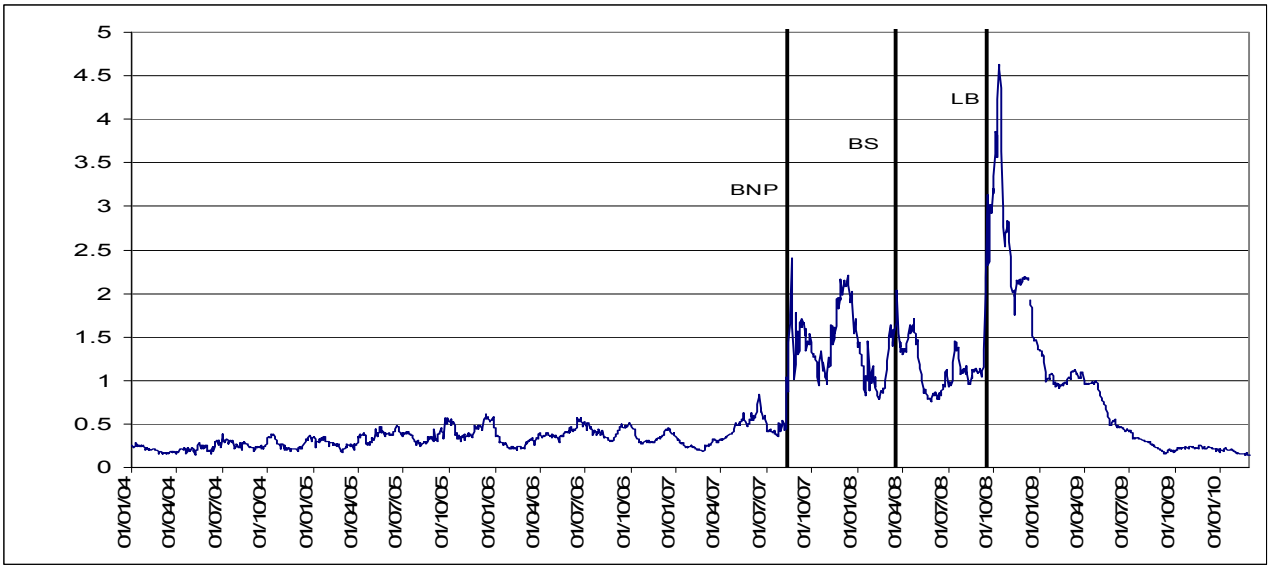
Spread between three-month Eurepo and Eonia swap (repo_eonia)



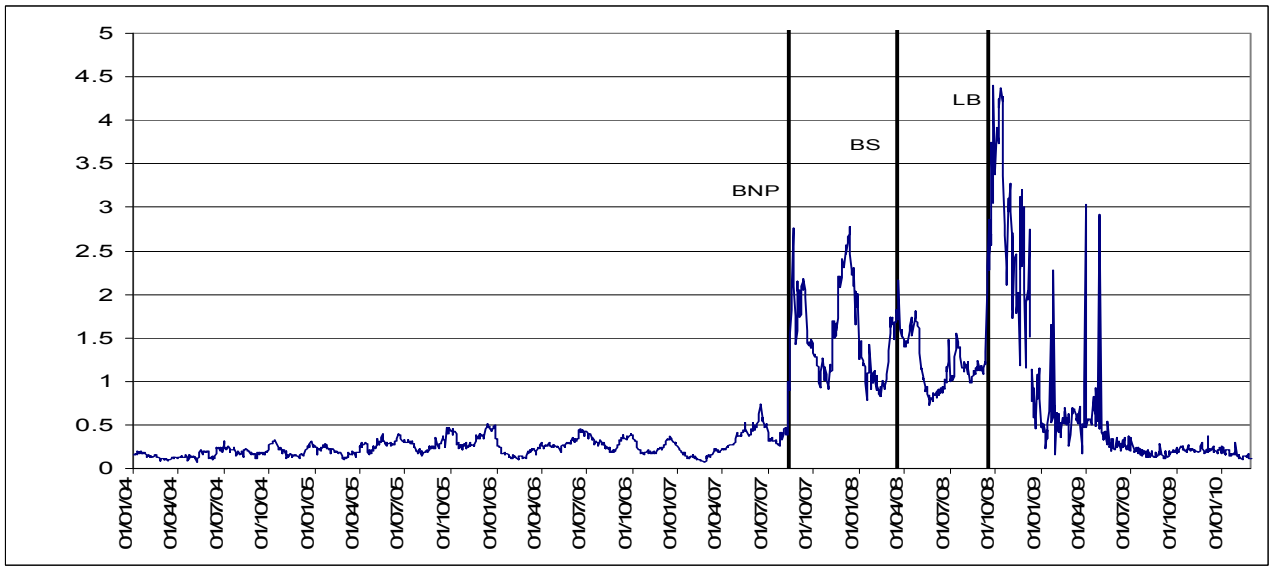
Three-month US dollar Libor spread (usspread)



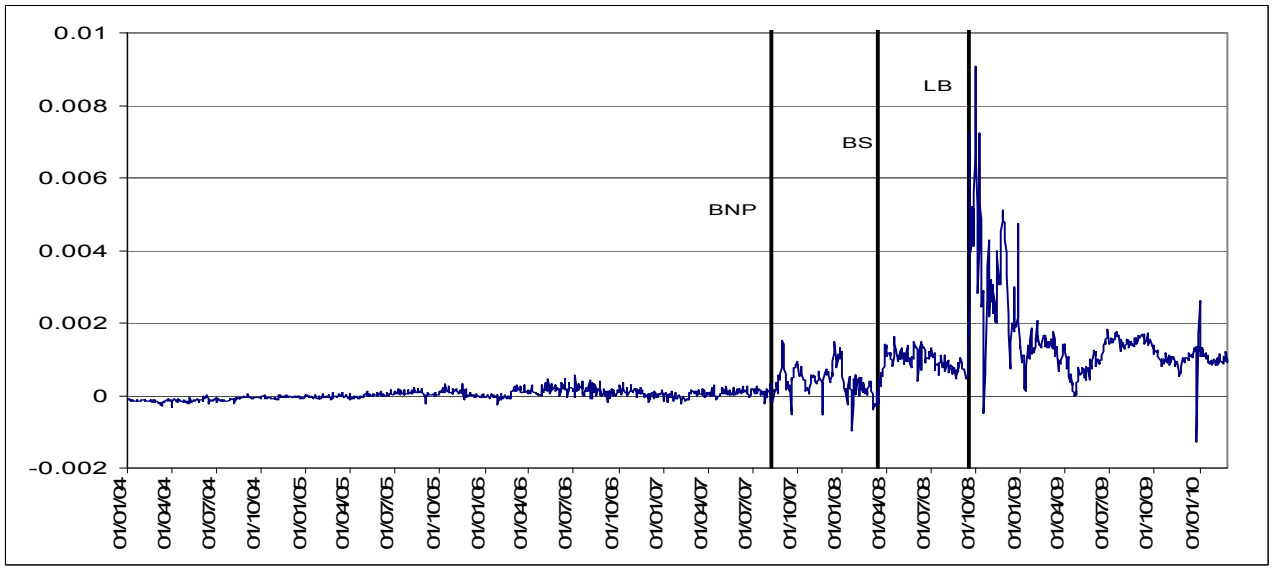
Spread between three-month dollar Libor and treasury bills (ted)



Spread between three-month ABCP and treasury bills (abcp)



Three-month deviation from covered interest parity for euro/dollar exchange rate (cip)



D – Euribor panel and CDS

There are 43 banks in the Euribor panel, nearly all of them European.[45] CDSs are available for 36 banks, but there are many missing values for 11 of them, which leaves only 25 banks with long enough time series. However, after the crisis the number of the banks for which there are time series for nearly all the days increases to 28. The names of the banks, their country and some statistics are reported in Table B.

Table B. Euribor panel banks: main statistics

Name	Country	Pre Crisis (936 obs)			Post Crisis (670 obs)		
		Missing	Mean	St. dev.	Missing	Mean	St. dev.
ABN Amro Bank	Netherland	0	9.9	3.7	0	85.2	31.9
AIB Group	Ireland	54	10.6	3.1	3	203.5	133.7
Banca IntesaBci	Italy	2	14.1	5.5	0	68.9	33.6
Banco Bilbao Vizcaya Argentaria	Spain	1	11.2	3.4	0	84.4	31.2
Banco Santander Central Hispano	Spain	2	11.9	3.7	0	85.3	31.4
Bank of Ireland	Ireland	8	10.2	3.2	2	213.1	135.5
Bank of Tokyo - Mitsubishi	Japan	278	13.4	5.5	12	67.8	32.1
Banque et Caisse d'Épargne de l'État	Luxembourg	…	…	…	…	…	…
Barclays Capital	United Kingdom	2	9.6	3.0	0	109.3	51.5
Bayerische Landesbank Girozentrale	Germany	934	NA	NA	144	NA	NA
BNP - Paribas	France	2	9.1	2.9	0	60.7	21.4
Caixa Geral De Depósitos (CGD)	Portugal	892	NA	NA	75	95.3	31.8
Citibank	United States	2	15.9	5.5	19	215.1	141.9
Commerzbank	Germany	3	17.5	7.4	0	81.0	26.2
Confederacion Española de Cajas de Ahorros	Spain	…	…	…	…	…	…
Crédit Agricole s.a.	France	17	9.4	2.6	2	80.2	27.3
Crédit Industriel et Commercial CIC	France	…	…	…	…	…	…
Den Danske Bank	Denmark	88	9.2	3.1	32	87.4	47.4
Deutsche Bank	Germany	0	15.0	3.5	0	89.3	31.8
Dexia Bank	Belgium	60	10.8	2.6	596	NA	NA
Dresdner Bank	Germany	2	14.4	6.3	0	82.0	28.3
DZ Bank Deutsche Genossenschaftsbank	Germany	…	…	…	…	…	…
Erste Bank der Österreichischen Sparkassen	Austria	19	14.2	2.6	8	154.9	92.0
Fortis Bank	Belgium	17	17.0	5.4	8	86.2	46.7
HSBC France	France	2	10.2	3.6	0	73.8	32.6
ING Bank	Netherland	2	9.5	4.0	0	83.0	36.0
J.P. Morgan Chase & Co.	United States	1	24.1	7.6	9	93.4	40.5
KBC	Belgium	936	NA	NA	244	NA	NA
Landesbank Baden - Württemberg Girozentrale	Germany	934	NA	NA	312	NA	NA
Landesbank Berlin	Germany	…	…	…	…	…	…
Landesbank Hessen - Thüringen Girozentrale	Germany	…	…	…	…	…	…
Monte dei Paschi di Siena	Italy	1	16.0	5.9	0	79.5	28.7
National Bank of Greece	Greece	…	…	…	…	…	…
Natixis	France	936	NA	NA	68	174.7	82.5
Norddeutsche Landesbank Girozentrale	Germany	936	NA	NA	283	NA	NA
Nordea	Finland	905	NA	NA	199	NA	NA
Rabobank	Netherland	6	6.8	2.0	0	76.6	44.6
RZB - Raiffeisen Zentralbank Österreich AG	Austria	936	NA	NA	232	NA	NA
Société Générale	France	2	10.0	3.0	0	81.5	28.9
Svenska Handelsbanken	Sweden	851	NA	NA	234	NA	NA
UBS (Luxembourg) S.A.	Switzerland	2	8.6	3.1	0	122.4	70.4
Unicredit	Italy	2	13.5	3.3	0	92.7	42.1
WestLB AG	Germany	900	NA	NA	38	111.3	34.2

Note: The beginning of the crisis is set on August 6, 2007. *NA* means the statistics are not calculated.

[45] During the period considered the number of banks dropped to 42. They included La Caixa Barcelona (Spain) from December 1, 2009 and excluded Dresdner Bank (acquired by Commerzbank), Fortis (acquired by BNP-Paribas). ABN Amro was replaced by RBoS.

E – Regression analysis

Table C presents the integration test for the Euribor spread (*eurspread*), liquidity risk (*liq*) and credit risk (*cred*). The tests show that before the turmoil the Euribor spread is stationary, its liquidity component seems fractionally integrated, while credit risk is I(1). After the crisis all the series are I(1). Tables 3-11 show the regression results for the three time series in the three periods considered (see Sections 5 and 6).

Table C. Integration tests

	PRE CRISIS						*PRE CRISIS*					
	DF-GLS mu Test Statistic			**Critical values**			**KPSS Test Statistic**			**Critical values**		
Lag	eurspread	liq	cred	1 p. c.	5 p. c.	10 p. c.	eurspread	liq	cred	1 p. c.	5 p. c.	10 p. c.
1	-8.61	-7.26	-0.02	-2.58	-1.96	-1.64	0.66	14.00	28.50	0.74	0.46	0.35
2	-6.96	-5.77	-0.10	-2.58	-1.96	-1.64	0.50	9.95	19.40	0.74	0.46	0.35
3	-6.02	-4.95	-0.14	-2.58	-1.97	-1.64	0.41	7.77	14.70	0.74	0.46	0.35
4	-5.56	-4.52	-1.01	-2.58	-1.97	-1.64	0.35	6.40	11.90	0.74	0.46	0.35
5	-5.32	-4.28	-1.21	-2.58	-1.97	-1.65	0.31	5.47	10.00	0.74	0.46	0.35
	POST CRISIS						*POST CRISIS*					
	DF-GLS mu Test Statistic			**Critical values**			**KPSS Test Statistic**			**Critical values**		
Lag	eurspread	liq	cred	1 p. c.	5 p. c.	10 p. c.	eurspread	liq	cred	1 p. c.	5 p. c.	10 p. c.
1	-0.89	-1.17	-0.80	-2.58	-1.97	-1.65	6.39	8.63	14.50	0.74	0.46	0.35
2	-0.99	-1.31	-0.72	-2.58	-1.97	-1.65	4.28	5.77	9.78	0.74	0.46	0.35
3	-0.95	-1.29	-0.71	-2.58	-1.97	-1.65	3.23	4.34	7.39	0.74	0.46	0.35
4	-1.02	-1.40	-0.62	-2.58	-1.97	-1.65	2.59	3.48	5.95	0.74	0.46	0.35
5	-1.13	-1.54	-0.59	-2.58	-1.97	-1.65	2.16	2.91	4.98	0.74	0.46	0.35

Note: The beginning of the crisis is set on August 6h, 2007. Null hypothesis of DF-GLS is integration; that of KPSS is stationarity.

Table 4. Euribor spread before the crisis

	OLS				**GARCH (1,1)**		
	(A)	(B)	(C)		(A)	(B)	(C)
eurspread (-1)	0.4215***		0.9321***	eurspread (-1)	0.5933***		0.9037***
	(0.0699)		*(0.0323)*		*(0.0520)*		*(0.0337)*
eurspread (-2)	0.1473***		-0.0739***	eurspread (-2)	0.0953*		-0.0414
	(0.0539)		*(0.0255)*		*(0.0501)*		*(0.0323)*
eurspread (-3)	0.1289***		0.0299	eurspread (-3)	0.1867***		0.0438
	(0.0477)		*(0.0211)*		*(0.0545)*		*(0.0267)*
Δrepo_eonia		0.5414***	0.7547***	Δrepo_eonia		0.6050***	0.6115***
		(0.0600)	*(0.0514)*			*(0.0684)*	*(0.0532)*
Δrepo_eonia (-1)		0.4071***		Δrepo_eonia (-1)		0.4472***	
		(0.0592)				*(0.0685)*	
Δrepo_eonia (-2)		0.2101***		Δrepo_eonia (-2)		0.2035***	
		(0.0420)				*(0.0424)*	
Δusspread			0.0262**	Δusspread			0.0271***
			(0.0111)				*(0.0104)*
Constant	0.0171***	0.0567***	0.0064***	Constant	0.0068***	0.0565***	0.0052***
	(0.0031)	*(0.0006)*	*(0.0011)*		*(0.0016)*	*(0.0005)*	*(0.0012)*
				ARCH			
				L.arch	0.2043***	0.7319***	0.1354***
					(0.0408)	*(0.0547)*	*(0.0382)*
				L.garch	0.8238***	-0.0048	0.8614***
					(0.0375)	*(0.0248)*	*(0.0294)*
				Constant	0.0000	0.0000***	0.0000**
					(0.0000)	*(0.0000)*	*(0.0000)*
Adj. R-sq	0.3561	0.2131	0.7719	Chi-sq	1096.1628	102.8785	2055.5558
N	933	933	933	N	933	933	933

Note: The dependent variable is the level of Euribor spread between January 2, 2004 and August 3, 2007. The number of lags is in parentheses, while Δ indicates first differences. OLS estimation uses Newey-West standard errors (up to 5 lags). GARCH estimations are robust to heteroschedasticity. Standard errors are in parentheses. One, two or three asterisks denote significance at the 10, 5 and 1 per cent confidence level, respectively.

Table 5. Liquidity risk before the crisis

	OLS				GARCH (1,1)		
	(A)	(B)	(C)		(A)	(B)	(C)
liq (-1)	0.4938***		0.9639***	liq (-1)	0.6496***		0.9360***
	(0.0691)		*(0.0304)*		*(0.0541)*		*(0.0328)*
liq (-2)	0.1918***		-0.0623**	liq (-2)	0.0898*		-0.0344
	(0.0551)		*(0.0260)*		*(0.0508)*		*(0.0332)*
liq (-3)	0.1933***		0.0564***	liq (-3)	0.2122***		0.0639**
	(0.0519)		*(0.0215)*		*(0.0520)*		*(0.0266)*
Δrepo_eonia		0.5465***	0.7682***	Δrepo_eonia		0.6460***	0.6289***
		(0.0703)	*(0.0511)*			*(0.0779)*	*(0.0526)*
Δrepo_eonia (-1)		0.4181***		Δrepo_eonia (-1)		0.4948***	
		(0.0743)				*(0.0891)*	
Δrepo_eonia (-2)		0.2162***		Δrepo_eonia (-2)		0.2112***	
		(0.0541)				*(0.0464)*	
Δusspread			0.0251**	Δusspread			0.0285***
			(0.0113)				*(0.0109)*
Constant	0.0030***	0.0257***	0.0011***	Constant	0.0012**	0.0277***	0.0008***
	(0.0008)	*(0.0010)*	*(0.0003)*		*(0.0005)*	*(0.0009)*	*(0.0003)*
				ARCH			
				L.arch	0.2024***	0.8765***	0.1292***
					(0.0391)	*(0.0479)*	*(0.0370)*
				L.garch	0.8249***	-0.0173	0.8642***
					(0.0355)	*(0.0138)*	*(0.0311)*
				Constant	0.0000	0.0000***	0.0000*
					(0.0000)	*(0.0000)*	*(0.0000)*
Adj. R-sq	0.6552	0.1078	0.8808	Chi-sq	2719.6318	103.7504	7753.2515
N	933	933	933	N	933	933	933

Note: The dependent variable is the level of liquidity risk between January 2, 2004 and August 3, 2007. The number of lags is in parentheses, while Δ indicates first differences. OLS estimation uses Newey-West standard errors (up to 5 lags). GARCH estimations are robust to heteroschedasticity. Standard errors are in parentheses. One, two or three asterisks denote significance at the 10, 5 and 1 per cent confidence level, respectively.

Table 6. Credit risk before the crisis

	OLS				GARCH (1,1)		
	(A)	(B)	(C)		(A)	(B)	(C)
Δcred (-1)	0.2125		0.2018	Δcred (-1)	-0.0958*		-0.1012*
	(0.1851)		*(0.1688)*		*(0.0556)*		*(0.0552)*
Δcred (-2)	0.0201		0.0167	Δcred (-2)	0.0467		0.0679
	(0.0779)		*(0.0712)*		*(0.0395)*		*(0.0435)*
Δcred (-3)	-0.0307		-0.0083	Δcred (-3)	0.0862*		0.0845
	(0.1185)		*(0.0980)*		*(0.0471)*		*(0.0720)*
Δcred (-4)	0.1703		0.1673*	Δcred (-4)	-0.0038		-0.0317
	(0.1098)		*(0.0996)*		*(0.0442)*		*(0.0499)*
Δcred (-5)	0.1012		0.0968	Δcred (-5)	0.0911*		0.0933*
	(0.0668)		*(0.0634)*		*(0.0483)*		*(0.0500)*
Δ.itge10		0.0361	0.0319	Δ.itge10		-0.0014	-0.0026
		(0.0238)	*(0.0210)*			*(0.0024)*	*(0.0030)*
Δitge10 (-1)		0.0168		Δitge10 (-1)		0.0035	
		(0.0134)				*(0.0027)*	
ΔCoef. Var.			0.0058	ΔCoef. Var.			0.0069
			(0.0035)				*(0.0148)*
Constant	0.0000	0.0000	0.0000	Constant	-0.0000	-0.0000*	-0.0000*
	(0.0000)	*(0.0000)*	*(0.0000)*		*(0.0000)*	*(0.0000)*	*(0.0000)*
				ARCH			
				L.arch	0.4060***	0.4375***	0.5284**
					(0.1234)	*(0.1287)*	*(0.2562)*
				L.garch	0.6211***	0.6105***	0.5285***
					(0.1211)	*(0.1108)*	*(0.1972)*
				Constant	0.0000	0.0000	0.0000
					(0.0000)	*(0.0000)*	*(0.0000)*
Adj. R-sq	0.0974	0.0671	0.1482	Chi-sq	16.9411	1.8699	25.9966
N	930	934	930	N	930	934	930

Note: The dependent variable is the first difference of credit risk between January 2, 2004 and August 3, 2007. The number of lags is in parentheses, while Δ indicates first differences. OLS estimation uses Newey-West standard errors (up to 5 lags). GARCH estimations are robust to heteroschedasticity. Standard errors are in parentheses. One, two or three asterisks denote significance at the 10, 5 and 1 per cent confidence level, respectively.

Table 7. Euribor spread during the crisis

	OLS				GARCH (1,1)		
	(A)	(B)	(C)		(A)	(B)	(C)
Δeurspread (-1)	-0.0015		0.4427***	Δeurspread (-1)	0.0733		0.3884***
	(0.1048)		*(0.0369)*		*(0.0646)*		*(0.0582)*
Δeurspread (-2)	0.0646		0.0442	Δeurspread (-2)	0.0522		0.0838***
	(0.0743)		*(0.0310)*		*(0.0516)*		*(0.0284)*
Δeurspread (-3)	-0.1268		-0.0202	Δeurspread (-3)	0.0009		0.0712**
	(0.0847)		*(0.0279)*		*(0.0498)*		*(0.0348)*
Δeurspread (-4)	0.0446		0.0637*	Δeurspread (-4)	0.1064*		0.0061
	(0.0694)		*(0.0372)*		*(0.0544)*		*(0.0320)*
Δeurspread (-5)	0.1027***		0.0153	Δeurspread (-5)	0.1134**		0.0009
	(0.0346)		*(0.0289)*		*(0.0542)*		*(0.0342)*
ΔVIX		0.0008*	0.0010**	ΔVIX		-0.0006*	-0.0006**
		(0.0004)	*(0.0004)*			*(0.0003)*	*(0.0003)*
ΔVIX (-1)		0.0006		ΔVIX (-1)		0.0000	
		(0.0005)				*(0.0004)*	
Δitge10		7.8728**	6.9193**	Δitge10		1.7743	0.4008
		(3.6005)	*(2.7675)*			*(2.7675)*	*(1.6973)*
Δitge10 (-1)		3.7348		Δitge10 (-1)		1.7190	
		(3.4744)				*(2.1663)*	
ΔCoef. Var.		0.0736***	0.0646***	ΔCoef. Var.		0.0336	0.0232
		(0.0189)	*(0.0155)*			*(0.0444)*	*(0.0320)*
ΔCoef. Var. (-1)		0.0482*		ΔCoef. Var. (-1)		0.0331	
		(0.0255)				*(0.0392)*	
Δrepo_eonia		0.8815***	0.9770***	Δrepo_eonia		0.8433***	0.8947***
		(0.0721)	*(0.0796)*			*(0.0545)*	*(0.0371)*
Δrepo_eonia (-1)		0.2921***		Δrepo_eonia (-1)		0.2559***	
		(0.0443)				*(0.0436)*	
Δusspread		-0.1044*	-0.1189**	Δusspread		-0.0151	-0.0693
		(0.0589)	*(0.0510)*			*(0.0605)*	*(0.0722)*
Δusspread (-1)		-0.0031		Δusspread (-1)		-0.0817	
		(0.0557)				*(0.0499)*	
Δcip		0.0509***	0.0447**	Δcip		0.0228	0.0015
		(0.0191)	*(0.0205)*			*(0.0139)*	*(0.0113)*
Δcip (-1)		-0.0056		Δcip (-1)		-0.0120	
		(0.0288)				*(0.0113)*	
lehman	0.0659**	0.0398**	0.0190*	lehman	0.0396*	0.0750***	0.0236**
	(0.0278)	*(0.0174)*	*(0.0111)*		*(0.0235)*	*(0.0148)*	*(0.0110)*
post_leh	-0.0064**	-0.0042**	-0.0017	post_leh	-0.0021	0.0010	0.0004
	(0.0031)	*(0.0021)*	*(0.0012)*		*(0.0021)*	*(0.0010)*	*(0.0010)*
Constant	0.0018	0.0013	0.0005	Constant	0.0009	-0.0017**	-0.0007
	(0.0019)	*(0.0018)*	*(0.0009)*		*(0.0021)*	*(0.0009)*	*(0.0009)*
				ARCH			
				L.arch	0.1038**	0.4391***	0.4345***
					(0.0416)	*(0.1317)*	*(0.1444)*
				L.garch	0.8825***	0.6965***	0.7114***
					(0.0478)	*(0.0594)*	*(0.0682)*
				Constant	0.0000	0.0000	0.0000
					(0.0000)	*(0.0000)*	*(0.0000)*
Adj. R-sq	0.1596	0.6487	0.7173	Chi-sq	12.2831	542.7198	746.7522
N	664	668	664	N	664	668	664

Note: The dependent variable is the first difference of Euribor spread between August 6, 2007 and February 26th 2010. The number of lags is in parentheses, while Δ indicates first differences. OLS estimation uses Newey-West standard errors (up to 5 lags). GARCH estimations are robust to heteroschedasticity. Standard errors are in parentheses. One, two or three asterisks denote significance at the 10, 5 and 1 per cent confidence level, respectively.

Table 8. Liquidity risk during the crisis

	OLS				GARCH (1,1)		
	(A)	(B)	(C)		(A)	(B)	(C)
Δliq (-1)	0.0301		0.4189***	Δliq (-1)	0.1324**		0.3907***
	(0.0963)		*(0.0397)*		*(0.0562)*		*(0.0532)*
Δliq (-2)	0.0896		0.0530	Δliq (-2)	0.0194		0.0538**
	(0.0712)		*(0.0381)*		*(0.0426)*		*(0.0263)*
Δliq (-3)	-0.0773		0.0170	Δliq (-3)	0.0182		0.0259
	(0.0818)		*(0.0411)*		*(0.0458)*		*(0.0264)*
Δliq (-4)	0.0705		0.0683**	Δliq (-4)	0.0607		0.0270
	(0.0633)		*(0.0283)*		*(0.0515)*		*(0.0298)*
Δliq (-5)	0.1106***		0.0050	Δliq (-5)	0.1193**		0.0439
	(0.0339)		*(0.0320)*		*(0.0505)*		*(0.0295)*
Δrepo_eonia		0.8464***	0.9409***	Δrepo_eonia		0.7816***	0.8325***
		(0.0690)	*(0.0798)*			*(0.0413)*	*(0.0435)*
Δrepo_eonia (-1)		0.2803***		Δrepo_eonia (-1)		0.2644***	
		(0.0445)				*(0.0437)*	
Δusspread		0.0520***	0.0401***	Δusspread		0.0785**	0.0789**
		(0.0190)	*(0.0140)*			*(0.0323)*	*(0.0381)*
Δusspread (-1)		0.0138		Δusspread (-1)		0.0262	
		(0.0261)				*(0.0322)*	
ΔCoef. Var.		-0.1568*	-0.1668*	ΔCoef. Var.		0.0911	0.0858
		(0.0898)	*(0.0931)*			*(0.0563)*	*(0.0601)*
ΔCoef. Var. (-1)		-0.0091		ΔCoef. Var. (-1)		-0.0044	
		(0.0565)				*(0.0571)*	
lehman	0.0574**	0.0506**	0.0250**	lehman	0.0755***	0.0081	-0.0006
	(0.0258)	*(0.0214)*	*(0.0121)*		*(0.0287)*	*(0.0202)*	*(0.0161)*
post_leh	-0.0051*	-0.0046*	-0.0020	post_leh	-0.0028	0.0006	0.0000
	(0.0028)	*(0.0025)*	*(0.0014)*		*(0.0026)*	*(0.0016)*	*(0.0013)*
Constant	0.0010	0.0010	0.0003	Constant	0.0017	-0.0013	-0.0002
	(0.0018)	*(0.0020)*	*(0.0010)*		*(0.0025)*	*(0.0015)*	*(0.0012)*
				ARCH			
				L.arch	0.1290**	0.2534***	0.2310*
					(0.0652)	*(0.0848)*	*(0.1215)*
				L.garch	0.8637***	0.7815***	0.8041***
					(0.0614)	*(0.0560)*	*(0.0791)*
				Constant	0.0000	0.0000	0.0000
					(0.0000)	*(0.0000)*	*(0.0000)*
Adj. R-sq	0.1521	0.5371	0.6299	Chi-sq	28.8434	410.9788	432.7132
N	664	668	664	N	664	668	664

Note: The dependent variable is the first difference of liquidity risk between August 6, 2007and February 26th 2010. The number of lags is in parentheses, while Δ indicates first differences. OLS estimation uses Newey-West standard errors (up to 5 lags). GARCH estimations are robust to heteroschedasticity. Standard errors are in parentheses. One, two or three asterisks denote significance at the 10, 5 and 1 per cent confidence level, respectively.

Table 9. Credit risk during the crisis

	OLS				GARCH (1,1)		
	(A)	(B)	(C)		(A)	(B)	(C)
	D.cred	D.cred	D.cred		D.cred	D.cred	D.cred
Δcred (-1)	0.2853***		0.2664***	Δcred (-1)	0.3665***		0.3804***
	(0.0647)		*(0.0646)*		*(0.0493)*		*(0.0450)*
ΔVIX		0.0012***	0.0012***	ΔVIX		0.0011***	0.0009***
		(0.0002)	*(0.0002)*			*(0.0002)*	*(0.0002)*
ΔVIX (-1)		0.0010***		ΔVIX (-1)		0.0008***	
		(0.0002)				*(0.0002)*	
Δitge10		0.0763***	0.0787***	Δitge10		0.0413***	0.0452***
		(0.0185)	*(0.0168)*			*(0.0110)*	*(0.0132)*
Δitge10 (-1)		0.0072		Δitge10 (-1)		0.0301**	
		(0.0160)				*(0.0118)*	
Δgrge10		0.0110**	0.0115**	Δgrge10		0.0038	0.0056*
		(0.0055)	*(0.0048)*			*(0.0031)*	*(0.0033)*
Δgrge10 (-1)		0.0092*		Δgrge10 (-1)		0.0034	
		(0.0050)				*(0.0029)*	
Constant	0.0002	0.0002	0.0001	Constant	0.0001	0.0004	0.0002
	(0.0004)	*(0.0005)*	*(0.0004)*		*(0.0002)*	*(0.0003)*	*(0.0002)*
				ARCH			
				L.arch	0.3617***	0.2810**	0.2919***
					(0.0966)	*(0.1204)*	*(0.0830)*
				L.garch	0.6986***	0.7438***	0.7285***
					(0.0550)	*(0.0929)*	*(0.0617)*
				Constant	0.0000**	0.0000	0.0000**
					(0.0000)	*(0.0000)*	*(0.0000)*
Adj. R-sq	0.0800	0.2332	0.2501	Chi-sq	55.2752	109.9911	124.0568
N	668	668	668	N	668	668	668

Note: The dependent variable is the first difference of credit risk between August 6, 2007 and February 26, 2010. The number of lags is in parentheses, while Δ indicates first differences. OLS estimation uses Newey-West standard errors (up to 5 lags). GARCH estimations are robust to heteroschedasticity. Standard errors are in parentheses. One, two or three asterisks denote significance at the 10, 5 and 1 per cent confidence level, respectively.

Table 10. Euribor spread after May 2009

	OLS				GARCH (1,1)		
	(A)	(B)	(C)		(A)	(B)	(C)
Δeurspread (-1)	0.0450		0.6782***	Δeurspread (-1)	-0.0381		0.5522***
	(0.0950)		*(0.0826)*		*(0.0956)*		*(0.0892)*
Δeurspread (-2)	-0.0952		-0.0556	Δeurspread (-2)	-0.1058		0.0181
	(0.0746)		*(0.0553)*		*(0.1045)*		*(0.0510)*
Δeurspread (-3)	-0.1496		0.0280	Δeurspread (-3)	-0.1392*		0.0405
	(0.0953)		*(0.0294)*		*(0.0843)*		*(0.0463)*
Δrepo_eonia		0.7997***	0.9939***	Δrepo_eonia		0.7473***	0.9120***
		(0.0404)	*(0.0535)*			*(0.0516)*	*(0.0701)*
Δrepo_eonia (-1)		0.4087***		Δrepo_eonia (-1)		0.2313***	
		(0.0651)				*(0.0772)*	
Δusspread		0.2874*	0.0943	Δusspread		0.1167*	0.0577
		(0.1535)	*(0.0788)*			*(0.0682)*	*(0.0814)*
Δusspread (-1)		0.1566		Δusspread (-1)		0.0290	
		(0.1132)				*(0.0839)*	
Constant	-0.0018*	-0.0000	-0.0000	Constant	-0.0009	-0.0002	0.0001
	(0.0011)	*(0.0007)*	*(0.0003)*		*(0.0007)*	*(0.0003)*	*(0.0003)*
				ARCH			
				L.arch	0.0156	0.3034	0.0381
					(0.0121)	*(0.3304)*	*(0.0515)*
				L.garch	0.9738***	0.7152***	0.9538***
					(0.0155)	*(0.2294)*	*(0.0614)*
				Constant	-0.0000	0.0000	-0.0000
					(0.0000)	*(0.0000)*	*(0.0000)*
Adj. R-sq	0.0215	0.6880	0.8041	Chi-sq	3.7079	255.6158	173.5503
N	200	202	200	N	200	202	200

Note: The dependent variable is the first difference of Euribor spread between May 19, 2009 and February 26, 2010. The number of lags is in parentheses, while Δ indicates first differences. OLS estimation uses Newey-West standard errors (up to 5 lags). GARCH estimations are robust to heteroschedasticity. Standard errors are in parentheses. One, two or three asterisks denote significance at the 10, 5 and 1 per cent confidence level, respectively.

Table 11. Liquidity risk after May 2009

	OLS				GARCH (1,1)		
	(A)	(B)	(C)		(A)	(B)	(C)
Δliq (-1)	0.0163		0.6380***	Δliq (-1)	0.0630		0.5394***
	(0.0935)		*(0.0777)*		*(0.0804)*		*(0.0744)*
Δliq (-2)	-0.1434*		-0.0628*	Δliq (-2)	-0.1099		-0.0283
	(0.0852)		*(0.0370)*		*(0.1044)*		*(0.0418)*
Δliq (-3)	-0.1827*		-0.0098	Δliq (-3)	-0.1402		-0.0060
	(0.0978)		*(0.0314)*		*(0.0962)*		*(0.0386)*
ΔCoef. Var.		0.0543	0.1160**	ΔCoef. Var.		0.1058*	0.1112**
		(0.0599)	*(0.0467)*			*(0.0639)*	*(0.0517)*
ΔCoef. Var. (-1)		0.0618		ΔCoef. Var. (-1)		0.0128	
		(0.0548)				*(0.0527)*	
Δrepo_eonia		0.7951***	0.9570***	Δrepo_eonia		0.7604***	0.8730***
		(0.0437)	*(0.0528)*			*(0.0590)*	*(0.0605)*
Δrepo_eonia (-1)		0.3917***		Δrepo_eonia (-1)		0.3158***	
		(0.0551)				*(0.0609)*	
Constant	-0.0015	-0.0007	-0.0001	Constant	-0.0013	-0.0004	-0.0001
	(0.0010)	*(0.0008)*	*(0.0004)*		*(0.0009)*	*(0.0006)*	*(0.0005)*
				ARCH			
				L.arch	0.0264	0.1646*	0.1034**
					(0.0286)	*(0.0911)*	*(0.0447)*
				L.garch	0.9494***	0.7643***	0.8491***
					(0.0547)	*(0.1040)*	*(0.0529)*
				Constant	0.0000	0.0000*	0.0000*
					(0.0000)	*(0.0000)*	*(0.0000)*
Adj. R-sq	0.0428	0.6244	0.7530	Chi-sq	3.8601	180.8506	249.5411
N	200	202	200	N	200	202	200

Note: The dependent variable is the first difference of liquidity risk between May 19, 2009 and February 26, 2010. The number of lags is in parentheses, while Δ indicates first differences. OLS estimation uses Newey-West standard errors (up to 5 lags). GARCH estimations are robust to heteroschedasticity. Standard errors are in parentheses. One, two or three asterisks denote significance at the 10, 5 and 1 per cent confidence level, respectively.

Table 12. Credit risk after May 2009

	OLS				OLS		
	(A)	(B)	(C)		(A)	(B)	(C)
Δcred (-1)	0.3311***		0.3218***	Δcred (-1)	0.3311***		0.3249***
	(0.0558)		*(0.0466)*		*(0.0558)*		*(0.0463)*
ΔVIX		0.0007**	0.0010***	Δauch		-0.1382***	-0.1296***
		(0.0003)	*(0.0003)*			*(0.0251)*	*(0.0318)*
ΔVIX (-1)		0.0007***		Δauch (-1)		-0.1668***	
		(0.0002)				*(0.0248)*	
Δitge10		0.0463***	0.0441***	Δitge10		0.0463***	0.0535***
		(0.0101)	*(0.0107)*			*(0.0091)*	*(0.0094)*
Δitge10 (-1)		0.0491***		Δitge10 (-1)		0.0511***	
		(0.0117)				*(0.0087)*	
Δgrge10		0.0034	0.0060*				
		(0.0030)	*(0.0031)*				
Δgrge10 (-1)		0.0009					
		(0.0035)					
Constant	-0.0002	-0.0003	-0.0002	Constant	-0.0002	-0.0001	-0.0001
	(0.0004)	*(0.0004)*	*(0.0003)*		*(0.0004)*	*(0.0003)*	*(0.0003)*
N	202	202	202	N	202	202	202
Adj. R-sq	0.1050	0.3092	0.2880	Adj. R-sq	0.1050	0.4166	0.2925

Note: The dependent variable is the first difference of credit risk between May 19, 2009 and February 26, 2010. The number of lags is in parentheses, while Δ indicates first differences. OLS estimation uses Newey-West standard errors (up to 5 lags). Standard errors are in parentheses. One, two or three asterisks denote significance at the 10, 5 and 1 per cent confidence level, respectively.

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